Darwin Pipeline Duplication Project

Supplementary Environmental Report

May 2023

Acronym and Abbreviations	Meaning
AAPA	Aboriginal Areas Protection Authority
AAPowerLink	Australia-Asia Powerlink Project
ACCUs	Australian Carbon Credit Units
AFANT	Amateur Fishermen's Association of the Northern Territory
AHD	Australian Height Datum
AIMS	Australian Institute of Marine Science
AIS	Automatic Identification System
ALAN	Artificial Light At Night
ALARP	As Low As Reasonably Practicable
AMSA	Australian Marine Safety Authority
ANC	Acid Neutralising Capacity
ANZG	Australian and New Zealand Guidelines
ASS	Acid Sulfate Soils
ASSDMP	Acid Sulfate Soil and Dewatering Management Plan
AUV	Autonomous Underwater Vehicles
AWNT	Arnhem-west Northern Territory
AWTI	Above water tie in
BHD	Backhoe dredger
BIAs	Biologically Important Areas
BOM	Bureau of Meteorology
BTEXN	Benzene, Toluene, Ethylbenzene, Naphthalene
CCS	Carbon Capture and Storage
CEMP	Construction Environmental Management Plan
Cd	Cadmium
CHARM	Chemical Hazard Risk Management
Chl-a	Chlorophyll-a
CM&C	Department of the Chief Minister and Cabinet
Co	Cobalt
CR	Critically Endangered
Cr	Chromium

Acronym and Abbreviations	Meaning
CSD	Cutter Suction Dredgers
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSV	Construction support vessel
Cu	Copper
°C	Degrees Celsius
DAHs	Dissolved Aromatic Hydrocarbons
DAWE	Department of Agriculture, Water and Environment
DENR	Department of Environment and Natural Resources
DEPWS	Department of Environment, Parks and Water Security
DGV	Default Guideline Value
DHAC	Darwin Harbour Advisory Committee
DIPL	Department of Infrastructure, Planning and Logistics
DITT	Department of Industry, Tourism and Trade
DLNG	Darwin Liquefied Natural Gas
DoD	Department of Defence
DoEE	Department of Environment and Energy
DHAC	Darwin Harbour Advisory Committee
DPD	Darwin Pipeline Duplication
DP	Dynamically Positioned
DSDMP	Dredging and Spoil Disposal Management Plan
EAAP	Environmental Assessment Administrative Procedures
ECNT	Environment Centre Northern Territory
EEDI	Efficiency Design Index
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EN	Endangered
ENSO	El Niño Southern Oscillation
EP	Environment Plan
EP Act	*Environment Protection Act 2019* (Northern Territory)
EPA	NT Environment Protection Authority

Acronym and Abbreviations	Meaning
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EPL	Environment Protection Licence
ERF	Emissions Reduction Fund
ESD	Ecologically Sustainable development
FCGT	Flood, clean, gauge, testing
FID	Final investment decision
FLNG	Floating Liquid Natural Gas
FME	Full Moon Equivalents
FPSO	Floating Production Storage and Offloading
FPV	Fall Pipe Vessel
GA	Geoscience Australia
GEP	Gas Export Pipeline
GHG	Greenhouse Gas
HAT	Highest Astronomical Tide
Ha	Hectare
Hg	Mercury
IAP2	International Association for Public Participation
IEA	International Energy Agency
ILT	In-line Tee
ISO	International Organisation for Standarization
IMMRP	Integrated Marine Monitoring and Research Program
IMR	Inspection, Maintenance and Repair
IMS	Invasive Marine Species
LAT	Lowest Astronomical Tide
LNG	Liquefied Natural Gas
LoR	Limit of Reporting
m	Metre
MA	Management Action
MDO	Marine Diesel Oil
MFE	Mass Flow Excavation

Acronym and Abbreviations	Meaning
MFO	Marine fauna observer
MNES	Matters of National Environmental Significance
MBES	Multi-beam echosounder
MEG	Monoethylene Glycol
MMNMP	Marine Megafauna Noise Management Plan
MNES	Matters of National Environmental Significance
MSL	Mean sea level
Mt	Million tonnes
MTPA	Million tonnes per annum
NAGD	National Assessment Guidelines for Dredging
NDCs	Nationally determined contributions
NDE	Non-destructive evaluation
NEMP	Nearshore Environmental Monitoring Program
NESP	National Australian Science Program
NGER Act	*National Greenhouse and Energy Reporting Act 2007*
Ni	Nickel
NL	Not Listed
NOECs	No Observable Effect Concentrations
NOI	Notice of Intent
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NORMs	Naturally occurring radioactive materials
NSESD	National Strategy for Ecologically Sustainable Development
NT	Northern Territory
NTDPIR	NT Department of Primary Industry and Resources
NT EPA	NT Environment Protection Authority
NTG	Northern Territory Government
OCNS	Offshore Chemical Notification Scheme
OECD	Organisation for Economic Cooperation and Development
OEMP	Operations Environmental Management Plan
OFOV	Orientation Field Of View

Acronym and Abbreviations	Meaning
OPP	Offshore Project Proposal
OTP	Onshore Tie-in Point
PAH	Polynuclear Aromatic Hydrocarbons
PAR	Photosynthetic Active Radiation
PASS	Potential Acid Sulfate Soil
PCB	Polychlorinated Biphenyls
PLET	Pipeline End Termination
PLRs	Pig launcher/receivers
PCBs	Polychlorinated biphenyls
pig	Pipeline Inspection Gauge
PMST	Protected Matters Search Tool
PNEC	Protected No Effect Concentration
PSD	Particle size distribution
PTS	Permanent Threshold Shift
QRA	Quantitative Risk Assessment
Referral	Darwin Pipeline Duplication (DPD Project NT EPA Referral (December 2021)
RBI	Risk-based inspection
RL	Relative Level
RFFHMP	Recreational Fishing and Fish Health Monitoring Program
RFPA	Reef Fish Protection Area
RPA	Reef Protection Area
ROVs	Remotely Operated Vehicles
SDG	Sustainable Development Goals
SDS	Safety Data Sheet
SEEMP	Ship Energy Efficiency Management Plan
SEP	Stakeholder Engagement Plan
SER	Supplementary Environmental Report
SHB	Split Hopper Barges
SIMAP	Spill Impact Mapping and Analysis Program
SKM	Sinclair Knight Merz

Acronym and Abbreviations	Meaning
SPL	Sound pressure level
SSC	Suspended sediment concentrations
SSS	Side scan sonar
SWPLB	Shallow water pipelay barge
TBT	Tributyl Tin
TIS	Traffic Impact Statement
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TPWC	*Territory Parks and Wildlife Conservation Act 1976* (Northern Territory)
TRH	Total Recoverable Hydrocarbons
TSHD	Trailing suction hopper dredger
TSS	Total suspended solids
TSDMMP	Trenching and Spoil Disposal Management and Monitoring Plan
TTS	Temporary Threshold Shift
TWAF	Total water accommodated fraction
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USBL	Ultrashort base line
UXO	Unexploded Ordnance
VU	Vulnerable
WAMSI	Western Australian Marine Science Institute
WET	Whole Effluent Testing
WHO	World Health Organisation
Zn	Zinc
ZoI	Zone of Influence
ZoHI	Zone of High Impact
ZoMI	Zone of Moderate Impacts

Contents

1 Introduction 17

1.1 Project Overview 17
1.2 Assessment process 18

2 Project Description Updates 26

2.1 Project summary 26
2.2 Project area 37
2.3 Pre-lay trenching and span rectification 37
2.4 Pipeline installation 48
2.5 Rock installation 50
2.6 Flooding, cleaning, gauging and testing 51
2.7 Onshore site set-up 54
2.8 Vessel activities 57
2.9 Project schedule 61

3 Alternatives 62

3.1 Background: the Barossa Development 62
3.2 Justification for DPD Project 63
3.3 Pipeline route environmental assessments 65
3.4 Options for Darwin Harbour route alignment 79
3.5 Pipeline route optimisation 80

4 Stakeholder Engagement 90

4.1 Engagement objectives 90
4.2 Stakeholders 90
4.3 Engagement prior to referral submission to NT EPA 92
4.4 Engagement following referral of submission to NT EPA 93
4.5 Ongoing and future engagement 94

5 Responses to Submissions 95

6 Matters of National Environmental Significance 119

7 Environmental Impact and Risk Assessment 120

7.1 Regulatory assessment 120
7.2 Environmental factors 122
7.3 Additional studies 122

7.4	Environmental impact and risk assessment methodology	125
7.5	Cumulative impact assessment	130
8	Marine Environmental Quality	132
8.1	Environmental objective	132
8.2	Additional information required	132
8.3	Legislation, policy, and guidance	133
8.4	Environmental values	134
8.5	Potential significant impacts	142
8.6	Environmental management	206
8.7	Conclusion of residual impacts and risks and predicted outcome	206
9	Marine Ecosystems	208
9.1	Environmental objective	208
9.2	Additional information required	208
9.3	Legislation, policy and guidance	209
9.4	Environmental values	210
9.5	Potential significant impacts	241
9.6	Environmental management	285
9.7	Conclusion of residual impacts and risks and predicted outcome	285
10	Atmospheric Processes	288
10.1	Environmental objective	288
10.2	Additional information required	288
10.3	Legislation, policy and guidance	307
10.4	Environmental values	307
10.5	Potential significant impacts	312
10.6	Environmental management and mitigation	317
10.7	Conclusion of residual impacts and risks and predicted outcome	317
11	Other Environmental Factors	318
11.1	Coastal Processes	318
11.2	Community and Economy	321
11.3	Culture and Heritage	343
12	Management Actions	361
13	Cumulative Impact Assessment	380
13.1	Identification of relevant projects and activities	380

13.2 Marine Environmental Quality 392
13.3 Marine Ecosystems 395
13.4 Atmospheric Processes 398
13.5 Other Environmental Factors 398
13.6 Conclusion 399

14 Whole of Environment Assessment 401

14.1 Marine Environmental Quality 401
14.2 Marine Ecosystems 402
14.3 Atmospheric Processes 403
14.4 Cumulative Impacts 404
14.5 Summary 404

15 Consideration of Project Against Legislated Principles and Duties 405

15.1 Ecologically sustainable development 405
15.2 Environmental decision-making hierarchy 409
15.3 Waste management hierarchy 409
15.4 Ecosystem-based management 410
15.5 Impacts of a changing climate 410
15.6 General duty of proponents 411

16 References 413

Figures

Figure 1-1 Proposed Bayu-Undan CCS project (uses the existing Bayu-Undan to Darwin gas pipeline) 17
Figure 2-1 DPD Project area 27
Figure 2-2 Indicative trench design – Middle Arm and shore crossing 38
Figure 2-3 Indicative trench design – clearwater and anchor protection 39
Figure 2-4 Proposed pipeline route with trenching, pre-sweep and sand waves sections and the proposed trenching vessel 42
Figure 2-5 Proposed onshore and intertidal trench locations 45
Figure 2-6 Temporary causeway location 46
Figure 2-7 Schematic showing five pigs separated by 500 m 52
Figure 2-8 Indicative onshore site layout 56
Figure 2-9 Annual harbour visits FY2011-12 to FY20-21 57
Figure 2-10 DPD Project execution schedule (Indicative) 61
Figure 3-1 Options for the use of the existing pipeline for Barossa gas (A) or CCS service (B) 63
Figure 3-3 Section of the original DPD pipeline northern route, as described in the referral, showing shipping channel encroachment 82
Figure 3-4 Sections of the original DPD pipeline northern route showing encroachment into shipping channel in two areas 83

Figure 3-5 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 1), showing reduced shipping channel encroachment 84
Figure 3-6 Sections of the revised DPD pipeline northern route (option 1) showing reduced encroachment into shipping channel in two areas 85
Figure 3-7 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 2), showing reduced shipping channel encroachment 86
Figure 3-8 Sections of the revised DPD pipeline northern route (option 2) showing removed encroachment into shipping channel in the north and reduced encroachment in the south 87
Figure 3-9 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 3), showing removal of all shipping channel encroachment. This represents the final selected route. 88
Figure 3-10 Sections of the revised DPD pipeline (option 3), following stakeholder engagement, showing removal of all shipping channel encroachment. This represents the final selected route. 89
Figure 7-1 NT EP Act environmental approvals flowchart showing DPD Project position 121
Figure 8-1 Sediment and water quality sampling sites (November 2021) and geotechnical sampling sites (January 2022) along the proposed Barossa Development pipeline route and at the proposed spoil ground (SG). 137
Figure 8-2 Metal concentrations in comparison to the screening levels presented in the National Assessment Guidelines for Dredging, 2009 (CoA, 2009) (refer RPS, 2022a; **Appendix 6** for full details) 140
Figure 8-3 Trenching areas and spoil disposal ground 144
Figure 8-4 Proposed trenching impact reporting zones, based on INPEX (2010) 149
Figure 8-5 Predicted 95th percentile trenching-excess SSC for the trenching program transitioning into the summer/wet season (1st October to 9th November 2019) 153
Figure 8-6 Predicted 95th percentile trenching-excess SSC for the entire trenching program transitioning into winter/dry season (1 April to 10 May 2019) 154
Figure 8-7 Predicted 95th percentile maximum trenching excess bottom thickness (mm) for the trenching program transitioning into winter/dry season (1st April to 10th May 2019) 157
Figure 8-8 Predicted 95th percentile trenching-excess bottom thickness (mm) at the last time step of the trenching program transitioning into winter/dry season (1st April to 10th May 2019) 158
Figure 8-9 Predicted 95th percentile maximum trenching-excess bottom thickness (mm) for the trenching program transitioning into summer/wet season (1st October to 9th November 2019) 159
Figure 8-10 Predicted 95th percentile trenching excess bottom thickness (mm) at the last time step of the trenching program transitioning into summer/wet season (1st October to 9th November 2019) 160
Figure 8-11 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into winter/dry season (1st April to 10th May 2019) 163
Figure 8-12 Predicted Zone of Influence following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into winter/dry season (1st April to 10th May 2019) 164
Figure 8-13 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into summer/wet season (1st October to 9th November 2019) 165
Figure 8-14 Predicted Zone of Influence following application of the appropriate spatial thresholds (**Table** 8-2) to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into summer/wet season (1st October to 9th November 2019) 166
Figure 8-15 Contingency treated seawater discharge modelling locations 172
Figure 8-16 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP84 (based on 25 simulations with different metocean conditions) 176
Figure 8-17 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP102 (based on 25 simulations with different metocean conditions) 177
Figure 8-18 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP114 (based on 25 simulations with different metocean conditions 178

Figure 8-19 Predicted corrosion inhibitor concentrations assessed over a 12-hour continuous exposure period (calculated from 25 simulations) 182
Figure 8-20 Stochastic MDO spill modelling (100 simulations) – Scenario 1 – dry season 194
Figure 8-21 Stochastic MDO spill modelling (100 simulations)– Scenario 1 – wet season 195
Figure 8-22 Stochastic MDO spill modelling (100 simulations)– Scenario 2 – dry season (Note: no dissolved oil exposure at MEVA [50ppb]) 197
Figure 8-23 Stochastic MDO spill modelling (100 simulations)– Scenario 2 – wet season (Note: no dissolved oil exposure at MEVA [50ppb]) 198
Figure 8-24 Stochastic MDO spill modelling (100 simulations)– Scenario 3 – dry season (Note: no dissolved oil exposure at MEVA [50ppb]) 200
Figure 8-25 Stochastic MDO spill modelling (100 simulations)– Scenario 3 – wet season (Note: no dissolved oil exposure at MEVA [50ppb]) 201
Figure 8-26 Stochastic MDO spill modelling (100 simulations)– Scenario 4 – dry season (Note: no dissolved oil exposure at MEVA [50ppb]) 203
Figure 8-27 Stochastic MDO spill modelling (100 simulations)– Scenario 4 – wet season 204
Figure 9-1 Example image of silty shelly sand habitat with sparse soft corals within the RFPA (site RFPA3, refer **Appendix 6**) 212
Figure 9-2 Shaded relief of bathymetry between KP80 and KP81 of the pipeline route (red dashed with KP markers) within the Charles Point Wide RFPA 213
Figure 9-3 RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021) 215
Figure 9-4 RPS surveys habitat mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021) 216
Figure 9-5 RPS surveys habitat mapping along offshore pipeline route 217
Figure 9-6 Combined AIMS 2021 and 2019 habitat mapping data used to inform the impact assessment sections 219
Figure 9-7 Vessel traffic by vessel type in Darwin Harbour on June 6, 7 and 8 2022 from AIS data (AIS Live) 238
Figure 9-8 AMSA shipping density data for Darwin Harbour from January to May 2022 239
Figure 9-9 Project activities and infrastructure overlaid over mapped benthic habitat 245
Figure 9-10 Field survey transect verified the nearshore habitat was not AIMS predicted seagrass and macroalgae, but more comparable to INPEX sand community habitat 246
Figure 9-11 Benthic habitat survey locations off Mandorah. Survey data verified assessed the benthic habitat present in the potential anchoring zone 250
Figure 9-12 Field survey verification of habitat – Weed Reef 251
Figure 9-13 Location of modelled noise sources 259
Figure 9-14 Turtle nesting beaches near Darwin Harbour 272
Figure 9-15 Darwin light pollution from satellite imagery 272
Figure 9-16 Vessel activity zones in Darwin Harbour 273
Figure 9-17 Vessel activity zones approaching Darwin Harbour 273
Figure 10-1 Barossa-DLNG schematic 289
Figure 10-2 GHG inventory assessment boundary 290
Figure 10-3 Climate transition action plan 299
Figure 11-1 Commonwealth northern prawn fishery 325
Figure 11-2 Fishing intensity in the northern prawn fishery, 2020 (ABARES, 2022) 326
Figure 11-3 Frequency of reported visits by APS interviewees to fish area grids (from Cardno, 2013) 334
Figure 11-4 Noise attenuation from construction vessels 337
Figure 11-5 Location of known shipwrecks in study area. 347
Figure 11-6 UXO locations in Darwin Harbour 349
Figure 11-7 Location of ROV survey shortlisted anomalies 352
Figure 11-8 ROV survey target locations overlaid on a map of known historic maritime infrastructure in Darwin Harbour. 353

Figure 11-10 Authority Certificate C2022/098 Subject Land in Darwin Harbour 357
Figure 13-1 Projects and activities considered for cumulative impacts 390
Figure 13-2 Indicative timeline of DPD project and other projects that may create cumulative impacts 391

Tables

Table 1-1 Additional information required to address potential significant environmental impacts 20
Table 2-1 Updates to the key components of the DPD Project since referral submission 28
Table 2-2 Provisional outline of proposed trenching activities including trenching of shore crossing 41
Table 2-3 Estimated Volumes of Discharge at the Commonwealth waters PLET During the FCGT 52
Table 2-4 Discharge rates [m^3/hr] at the Commonwealth waters PLET based on pig speed and pipeline diameter 53
Table 2-5 Vessel description/summary 58
Table 3-1 Comparative assessment of potential environmental impacts, risks, benefits and adherence to EP Act principles from the proposed DPD Project Darwin Harbour pipeline route, the Gunn Point pipeline route, the Bayu-Undan pipeline tie-in option 67
Table 4-1 Stakeholders groups and organisations 91
Table 5-1 Summary table of submissions and responses. 97
Table 7-1 Additional studies undertaken since the referral 122
Table 7-2 Likelihood description 127
Table 7-3 Consequence categories adopted in the risk assessment 128
Table 7-4 Santos' Risk matrix 130
Table 8-1 Water Quality Sampling Parameters 135
Table 8-2 Tolerance limits for excess SSC and sedimentation (following INPEX, 2018) 148
Table 8-3 Chemical composition of Hydrosure 168
Table 8-4 Ecotoxicological testing results for Hydrosure (from Chevron, 2015) 169
Table 8-5 NOEC values for varying species protection levels for Hydrosure based on WET testing (Chevron, 2015) 170
Table 8-6 Volumes and locations of the three scenarios for treated seawater discharges 173
Table 8-7 Summary of model parameters used to model discharges from the Commonwealth PLET 179
Table 8-8 Summary of MDO characteristics 186
Table 8-9 Floating hydrocarbon exposure values 187
Table 8-10 Shoreline hydrocarbon accumulation exposure values 188
Table 8-11 Dissolved aromatic hydrocarbon exposure values 189
Table 8-12 Entrained hydrocarbon exposure values 190
Table 8-13 Summary of oil spill model settings for four modelled diesel release scenarios 191
Table 8-14 Residual impact and risk rating for Marine Environmental Quality 207
Table 9-1 Description of EPBC Act listed migratory mammal species potentially present within the Project area 224
Table 9-2 Description of listed marine turtles potentially within the Project area 232
Table 9-3 Indicative noise levels from typical Darwin Harbour vessels and DPD Project trenching vessels 241
Table 9-4 Summary of the areal overlap of Project infrastructure with different benthic habitats. 243
Table 9-5 Noise Modelling Locations and Scenarios 257
Table 9-6 Trenching noise source levels 260
Table 9-7 Tide heights within Darwin Harbour (Williams et al., 2006) 261
Table 9-8 Noise impact thresholds for marine megafauna groups in Darwin Harbour 262
Table 9-9 PTS, TTS and behavioural response threshold ranges for each marine megafauna group for each modelled scenario/location at mean sea level 264
Table 9-10 Influence of BHD hydraulic hammering time on PTS and TTS ranges for each marine megafauna group at mean sea level 266

Table 9-11 Quantitative behavioural disturbance threshold ranges for marine megafauna across varying tidal states 267
Table 9-12 Residual impact and risk rating for Marine Ecosystems 286
Table 10-1 GHG Emissions Source Inclusions 290
Table 10-2 Emissions estimate for the 25-year lifecycle of the overall Barossa Development (including DPD) – Prior to any offsets 291
Table 10-3 Scope 1 emissions estimate for the 25-year lifecycle of the overall Barossa Development (including DPD) – Prior to any offsets 292
Table 10-4 Barossa Development scope 3 emissions estimates 294
Table 10-5 Santos 2021 -2022 scope 1 emissions, based on equity share 296
Table 10-6 Barossa GHG emissions in context 297
Table 11-1 Residual impact rating for Coastal Processes 321
Table 11-2 Residual impact risk rating for Community and Economy 341
Table 11-3 Known shipwrecks in the MAHA study area 345
Table 11-4 Known UXO within the MAHA study area 350
Table 11-5 Levels of cultural heritage significance 353
Table 11-6 ROV survey findings of targets of cultural significance and classification 354
Table 11-7 Residual impact risk rating for Culture and Heritage 360
Table 12-1 Management actions that will be used for avoidance, mitigation and monitoring of impacts to the relevant environmental factors for the DPD Project 362
Table 13-1 Relevant Projects 381
Table 13-2 Assigned Classification of Projects Relevant to Cumulative Impacts 387
Table 15-1 Principles of Ecological Sustainable Development Addressed 406
Table 15-2 General duty of proponents addressed in the SER 411

Appendices

Appendix 1: Additional information requirements for the Supplementary Environmental Report

Appendix 2: Register of all submissions and responses received for the DPD Project

Appendix 3: Sediment Dispersion Modelling Report

Appendix 4: Draft Trenching and Spoil Disposal Management and Monitoring Plan

Appendix 5: Treated Seawater Discharge Modelling Report

Appendix 6: Pipeline Benthic Survey Report

Appendix 7: Draft Marine Megafauna Noise Management Plan

Appendix 8: Underwater Noise Modelling Report (Talis Consultants, 2023)

Appendix 9: Underwater Noise Modelling Report – Rock Breaking Tools (Connell et al., 2023)

Appendix 10: Traffic Impact Assessment

Appendix 11: Draft Onshore Construction Environmental Management Plan (CEMP)

Appendix 12: Draft Acid Sulfate Soil and Dewatering Management Plan

Appendix 13: Stakeholder Engagement Plan (SEP)

Appendix 14: Darwin Harbour Lighting Impact Assessment

Appendix 15: Hydrocarbon Spill Modelling Report

Appendix 16: Maritime Archaeology Heritage Assessment

Appendix 17: Threatened and Migratory Species Likelihood of Occurrence Assessment

Appendix 18: Draft Offshore Construction Environmental Management Plan (CEMP)

Appendix 19: SER Contributors – Qualifications and Experience

1 Introduction

1.1 Project Overview

The Darwin Pipeline Duplication (DPD) Project will extend the Barossa Gas Export Pipeline to the Santos-operated Darwin Liquified Natural Gas (DLNG) facility and allow for the repurposing of the existing Bayu-Undan to Darwin pipeline to facilitate carbon capture and storage (CCS) options. It will effectively be a 'duplication' of a portion of the Bayu-Undan to Darwin pipeline to allow gas from the Barossa field to be transported to and processed at the existing DLNG facility.

Importantly, duplicating, rather than tying into the existing Santos Bayu-Undan to Darwin pipeline, allows continued supply of gas to the DLNG facility and preserves the existing Santos Bayu-Undan to Darwin pipeline for CCS at Bayu-Undan, subject to all regulatory approvals. The Bayu-Undan CCS project (**Figure 1-1**) has the potential to capture and store up to 10 million tonnes of carbon dioxide (CO_2) per annum, equivalent to about 2 per cent of Australia's carbon emissions each year (or four times the Barossa Development's estimated annual Scope 1 emissions), from other projects, customers and other hard to abate industries and has the potential to be the largest CCS project in the world. Importantly the DPD Project acts as a key enabler for the Barossa Development to reach net zero reservoir CO_2 emissions as per the stated intention of the recently amended Safeguard Mechanism. Bayu-Undan CCS would be able to manage the reservoir CO_2 emissions from the Barossa gas field. The regulatory approvals for the Bayu-Undan CCS project will be subject to separate regulatory approval processes. The Bayu-Undan CCS project is not being assessed in this DPD Project SER and is provided for context.

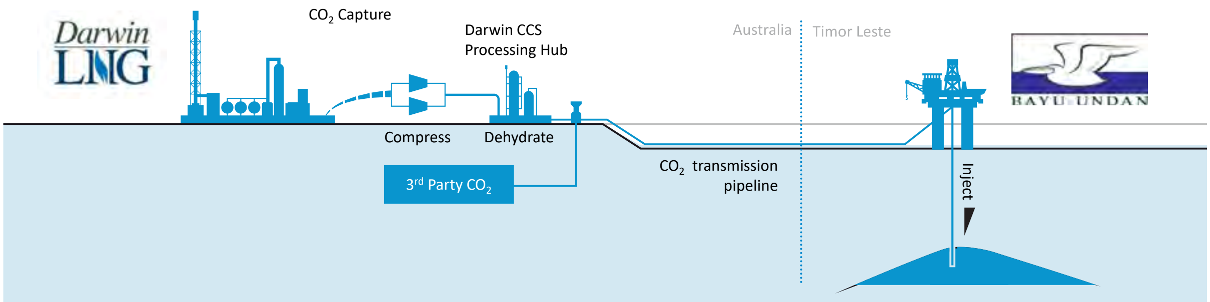


Figure 1-1 Proposed Bayu-Undan CCS project (uses the existing Bayu-Undan to Darwin gas pipeline)

CCS is the process where CO_2 is captured from an emission source, then dehydrated and compressed for transportation via pipeline to a storage site. The CO_2 is then injected into a geological formation that provides safe and permanent storage deep underground. This process applies technology that has been used in the industry for decades, injecting the gas back into the depleted underground reservoirs.

CCS is proven technology, with more than 27 commercial CCS facilities operating around the world today, with a storage capacity of over 36 million tonnes of CO2 per year (Global CCS Institute, 2021).

The International Energy Agency (IEA) Roadmap to Net Zero by 2050 (IEA, 2021b) envisages carbon capture, utilisation and storage growing to 7.6 billion tonnes of CO2 per year by 2050 from around 40 Mt per year today. CCS is recognised by the IEA, the Intergovernmental Panel on Climate Change, and the Australian Government as technology to achieve the world's climate goals.

The DPD Project that has been referred to the Northern Territory (NT) Environmental Protection Agency (EPA) includes the construction, operation and decommissioning of the ~100 km section of DPD Project pipeline in NT jurisdiction. Approximately 23 km of the pipeline in Commonwealth waters is outside of the scope of the referral.

The DPD Project referral, which was accepted by the NT EPA on 14 January 2022, presented a central and northern route option for the pipeline. Since the submission, the northern pipeline route option has been selected as the preferred route, with minor deviations, including two pipeline crossings over the Bayu-Undan to Darwin pipeline implemented after stakeholder consultation, to avoid encroachment into the Darwin Harbour shipping channel. Figures presented in this SER show the northern alignment option only (refer to **Figure 2-1**). Further details on the option selection process and optimisation of the pipeline route are provided in **Section 3**.

1.2 Assessment process

The NT *Environment Protection Act 2019* (EP Act) environmental impact assessment process allows the NT EPA to analyse the potential significant environmental impacts of a development proposal, and make recommendations to the Minister about the acceptability, or otherwise, of those potential environmental impacts.

Given this proposal also has the potential for significant impact to matters protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), a referral for this project was submitted to the Commonwealth Department of Climate Change, Energy, Environment and Water (DCCEEW) for assessment under the EPBC Act. The referral was assessed as a Controlled Action meaning the proposal was considered to have the potential for significant impacts to matters of national environmental significance (MNES). Santos is preparing to submit Preliminary Documentation as directed by DCCEEW for further assessment under the EPBC Act. This assessment is ongoing and separate to the NT EPA process under the EP Act, the subject of this Supplementary Environmental Report (SER).

Both the NT EP Act and the Commonwealth EPBC Act processes provide the community the opportunity to make written comments on the project proposals at various stages of the assessment process.

The initial step of the NT EPA process, or first tier of assessment, is undertaken through the referral in which the NT EPA determines if further assessment is required based on the referral information. The referral is made available on the NT EPA website for a public comment period of 20 business days, providing opportunities for affected or interested parties to comment on the referral. If the NT EPA determines further assessment is required, the NT EPA can request the submission of either a SER or an Environmental Impact Statement (EIS), or recommended assessment by inquiry. Each of these assessment pathways provide additional opportunities for affected or interested parties to comment on the environmental assessment document.

The construction, operation and decommissioning of the DPD Project pipeline in NT jurisdiction (i.e. ~100 km of the ~123 km long pipeline) was referred to the NT EPA on 10 December 2021. The NT EPA accepted the referral for the DPD Project on 14 January 2022. The NT EPA invited public comment on the referral between 18 January and 15 February 2022. A total of 318 submissions were received during the public comment period. This included group public submissions by 284 individuals with the same wording.

The NT EPA provided a Notice of Decision and Statement of Reasons on 7 April 2022 determining that the DPD Project required assessment under the EP Act at a Tier 2 level of assessment – assessment by Supplementary Environmental Report (SER). This SER responds to the Direction to Provide Additional Information provided on 12 January 2023 to supplement the DPD Project referral. The purpose of this SER is to:

+ Provide sufficient information as requested by the NT EPA to facilitate its environmental impact assessment of the DPD Project; and
+ Address submissions received from Government authorities and the public in relation to the referral information.

The NT EPA will invite public and Government agency submissions on the SER within a 25-business day consultation period following submission of the SER. Following public display of the SER and any subsequent NT EPA request for further information and the NT EPA's review of Santos' response to submissions, the NT EPA will complete its assessment of the proposal and prepare an assessment report, draft conditions and environmental approval for the Minister. This is required to occur within 40 days of the end of the submission period, or the outcome of any NT EPA direction to provide additional information in relation to the SER.

Table 1-1 summarises the additional information requested by the NT EPA to be included in the SER and identifies the section(s) in this SER where the information is provided. The additional information request is provided in full in **Appendix 1**. The issues raised during public display of the referral and Santos' response to these issues are provided in **Appendix 2** and summarised in **Table 5-1.**

Table 1-1 Additional information required to address potential significant environmental impacts

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
General	Provide the rationale for duplication of the existing Bayu-Undan pipeline, given that the potentially significant environmental impacts of the proposal could be avoided through use of the existing pipeline. Provide a detailed analysis of the potential significant environmental impacts of alternative approaches, methodologies or technologies for the action, demonstrating how the decision to proceed with the preferred option has been made with consideration of section 42(c) of the EP Act, and application of the environmental decision-making hierarchy, waste management hierarchy and principles of ecologically sustainable development. The analysis of alternatives must include the option of repurposing the existing Bayu-Undan pipeline for transport of gas to DLNG. Provide an update to demonstrate how the general duty requirements have been met in relation to information in the SER.	The duplication of a section of the Bayu-Undan to Darwin pipeline is required to enable the existing pipeline to be utilised for carbon capture and storage (CCS) at the Bayu-Undan facility, subject to all regulatory approvals. Refer to **Section 3.2** for further explanation. Three options for the pipeline's route in the Darwin Harbour area were considered during the project design phase. These were onshore pipelines through Gunn Point or Cox Peninsula or a subsea pipeline through Darwin Harbour itself. Further information is available in Section 5.2 of the EPA Referral. Further analysis of the pipeline route options ruled out the onshore pipeline through the Cox Peninsula for reasons including environmental and cultural heritage constraints. A detailed analysis of the potential environmental impacts of alternative approaches, methodologies or technologies, including the alternative Gunn Point pipeline route and re-purposing the existing Bayu-Undan pipeline are set out in **Table 3-1**, with discussion on route selection and optimisation in **Section 3.3** and **3.4** **Table 15-2** provides reference to the sections of the SER to demonstrate how the general duty requirements have been met.
Marine Environmental Quality	Provide interpreted outcomes of proposal-specific sediment dispersion plume modelling. The model must be developed using relevant contemporary modelling methodology and should address all proposal activities that have the potential to generate turbid plumes. Revise the impact assessment for sedimentation in the context of: + proposal-specific data;	**Section 8.5.1.1** and **Appendix 3** provides sediment dispersion plume modelling and interpreted outcomes for trenching and spoil disposal operations. The modelling indicates that there are no sensitive receptors (seagrass, hard corals or mangroves) located within or near zones of influence from trenching and spoil disposal activities. A Trenching and Spoil Disposal Management and

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	+ sediment dispersion/plume modelling outputs; and + updated habitat data (see below). Provide a draft trenching/dredging and spoil disposal management plan (DSDMP) for sub-sea trenching activities that includes: + baseline (pre-construction) condition of habitats within the zone of influence of the proposal (as required above) and relevant parameters to be monitored to detect impacts; + quantitative trigger levels for relevant parameters (and description of their derivation) corresponding to investigative and/or adaptive management actions that must be taken in the event that monitoring indicates trenching/dredging activities are likely to impact sensitive receptors; and + quantitative limit values relevant parameters (and description of their derivation) corresponding to stop work, recommencement and/or investigative actions if sensitive receptor monitoring results exceed limit values.	Monitoring Plan is provided in **Appendix 4.** This includes for baseline condition studies, monitoring parameters, quantitative trigger levels for relevant parameters and adaptive management actions.
Marine Environmental Quality	Provide details of any infrastructure and methods required for construction of the pipeline at the shore crossing. Identify and map potential impacts (including cumulative impacts) and proposed measures that would be applied to ensure construction impacts are not significant.	Temporary causeways will be required for construction of the pipeline at the shore crossing to assist with the pre-lay trenching. This is discussed in **Section 2.3.4**. The equipment and methods for trenching, including at the shore crossing, are discussed in **Section 2.3.1** and **Section 8.5.1.2** with sediment dispersion modelling outlined in **Section 8.5.1**. The potential impacts and proposed management measures for construction of the shoreline crossing are presented in **Section 8.5.1, Section 9.5.1, Section 12** and **Section 13.2**
Marine Environmental Quality	Demonstrate how Marine Environmental Quality would be protected in the event of discharge of hydrotest water in NT waters. Demonstrate that any discharge of hydrotest water in Commonwealth waters would not cause an exceedance of the 99% species protection level	An assessment of the potential impact of contingency discharges of treated seawater has been undertaken and the findings are discussed in **Section 8.5.2** with the modelling report provided as **Appendix 5**.

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	in any NT waters e.g. if a discharge were to be near the jurisdiction boundary. Describe the proposed mitigation measures to manage potential impacts of hydrostatic test water discharges to the marine environment. Include detail about hydrostatic test water discharge characterisation, dispersion modelling, physical and toxicity impacts, marine fauna impacts, chemical selection and dosing, discharge volume and rate, and criteria for toxicant concentrations in discharge water. Include consideration of how the 99% species protection concentration (ANZG) would be met for high conservation ecosystems or chemicals that have a tendency to bioaccumulate.	Treated seawater discharges (planned and unplanned) within Commonwealth waters, including any potential for impacts in NT waters, are assessed in **Section 8.5.2.** Mitigation measures are described in **Table 12-1**.
Marine Ecosystems	Provide the outcome of additional benthic habitat surveys of the proposal footprint and the zone of influence in Darwin Harbour, at the proposed spoil disposal site, and on knolls and rocky/mixed sedimentary environments within the zone of influence outside of Darwin Harbour. Surveys should use appropriate methods, with sufficient sampling intensity to provide robust understanding of baseline extent and composition of benthic primary producer habitats (see submission from the Department of Environment, Parks and Water Security). Survey design should be developed in consultation with the Flora and Fauna Division of Department of Environment, Parks and Water Security. Revise the assessment of potential impacts to benthic habitats (including seagrass meadows in Fannie Bay, Shoal Bay and Casuarina Coastal Reserve) using the benthic habitat survey data and sediment dispersion model outputs.	Additional benthic habitat surveys have been undertaken and potential impacts to benthic habitats are provided in **Section 8.5.1** and **9.5.1.** The benthic habitat survey report is provided in **Appendix 6** and the sediment dispersion modelling report used to inform the assessment is provided in **Appendix 3**. Impacts within a Zone of Influence are assessed in **Section 8.5.1**. The assessment found that the zone of influence does not reach seagrass meadows at Fannie Bay, Shoal Bay or Casuarina Coastal Reserve and therefore impacts to these seagrass habitat areas are not predicted.
Marine Ecosystems	Provide an underwater noise assessment conducted using contemporary best practice, including interpreted outcomes of underwater noise modelling, and modelling of cumulative noise resulting from the proposal and existing activities at sensitive receptors. Provide a detailed draft marine megafauna management plan for construction activities that includes:	An assessment of underwater noise impacts, including interpreted outcomes of modelling, is provided in **Section 9.5.1.8** and considers cumulative noise from the proposal and existing activities. The underwater noise modelling reports are provided in **Appendix 8** and **Appendix 9**.

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	+ Baseline (pre-construction) cumulative noise within the zone of influence of the proposal and relevant parameters to be monitored to detect impacts; + Noise trigger levels for relevant parameters (and description of their derivation) corresponding to actions that must be taken in the event that monitoring indicates that construction activities are likely to impact protected species; and + Management actions to be applied if noise triggers are exceeded in accordance with the environmental decision-making hierarchy.	A Marine Megafauna Noise Management Plan is in **Appendix 7**. It includes for the monitoring of management zones (fauna observation and exclusion zones) and management actions, in accordance with the environmental decision-making hierarchy, that are triggered if marine megafauna enter these zones.
Marine Ecosystems	Provide an assessment of potential impacts to important subsea structure/s within the Charles Point Reef Fish Protection Area and the measures that would be applied to ensure impacts are not significant.	The assessment of potential impacts to Charles Point Reef Protection Area is provided in **Section 9.5.1.3.** The Charles Point Reef Fish Protection Area contains a fish aggregation area that is associated with seabed structure. In comparison, the seabed along the pipeline route is flat and relatively featureless. This aggregation area is ~2.5 km in distance from the DPD Project pipeline route. Based on the modelling and impact assessments undertaken, the project will not have any potential impacts to this subsea structure and associated fish aggregation.
Marine Environmental Quality and Marine Ecosystems	The monitoring program for the draft DSDMP must provide for the assessment of cumulative impacts associated with trenching/dredging and spoil disposal, including from the addition of concurrent or consecutive dredging programs not related to the proposal. The DSDMP should include: + a communications strategy for engaging with government authorities and other proponents undertaking or proposing to undertake dredging in the harbour; and + a proposed approach to managing dredging in coordination with other proponents/dredging projects to avoid significant cumulative impacts to Darwin Harbour from dredging activities.	The monitoring program in the Trenching and Spoil Disposal Management and Monitoring Plan (TSDMMP) (see **Appendix 4)** and adaptive management process were developed in consideration of the potential for cumulative impacts of concurrent or consecutive dredging programs. The potential for cumulative impacts from concurrent or consecutive dredging programs is considered to be low (**Section 13.2** and **13.3**). The TSDMMP includes a communications strategy for engaging with stakeholders to minimise and manage the

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
		potential for cumulative impacts from dredging activities in Darwin Harbour. This plan is provided in **Appendix 4**
Atmospheric Processes	Provide details of the proposed greenhouse gas emissions over the life of the proposal (from extraction from the reservoir through to completion of liquefaction) including: + estimates of annual and total scope 1, scope 2 and scope 3 emissions over the life of the proposal; + a breakdown of scope 1, scope 2 and scope 3 emissions according to the emission source locations within the NT and / or elsewhere in Australia and / or outside of Australia; + a breakdown of emissions by source, including but not limited to stationary energy, fugitives and transport; and + a comparison of estimated emissions from the proposal against the proponent's emissions across its entire business, and Northern Territory and Australian greenhouse gas emissions as reported in Australia's National Greenhouse Accounts. Demonstrate how the proposal will be implemented to meet the NT EPA's objectives for the Atmospheric Processes environmental factor and the NT Government's goal of achieving net zero greenhouse gas emissions by 2050. Provide an overarching long-term emissions target trajectory and proposed interim targets, and the measures and methods that will be used to meet the targets. Demonstrate application of the decision-making hierarchy (part 2 of the EP Act), and that all reasonable and practicable measures would be applied to avoid and/or reduce emissions, including through best practice design, technology and management. Provide a description of any regulatory frameworks, including any licences, approvals or permits required, for greenhouse gas emissions within the NT, elsewhere in Australia or outside of Australia.	A breakdown of Scope 1, 2 and 3 greenhouse gas emissions estimates (from extraction from the Barossa reservoir through to completion of liquefaction), including those specific to the DPD Project, have been provided in **Section 10.2.1.** Scope 1 emissions from the DPD Project (0.08 Mt CO_2-e) are primarily from vessel-based construction activities (0.05 Mt CO_2-e) and represent: + <0.2% of the total lifecycle Barossa Development Scope 1 GHG emissions (51.6 Mt CO_2-e) + 1.68% of Santos' Equity Corporate annual (2021/2022) GHG emissions; + 0.02% of Australia's annual (2022) GHG emissions; and + 0.46% of NT annual GHG (2020) emissions. Barossa Development estimated annual (Scope 1 and 3) GHG emissions inclusive of onshore processing at the DLNG facility would equate to ~0.86% of the 2022 annual Australian emissions and 0.042% of 2022 global emissions. Overarching long-term emission trajectory and interim targets, together with measures and methods to meet targets, are outlined in **Section 10.2.3.** In addition to the Barossa-DPD emissions baselines set by the Safeguard Mechanism, Santos has industry leading emissions targets across its portfolio which include: + Net-zero Scope 1 and 2 emissions by 2040;

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
		+ A 30% reduction in absolute Scope 1 and 2 emissions by 2030; + A 40% reduction in Scope 1 and 2 emissions intensity by 2030; and + Reducing customer emissions (Santos Scope 3) by 1.5 MT CO_2-e per annum. The Project will meet the NT EPA's objectives for Atmospheric Processes and the NT Government's net zero 2050 goal. Information on this is provided in **Section 10.7.** Reasonable and practicable measures to avoid and/or reduce emissions from the DPD Project and application of the decision-making hierarchy are detailed in **Section 10.2.4.** A description of regulatory GHG frameworks has been presented in **Section 10.2.5.**

2 Project Description Updates

2.1 Project summary

The DPD Project pipeline will effectively be a 'duplication' of a portion of the existing Bayu-Undan to Darwin pipeline to allow gas from the Barossa field to be transported to and processed at the existing Darwin Liquified Natural Gas (DLNG) facility.

Importantly, duplicating, rather than tying into the existing Santos Bayu-Undan to Darwin pipeline, allows continued supply of gas to the DLNG facility and preserves the existing Santos Bayu-Undan to Darwin pipeline for potential carbon capture storage (CCS) at Bayu-Undan. CCS is recognised by the International Energy Agency, Intergovernmental Panel on Climate Change, and the Australian Government as technology to achieve the world's climate goals, and this Project would allow Santos to be part of this Global initiative.

The DPD Project that has been referred to the NT EPA includes the construction, operation and decommissioning of the ~100 km section of DPD Project pipeline in NT jurisdiction.

The DPD Project referral, which was accepted by the NT EPA on 14 January 2022, presented a central and northern route option for the pipeline. Since the submission, the northern pipeline route option has been selected as the preferred route, with minor deviations, including two pipeline crossings over the Bayu-Undan to Darwin pipeline implemented after stakeholder consultation, to avoid encroachment into the Darwin Harbour shipping channel. Figures presented in this SER show the northern alignment option only (refer to **Figure 2-1**). Further details on the option selection process and optimisation of the pipeline route are provided in **Section 3**.

There have been no significant updates to the DPD Project since the referral was submitted to the NT EPA. Santos has further progressed some elements of the design and methodology and where there have been updates to key components of the DPD Project, these are described in **Table 2-1**.

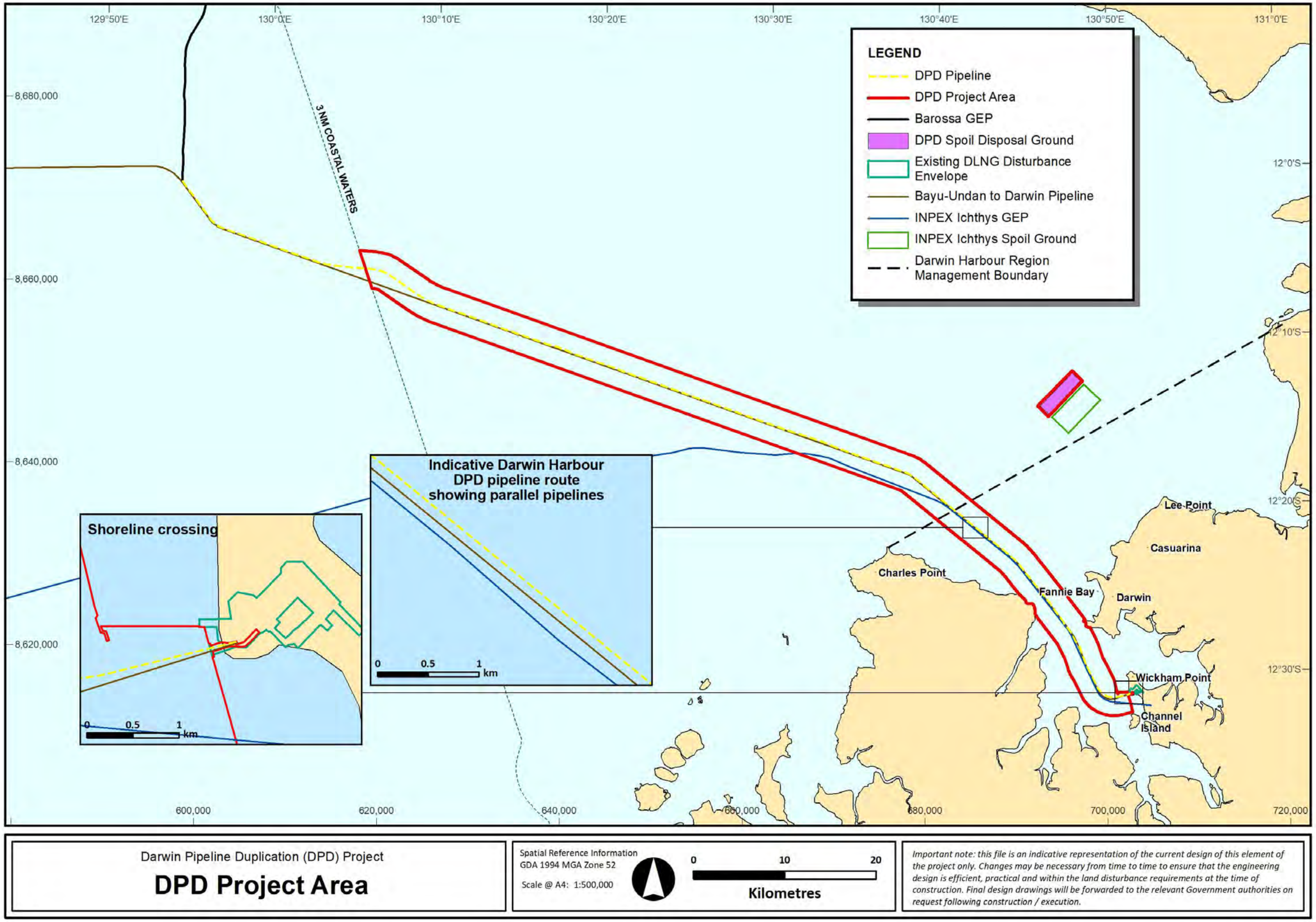


Figure 2-1 DPD Project area

Table 2-1 Updates to the key components of the DPD Project since referral submission

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
Construction Elements		
Pipeline and route selection	The DPD Project pipeline and pipeline route are detailed in Section 3, Section 5.2 and Section 5.3 of the referral. Key aspects of the pipeline and route are: + The pipeline will be ~100 km in NT waters; + The pipeline diameter from the Commonwealth/NT waters boundary is 26 inches up to an in-line tee (ILT) (located approximately 60 km offshore), after which the pipeline increases to 34 inches; + The Darwin Harbour corridor has been selected as the preferred route over a Gunn Point or Cox Peninsula corridor; + Within Darwin Harbour corridor a central (between existing Ichthys and Bayu-Undan to Darwin pipeline) and northern route (north-east of the Bayu-Undan to Darwin pipeline) are preferred options; and + Pipeline will extend to the proposed beach valve at the DLNG facility but not connect into the process plant as part of this referral.	Discussions with key stakeholders, including the Darwin Harbourmaster, have assisted to inform the final alignment of the pipeline through Darwin Harbour. Of the options presented in the referral, the northern route has been selected and optimised to avoid encroachment into the Darwin harbour shipping channel. This route option requires the DPD pipeline to cross the existing Bayu-Undan to Darwin pipeline twice necessitating the installation of concrete mattresses to support the pipeline over the crossings. Further detail on the route selection and optimisation is provided in **Section 3.**
Project area	The Project area is described and presented in Section 3.3 and Figure 3-1 of the referral.	A minor update to the onshore Project area at the DLNG facility has been made which results in a widening of the Project area to the south of the previous defined area but still within the DLNG disturbance footprint. This widening was to allow for a temporary access road to be constructed

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
		within the previously cleared area which will assist with vehicle and equipment access to the shore crossing site (refer **Figure 2-8**).
Project Schedule	An indicative Project schedule has been provided in Section 3.4 of the referral which includes indicative timing for construction commencement in Q3 2023 subject to all regulatory and joint venture approvals. Construction is estimated to take approximately 15 months to complete.	The indicative Project schedule has been updated for construction commencement in Q1 2024 subject to all regulatory and joint venture approvals. The construction activities will span a nominal cumulative period of 15-months in the field. Further detail on the DPD Project scheduling is provided in **Section 2.9**.
Surveys	Surveys to be undertaken as part of the DPD Project include pre-lay surveys, surveys during pipeline trenching and installation, routine inspection surveys during operations and post decommissioning surveys. Detail is provided in Section 3.5.1 of the referral. Site investigation works (e.g. geophysical, geotechnical and environmental surveys) required to inform detailed engineering were excluded from the referral given the potential environmental impacts and risks were considered insignificant in nature and scale (Section 1.6 of the referral).	Santos will continue to conduct low impact onshore and offshore site investigation works for Project planning and approval prior to the commencement of construction activities. These surveys are excluded from the scope of the referral and SER and include: + Environmental benthic habitat condition and water/sediment quality surveys (e.g. using remote operated vehicle, water/sediment sampling/monitoring equipment) + Underwater heritage surveys (e.g. using sonar equipment and remote operate vehicle) including recovery/movement of maritime heritage objects in accordance with Heritage Branch requirements. + Geophysical/ geotechnical surveys (e.g. using sonar, sub bottom profiler, sediment cores, onshore excavation equipment and cone penetration tests)

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
		+ Unexploded ordinance (UXO) surveys and removal (e.g. using sonar, remote operated vehicles, divers, and magnetometer) The results from these studies have further informed the baseline information on the existing environment and the potential impacts that may occur from the Project.
Pre-lay trenching and span rectification	Pre-lay trenching activities (including trenching at shore crossing) and span rectification activities are detailed in Section 3.1, Section 3.5.2.1 and Section 3.5.2.3 of the referral. Nominal trenching locations are presented in Figure 3-1 of the referral. Key aspects of pre-lay trenching and span rectification provided in the referral are: + Trenching in Darwin Harbour is required in shallow waters for pipeline stabilisation and protection from third-party activities (i.e. anchors); + Trenching is proposed via dredging vessels including Trailer Suction Hopper Dredge (TSHD) and Cutter Suction Dredge (CSD), used further from shore, and Backhoe Dredge (BHD) used closer to shore; + Excavators may be used onshore to dig the trench at the shore crossing at the DLNG facility which may be supported by a temporary rock groyne; + Seabed features (e.g. sand waves) may be rectified to prevent pipeline spanning using a TSHD or BHD; and	Pipeline route selection and optimisation has resulted in the pipeline route no longer encroaching into the shipping channel resulting in a reduction of approximately 4 km of trenching (refer **Section 3.3**). Approximately 12.5 km of trenching is now proposed. A revised trenching location map is provided in **Figure 2-4**. Additional detail on the trenching activity has been developed since the referral, including further detail on trench design, sand wave rectification, the use of two temporary causeways at the shore-crossing site and a description of potential for maintenance trenching, including use of a towed plough, is provided in **Section 2.3**. Further detail on onshore trenching for the installation of the pipeline between the end of the shore pull and the proposed beach valve location at the DLNG facility has been developed since the referral and is provided in **Section 2.4.3**. Mass Flow Excavation (MFE) was not previously mentioned in the referral and this equipment may now be used in limited sections to remove high spots and reducing the

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
	+ Installation of concrete mattresses or grout bags may also be used to act as a 'bridge' for the pipeline to preventing spanning.	need for mattress supports for pipeline span correction (refer **Section 2.3.5**).
Spoil disposal	Spoil disposal (from pre-lay trenching) at a spoil disposal ground is described in Section 3.1, Section 3.5.2.2 and Figure 1-1 of the referral. Key aspects of spoil disposal are: + Spoil that is collected during the trenching activities will be disposed of in a location north-east of Darwin Harbour. + The area of the spoil disposal ground is 6.25 km^2. This includes a 100 m buffer around the perimeter of the spoil ground area. + The maximum volume of spoil is anticipated to be ~750,000 m^3 pending over-trench and contingency trenching. The anticipated volume is expected to be ~250,000 m^3.	Further assessment of the anticipated and maximum spoil volumes has been undertaken following finalisation of pipeline routing. A reduced maximum volume of 500,000 $m^3$of spoil (down from ~750,000 m^3) has been allowed for, which still conservatively covers maintenance trenching, if this is required. However, a smaller volume of ~255,000 m^3 is expected based on the trenching design volume multiplied by an expected over dredge of 60%. This anticipated volume is within the modelled spoil volume of 306,000 m^3. There has been no change to the location or area of the spoil disposal ground. There will be no re-use of spoil collected during offshore trenching or span rectification for trench filling. Side casting will be used with onshore excavators at the shore-crossing location only to ensure the spoil remains wet as a mitigation for potential acid sulfate soils in the intertidal area.
Pipeline and cable crossings	**Section 3.5.2.4** of the referral details the approach for installing concrete mattresses to support potential crossing of the Bayu-Undan to Darwin Pipeline should a central pipeline route for the DPD Project be chosen and for crossing of existing cables. Rock installation could also be	A northern pipeline route has been selected, with two confirmed crossings of the Bayu-Undan to Darwin pipeline (refer **Figure 3-10**). The crossing locations have been selected in regions where the Bayu-Undan to Darwin pipeline is covered by a rock berm.

<table>
<tr><th colspan="2">Submitted as part of referral</th><th rowspan="2">Updates since referral submission</th></tr>
<tr><th>Component</th><th>Summary of referral elements</th></tr>
<tr><td></td><td>required to protect crossings from anchor drag or over-trawling by commercial fisheries.</td><td></td></tr>
<tr><td>Pipeline installation</td><td>Pipeline installation, including offshore pipelay and shore pull activities are described in Section 3.5.2.7 of the referral. Key aspects of these activities are:
+ Seabed disturbance from pipelay will be within a 50 m disturbance corridor along the Project pipeline, with additional disturbance closer to shore due to vessel anchoring;
+ Pipelay will be via both a dynamically positioned vessel in deeper waters (laying 2 km/day for ~65 km) and an anchored pipelay barge in shallow waters (laying 300-400 m/day for ~34 km);
+ The pipe will be pulled ashore from the pipelay barge, using a winch spread located onshore, through the pre-constructed trench, and winched up to ~2 m above Highest Astronomical Tide (HAT); and
+ The pulling arrangement will allow for the shore pull to be completed as a continuous operation, which may take approximately two weeks.</td><td>The pipeline installation approach remains consistent with the descriptions in the referral. Further detail is available on proposed onshore construction of the pipeline from the end of shore pull (~2 m above Highest Astronomical Tide) to the proposed beach valve location at the DLNG. Refer to Section 2.4.2.
Additional detail is also provided on potential consecutive shallow water pipelay using a shallow water pipelay barge and deep water pipelay using a deep water pipelay vessel requiring an above water tie-in Section 2.4.1.
Counteracts may be used along the pipeline route within Darwin Harbour where tight radius bends are required to facilitate the pipeline crossings.</td></tr>
<tr><td>Trench backfill / rock installation</td><td>Trench backfill, including the potential use of engineered fill from a borrow ground and rock installation, is described in Section 3.1, Section 3.5.2.1 and Section 3.5.2.7 of the referral.</td><td>Engineered backfill has now been assessed as not being required and therefore collection of material from a designated borrow ground has been removed from the DPD Project scope (refer to Section 2.5).</td></tr>
</table>

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
	The referral presents two options for trench backfill as a rock installation and engineered backfill. The referral describes that engineered backfill (sediment) from a borrow ground may be required to provide backfill for trenching. This borrow ground will be located in the sand wave region at the mouth of the harbour. The indicative volume of the borrow ground has been estimated to be greater than 1,500,000 m^3. The referral detailed that rock installation will likely be via fall pipe vessel (FPV) or side dump vessel (SDV) with support barges to transport rock. In shallow water at the shore crossing a BHD may be used to install rock. The expected volume of rock is estimated to be 200,000 tonnes with a maximum of no more than 500,000 tonnes.	Since the referral further definition of rock requirements has been developed. Rock will be sourced locally from Mt Bundey quarry for pipeline protection/stabilisation. Rock material may also be installed for scour protection around subsea structures, and protection at pipeline/cable crossings. Local quarried rock from Mount Bundey is planned to be transported by road logistics to the Project area and transferred to vessels for trench backfill. Up to 30,000 tonnes of rock material will be stored within the Project area at the DLNG facility. Further detail on the source of rock, rock transport and rock installation is provided in **Section 2.5**, **Section 11.2.5.2** and **Appendix 10.** Up to 30,000 tonne of additional rock may be required at the crossing locations over the Bayu-Undan to Darwin pipeline subject to detailed pipeline design.
Post-lay trenching	Post-lay trenching is detailed in Section 3.5.2.7 of the referral. Post-lay trenching is a contingency activity only that may be required to mechanically lower local areas of the pipeline using a plough or mechanical rock trencher.	No post-lay trenching activities will be undertaken as part of the DPD Project.
Flood/Clean/Gauge/Testing (FCGT) and dewatering/pre-commissioning	FCGT activities are detailed in Section 3.5.2.7 of the referral with key points summarised below: + Following pipe lay a series of pipeline inspection gauge (PIGs), used to manage liquid accumulation, will be pushed through the pipeline to clean the	Filling and pigging of the pipeline with treated seawater will occur from the onshore end within the DLNG facility footprint only and dewatered in Commonwealth waters. Further detail on this process is provided in **Section 2.6.1**.

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
	pipeline, gauge the pipeline and ensure all air is removed during the flooding process; + Pig launcher/receivers will be installed on the pipeline end termination point in Commonwealth waters and at the shore crossing; + The pigs are pushed using chemically treated seawater with water sourced from either Darwin Harbour (if the pig will be pushed from onshore to offshore) or offshore in Commonwealth waters (if the pig will be pushed from offshore to onshore); + The chemically treated seawater is typically a mixture of biocides (to prevent biofouling and bacterial corrosion on the internal surfaces), an oxygen scavenger (to control corrosion of the pipeline) and a dye (for leak detection during hydrotest); and + In the unlikely event of a wet buckle during pipelay, contingency filling of the pipeline may be required to preserve the pipeline prior to repair; discharge of treated seawater may occur within NT waters.	Further detail on the contingency filling and dewatering process, in the event of a wet buckle incident, is detailed in **Section 2.6.3**. Hydrotesting of onshore DPD pipeline (between the onshore tie-in point (OTP) and the beach valve) is now further detailed within **Section 2.6.1**.
Onshore construction and facilities	A description of onshore construction and facilities is described in Section 3.5.2.6 of the referral. All onshore temporary facilities including shore pull, laydown and ancillary facilities will be on NT land within the existing DLNG disturbance envelope.	Further detail and indicative site layouts associated with shore pull and pre-commissioning activities are provided in **Section 2.4.2.** Since submission of the referral, a temporary access road is now planned to be constructed within the existing DLNG facility disturbance footprint to allow vehicle and equipment access to the shore-crossing area. This has

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
		resulted in a slight widening of the Project area within the DLNG facility disturbance footprint. Further detail on the construction of the pipeline between the end of the shore pull OTP and the proposed beach valve at the DLNG facility is provided in **Section 2.4.3**. Where the referral referred to the potential construction of a temporary groyne, the SER details the construction of two temporary causeways (**Section 2.3.4**).
Vessel activities	Section 3.6.1 of the referral provides detail on the types of vessels required for the DPD Project and key vessel activities.	Broad vessel requirements remain the same as at the time of the referral. However, further details are now known on the types of the vessels and likely duration of use, as detailed in **Section 2.8**.
Operations Elements		
Pipeline operation	Section 3.1 and Section 3.5.3 of the referral provides a summary of pipeline operations and associated activities. Once constructed and commissioned the DPD Project pipeline will transport dry hydrocarbon gas from the Barossa field to the DLNG Facility for processing. First gas is expected to flow through the pipeline in first half of 2025 with an operation of ~25 years. Pipeline operations will include inspection, maintenance and repair (IMR) activities by vessels and Remotely Operated Vehicles (ROV)/ Underwater Autonomous Vehicles (UAV). Operations and maintenance of the DPD Project pipeline is expected to follow the same, or very similar management	There has been no change to details of pipeline operation or IMR requirements since the referral.

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
	procedures and risk-based approach currently used by Santos to operate and manage the Bayu-Undan to Darwin pipeline.	
Decommissioning Elements		
Proposed decommissioning	Section 3.1 and Section 3.5.4 of the referral provides proposed decommissioning approach. At end of Project life (>2050) it is expected that pipeline hydrocarbons will be displaced to the DLNG facility and the pipeline will be flushed with either raw seawater, air or nitrogen. The DPD Project pipeline and associated facilities will then be decommissioned in accordance with regulatory requirements at that time.	There has been no update to the proposed decommissioning approach since the referral.

2.2 Project area

The Project area continues to consist of the three distinct areas (**Figure 2-1**), being:

+ Offshore NT waters (i.e. NT waters outside Darwin Harbour Region Management Area). Note that this includes the proposed location for spoil disposal;
+ Darwin Harbour (i.e. waters within the Darwin Harbour Regional Management Area); and
+ Shore crossing and onshore location (where the pipeline crosses the shoreline within the existing DLNG disturbance footprint).

The locations for activities along the Project pipeline are described using 'kilometre points' (KPs), where KP0 is the beginning of the Project pipeline from the "pipeline end termination" (PLET) at the connection point with the Barossa GEP in Commonwealth waters. For the purposes of this SER, the Project begins at the boundary of NT waters at approximately KP23 and terminates at the proposed pipeline beach valve location at approximately KP122.69 within the DLNG facility disturbance footprint.

The DPD Project area within Offshore NT waters and Darwin Harbour has not been amended since the referral. There has been a minor widening of the onshore Project area to allow for construction of a temporary access road (refer **Figure 2-8**), part of which would have previously fallen outside of the Project area as included in the referral. However, this occurs within the existing DLNG facility disturbance footprint.

2.3 Pre-lay trenching and span rectification

Pre-lay trenching of the seafloor and shoreline will be required for the following reasons:

+ Maximising pipeline stability;
+ Pipeline free span rectification;
+ Maintaining free water clearance between pipeline and vessel hulls within the Darwin Harbour shipping fairways;
+ Protection of the pipeline from anchor drag, vessel impact and grounding or other third-party impacts which may lead to pipeline damage; and
+ Maintenance trenching if trenched areas accumulate sediments prior to pipelay.

2.3.1 Planned trenching operations

It is anticipated that approximately 12.5 km of trenching (including sand waves and pre sweep areas) will be required in sections within Darwin Harbour (~KP91.5 to KP121.6) and a further 300 m at the shore crossing up to the shore pull termination point (KP121.484 to KP122.690 respectively). Additional trenching between the shore-pull termination point and the beach valve (approximately 200 m) will be undertaken to facilitate laying of the onshore section of pipeline.

Trench design, including trench depth and presence/type of rockfill will vary across trenching locations dependent upon trench objectives. The DPD Project has optimised each trench length resulting in reduced trenching, and thereby reducing the extent of environmental impact from seabed disturbance and reducing potential turbidity effects from trenching. The trench designs have an approximate width of 3 m at the base, but vary in width at the top of the trench, up to a maximum of ~40 m. Indictive trench designs are shown in **Figure 2-2** and **Figure 2-3**, however specifications may alter slightly as designs are finalised.

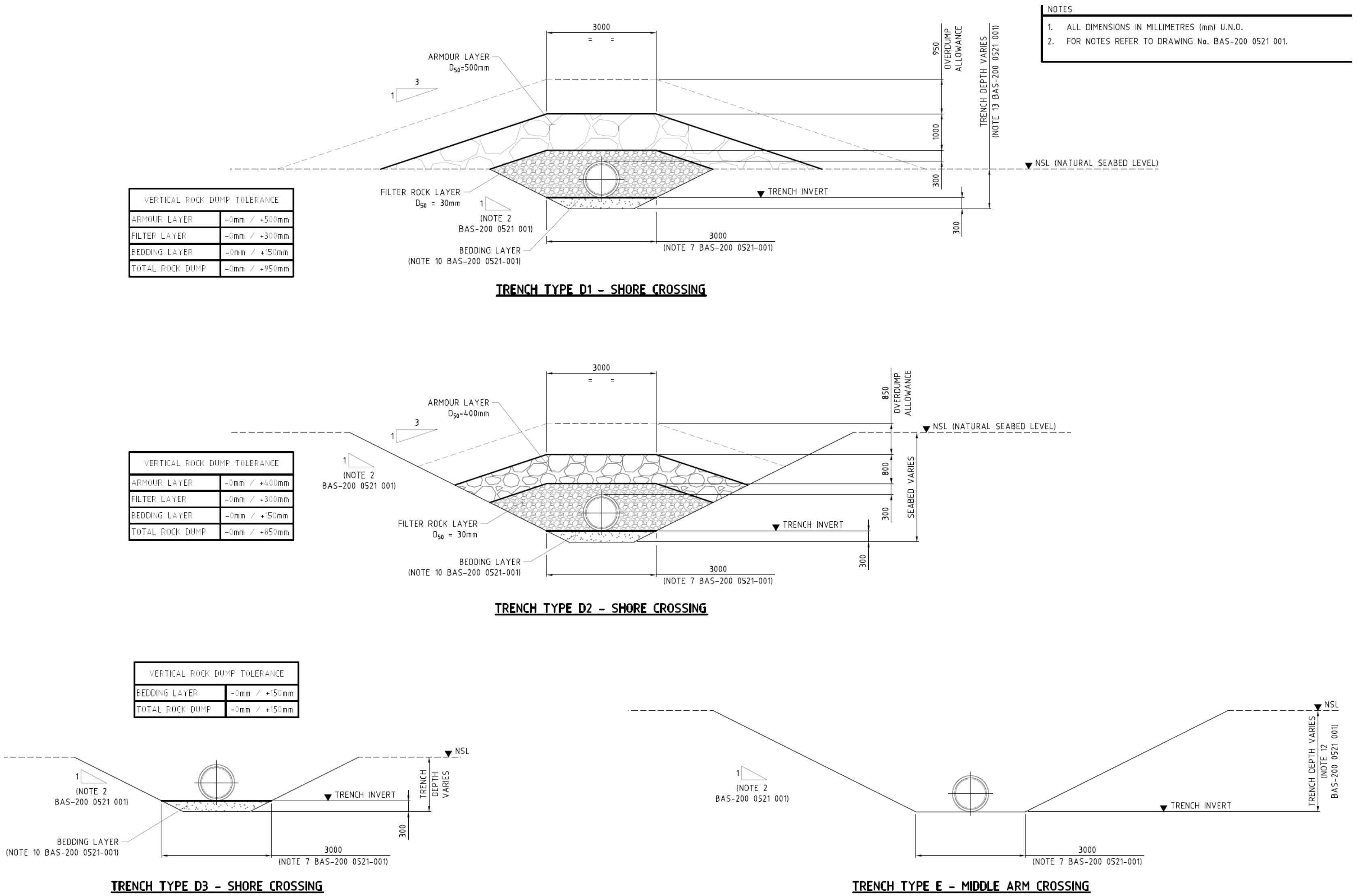


Figure 2-2 Indicative trench design – Middle Arm and shore crossing

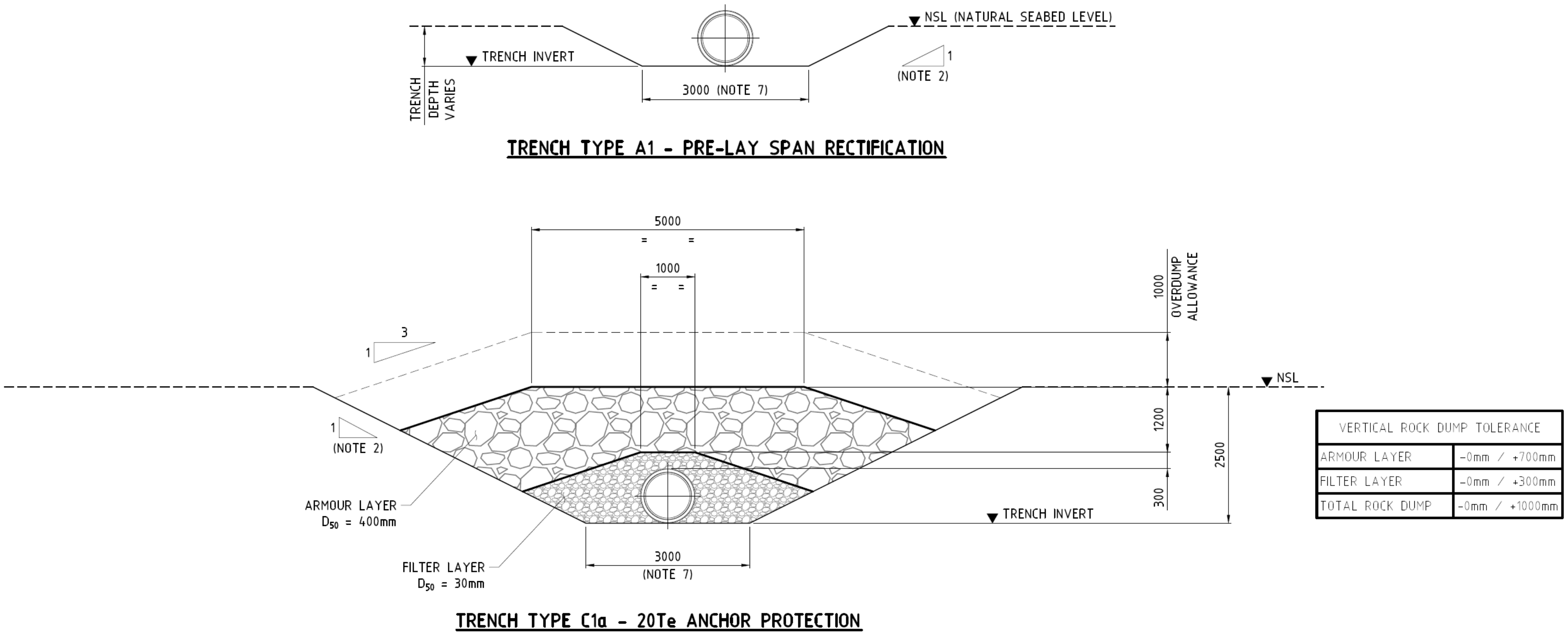


Figure 2-3 Indicative trench design – clearwater and anchor protection

The offshore trenching operations for the pipeline route in Darwin Harbour have been divided into eight sections made up of four trenching zones, three pre-sweep areas and a sand waves area as outlined in **Table 2-2** and shown in **Figure 2-4.**

The three pre-sweep areas and single sand waves area only require sediments to be removed, while the seven trenching sections require the removal of both sediment and rock material. Two trench zones are located onshore up to the beach valve.

The trenching in Trench Zones 1 to 4 will be completed using a variety of trenching vessels (refer **Table 2-2**) which include a backhoe dredge (BHD), a trailing suction hopper dredge (TSHD) and a cutter suction dredge (CSD) (which is used to crush harder material). Pre-sweep sediment removal and sand wave rectification will occur is applicable areas (**Table 2-2**).

The BHD will be used for trenching in the shallow water sections, such as the shore crossing, while the CSD will be used to cut the harder material further offshore. For hard material in the shallow water section, the BHD Xcentric Ripper (preferred) or hydraulic hammer may be required for mechanical rock breaking. A TSHD is used to remove CSD rubble and soft sediments, such as in the pre-sweep and sand wave sections. An excavator will be used to carry out trenching activities onshore from the intertidal area through to the beach valve. Indicative quantities of each material type required to be trenched are provided in **Table 2-2**.

Material trenched by BHD, TSHD or CSD will be disposed of at a designated offshore spoil disposal ground. The designated spoil disposal ground for trenched material is located adjacent to the previous INPEX Ichthys spoil disposal ground to the north of Darwin Harbour, within Beagle Gulf, approximately 12 km north-west of Lee Point (refer **Figure 2-1**). In order to mitigate against acid sulfate soil risks, material removed within the inter-tidal zone by excavators will be placed near the low tide mark to keep material wet and there will be dispersion of this material with tidal movement. Trenched material within the onshore zone between the shore pull termination point and the beach valve will be stockpiled and used to backfill the trench once this section of pipeline has been installed.

Trenching and disposal operations are proposed to take place over an indicative six-week period, but potentially up to 12 weeks, with concurrent operations of the TSHD, CSD and BHD, and onshore excavators.

Table 2-2 Provisional outline of proposed trenching activities including trenching of shore crossing

Trenching Activity Areas	Trench Design	Approximate Location Start (KP)	Location End (KP)	Equipment	Approximate Material to be Trenched (m^3)
Trench Zone On-shore Shore pull termination point to beach valve	Onshore	~122.5	~122.7	Excavator	5,000
Trench Zone to shore pull termination point	D1	~122.4	~122.5	Excavator	5,000
Trench Zone 1	D2	~122.4	~121.9	BHD and Barge	17,000
Trench Zone 2	D3	~121.9	~121.2	BHD and Barge	6,000
Pre-sweep Area 1	N/A	~121.2	~120.6	TSHD	4,000
Trench Zone 3	E	~120.7	~119.3	TSHD and CSD	48,000
Pre-Sweep Area 2	N/A	~116.4	~113.2	TSHD	35,000
Pre-Sweep Area 3	N/A	~106.5	~106.8	TSHD	3,000
Trench Zone 4	C1A	~106.6	~103.6	TSHD and CSD	117,000
Sand Waves Area	N/A	~94.4	~92.2	TSHD	15,000
Total Volume					255,000

*BHD – Backhoe Dredge; TSHD – Trailer Suction Hopper Dredge; CSD – Cutter Suction Dredge

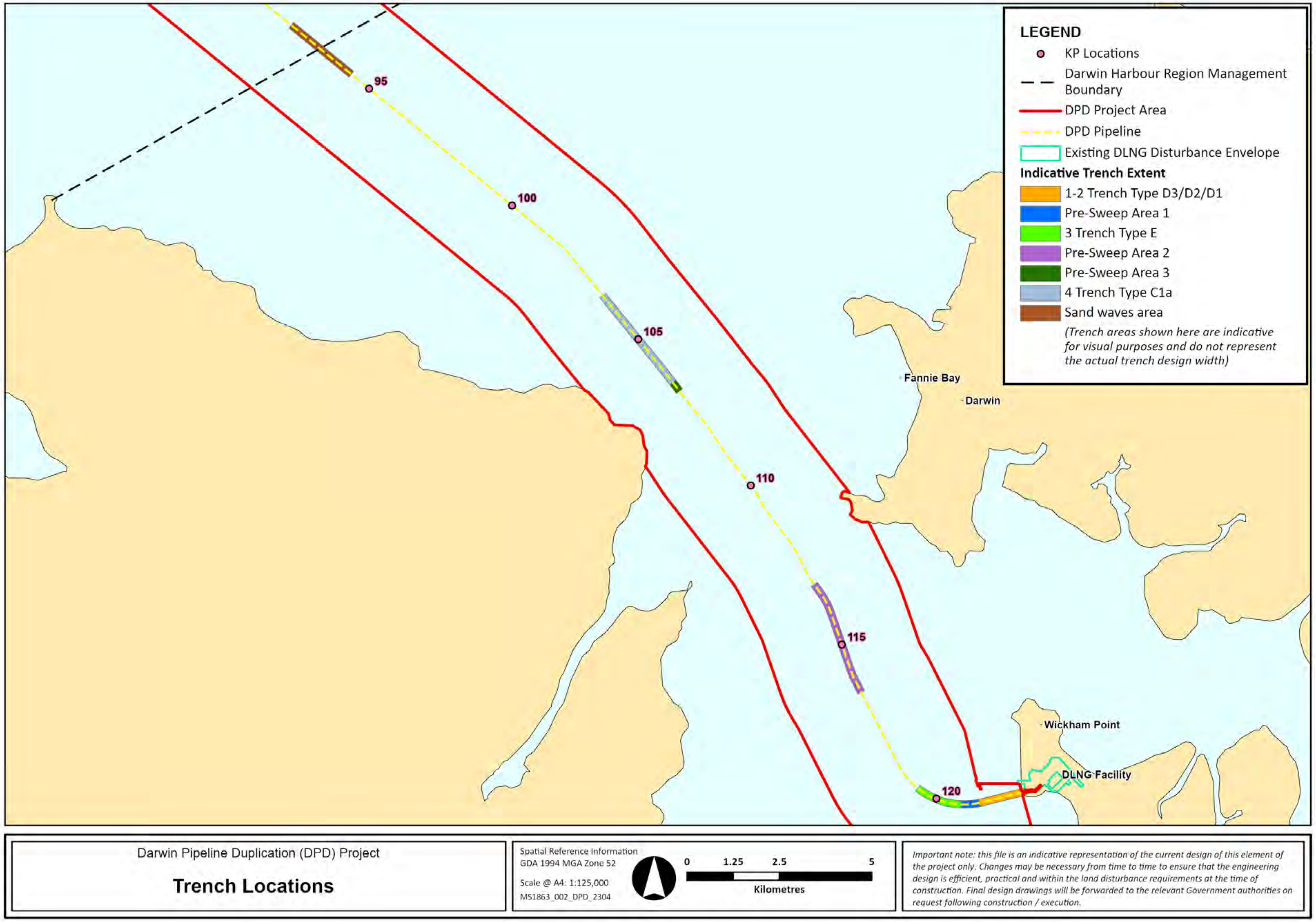


Figure 2-4 Proposed pipeline route with trenching, pre-sweep and sand waves sections and the proposed trenching vessel

2.3.2 Maintenance trenching

Depending on the final construction schedule, a maintenance trenching campaign may be required to ensure the trench remains in specification for pipe lay. Due to sediment mobility within the harbour over the wet season, material may deposit within the bottom of the trenches whilst they lay open for pipelay to commence. Bathymetry surveys will be undertaken following any cyclone events or prior to the pipelay campaign to determine the level of sediment build up and will indicate if maintenance trenching is required. This is typically completed with a multi-beam echosounder (MBES) which will be passed over the trench zones. As the bulk of the trenching will have been completed, including the removal of all hard material, it would be expected that only a TSHD and/or BHD would be utilised to carry out the maintenance trenching. It is anticipated that the primary vessel for maintenance trenching would be the TSHD, with the BHD only used if the shore crossing site was impacted. A towed plough may be deployed to remove any localised high spots from sediment infill prior to pipelay. The plough will be surface deployed and towed from a suitable vessel and only be used within areas that have been previously trenched minimising impact to benthic habitats.

Maintenance trenching may be required due to the mobility of the sediment within Darwin Harbour. Sediment mobility is difficult to determine, however, conservative estimates indicate that up to 20% of the primary trenching campaign may need to undergo maintenance trenching, resulting in no more than 80,000 m^3 of additional trench material to be removed. The maintenance works are likely to be isolated pockets along the entire trench corridor that require clean-up to ensure the pipeline is installed and buried correctly. This would be completed over a short timeframe due to the likelihood of only soft material being present post wet season, with an expected timeframe of no longer than two weeks. If maintenance trenching is required, this would likely occur at the end of the cyclone season around the months of April/May.

2.3.3 Onshore trenching

The route of the onshore pipeline section lies within the existing DLNG facility disturbance footprint and was cleared of native vegetation during construction of the Bayu-Undan to Darwin Gas Export Pipeline. The vegetation that is present consists of naturally regenerated native grasses and weeds. The grasses and topsoil will be stripped, and the trench will be excavated to approximately 2.5 m deep and up to 3 m wide at the base.

The onshore trenching works will be undertaken during wet and/or dry seasons. The trenching of the onshore works may require dewatering due to rainwater, if undertaken in the wet season. The management of the dewatering activities is detailed in the Onshore CEMP (**Appendix 11**). While considered unlikely, there may be some dewatering of groundwater required, and is included in the ASSDMP (**Appendix 12**) to ensure management of any acidic groundwater.

Excavated material from the trenches will be placed on the non-working side of the trench or stockpiled within the onshore Project area within the DLNG disturbance envelope for future reuse as backfill. Surplus material will be removed offsite. If any excavated material from onshore trenching is suspected to be potential acid sulfate soil, testing and treatment will be undertaken as per the ASSDMP (**Appendix 12**).

The construction works for the onshore trenching will be undertaken simultaneously with intertidal construction works. Therefore, trenching will initially be completed from the upstream weld of the beach valve location to the extent of the DPD site pad used for pipeline installation through the shore crossing (shore pull). This section will be approximately 130 m in length. Once the shore crossing facilities have been removed, the onshore trench will extend to the onshore termination point. This trench will be approximately 70 m in length and up to a maximum of 40 m wide. The onshore construction site and onshore trenching area can be seen in **Figure 2-8**.

2.3.4 Temporary causeways

Temporary causeways will be constructed to assist with pre-lay trenching of the shore crossing.

The construction of the causeways will require up to 1,600 m^3 of rock sourced locally from revetement rock or imported from the Mount Bundey quarry. The upper portion of the causeway will have a layer of smaller gravel or rocks applied to make the causeways suitable for machinery access to facilitate trenching.

Rock will be placed on the seabed by dump trucks and flattened out by a wheel loader until the causeway has reached the required distance from the shoreline. An excavator will be used where required to shape the causeway to ensure the width is suitable for access by the heavy machinery. Causeway design is shown in **Figure 2-6.**

The maximum area required for the temporary causeways has been estimated to be no greater than 200 m by 25 m, with a height up to ~4 m but an average height of ~2 m.

The causeways will be removed following use to return the intertidal area back to its natural grade. Recovered rock will be disposed offsite.

The causeways will be removed by excavators following completion of construction activities with recovered rock disposed of offsite in line with regulatory requirements.

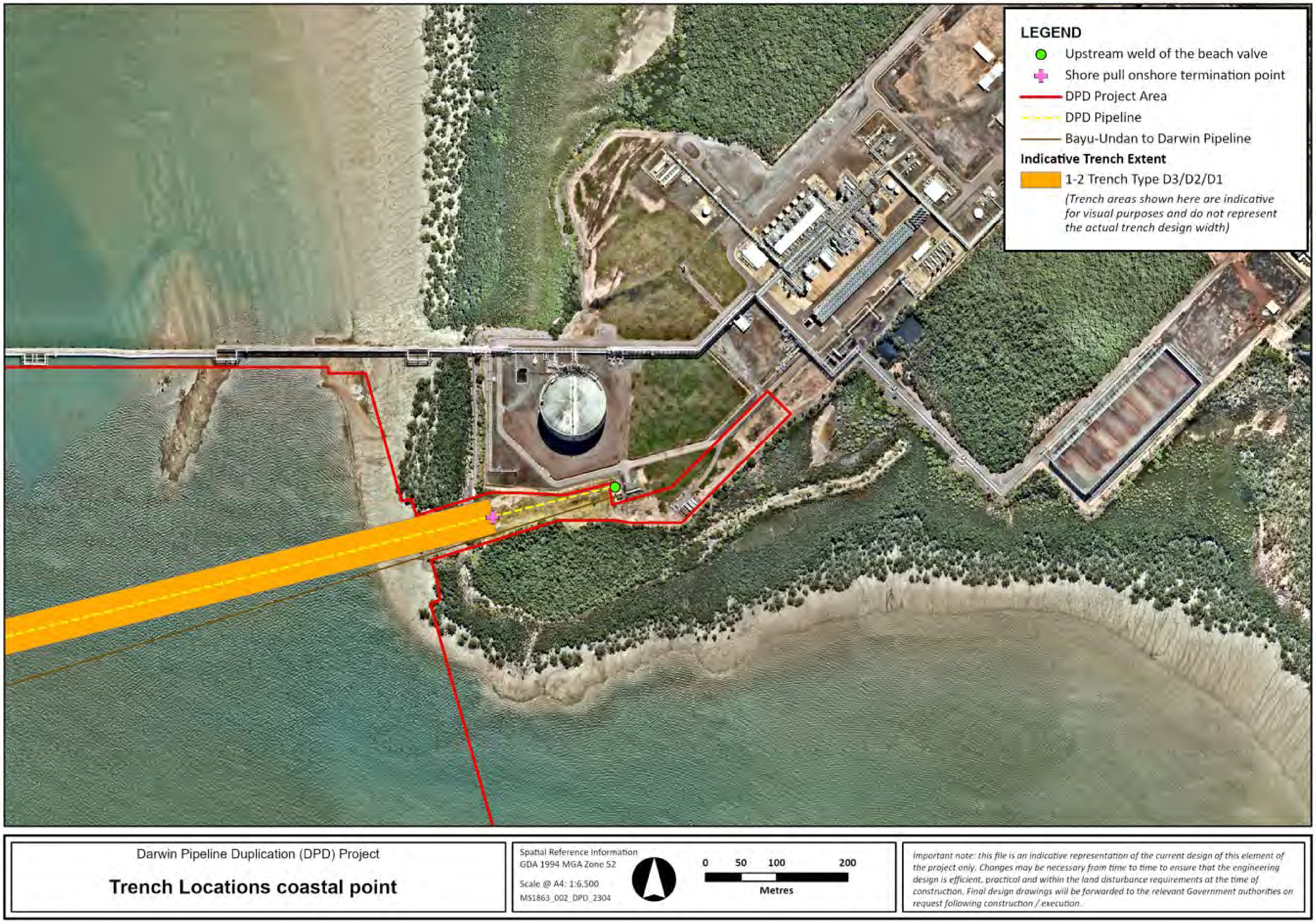


Figure 2-5 Proposed onshore and intertidal trench locations

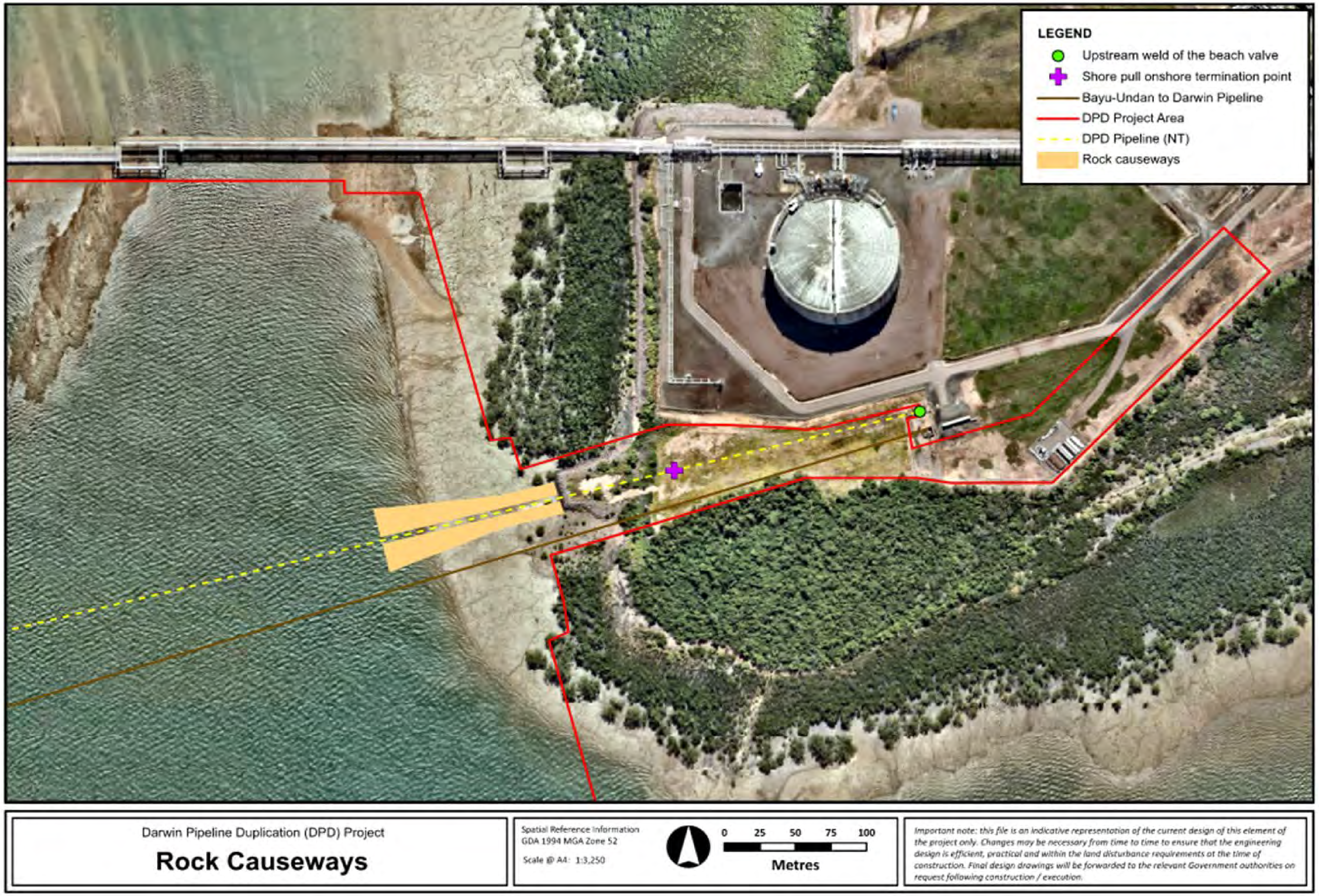


Figure 2-6 Temporary causeway location

2.3.5 Span rectification and foundation installation

Pre-lay span rectification will be required in some areas to reduce pipeline spanning. The use of a TSHD to rectify sand waves along with other sites outside of the planned trench zones by removal of sediment between KP92.2 and KP94.4 is detailed in **Section 2.3.1**. Additional areas may also require the use of the TSHD to prepare the benthic substrate prior to pipelay, and these will be assessed as works commence and progress. Pre-lay span rectification may also be performed using concrete mattresses, grout bags or mass flow excavation (MFE) subject to the seabed topography and benthic conditions.

An MFE tool works by accelerating a mass flow of water to blow away sediments within a localised area and can be used to accurately remove sediment high points and reduce pipeline spanning. MFE is an alternative to the installation of numerous concrete mattresses or grout bags. Where concrete mattresses or grout bags aim to support a spanning pipeline, the MFE will remove the span entirely limiting the exposure of the pipeline over its operational life and remove potential integrity concerns. The MFE would be deployed by a construction vessel using dynamic positioning and therefore no additional seabed disturbance due to the absence of anchoring is predicted other than within the localised area where the MFE operates.

The use of MFE has been identified as a potential method to reduce sediment high points at eight locations within two areas along the offshore pipeline route in NT waters. The first area is between KP51 to KP53 (consisting of four sites), approximately 40 km offshore from the Darwin Harbour boundary; the second area is between KP72 and KP81 (consisting of four sites), approximately 12 km from the Darwin Harbour boundary. At each location it is expected that typically less than 100 m of excavation, to a nominal width of 3 m at the bottom of the excavation, would be required along the pipeline route.

The use of MFE would occur during pre-lay activities and is expected to take an indicative 7-14 days to complete, with an estimated six hours of operation at each site.

The MFE tool will generate localised turbidity at the seabed during the excavation process. At the locations identified for MFE use, sediment characteristics, as identified by DPD Project sediment sampling (**Appendix 6**), indicate a high proportion of sand/gravel (70-90%), with a lesser contribution of fine sediments (silt/clay) (10-30%). Given the localised method and area of operation and the type of sediments observed at the excavation sites, turbidity created by the MFE tool is predicted to be localised and temporary. The lower fines content will also help mitigate large plume generation and limit turbidity.

The installation of concrete mattresses or grout bags may be used in addition to MFE where MFE proves unsuitable (e.g. if consolidated sediments are encountered that cannot be removed by MFE) or as an adjunct to MFE if there is residual spanning requiring further rectification. Each concrete mattress footprint is ~18 m^2 and may be installed in groups and stacked on top of each other to reach the desired height.

Post-lay span rectification, if required, is likely to be performed using grout bags aided by a remotely operated vehicle (ROV). The likely disturbance footprint, at each site, is approximately 25 m^2. Grout is an inert substance and will be used to fill the grout bags in-situ. Following grout bag filling, grout lines will be flushed resulting in small discharges of grout to the marine environment.

In addition to concrete mattresses for span rectification, for the in-line tee, a steel pre-lay foundation may be installed, complete with scour protection using mattresses or grout filled mats, with an approximate footprint of 375 m^2.

2.3.6 Cable crossings

The DPD pipeline will intersect with telecommunication and power cables at four locations within Darwin Harbour. The locations of the telecommunication and power cables are well known and are highlighted on maritime charts as 'no anchoring zones'. These locations are expected to be the crossing points however the cables are dynamically stable so they may shift slightly prior to the construction of the crossing. Telecommunications and power cables will be protected during pipelay operations using concrete mattresses if required. Supports either side of the individual cables will be provided, and it is likely that concrete mattresses will also be used to provide clearance between the Project pipeline and cables.

Detailed survey will be undertaken prior to any activities performed in the vicinity of the power and telecommunication routes. Furthermore, anchoring associated with pipelay activities in this area will include appropriate pull-on and pull-off separation distances to ensure no interaction with the cables present.

2.3.7 Pipeline crossings

The DPD pipeline crosses over the Bayu-Undan to Darwin pipeline at two locations in order to avoid encroaching into the Darwin shipping channel. The crossing locations have been selected in regions where the Bayu-Undan to Darwin pipeline is covered by a rock berm. The DPD pipeline is supported by concrete mattresses over the crossings to manage spanning and to ensure a minimum separation between the DPD pipeline and the Bayu-Undan to Darwin pipeline rock berm.

There is the potential to install approximately 30,000 tonnes of rock at the crossing locations subject to pipeline detailed design.

2.4 Pipeline installation

The DPD pipeline will extend from the point where the Barossa GEP reaches the existing Bayu-Undan to Darwin pipeline in Commonwealth waters, to the DLNG plant at Wickham Point in Darwin Harbour (refer **Figure 2-1).** The DPD pipeline will be located parallel to the existing Bayu-Undan to Darwin pipeline, with the exception of where it crosses the Bayu-Undan to Darwin pipeline in two locations, to minimise potential environmental and social impacts. Approximately 12.5 km of the pipeline route within Darwin Harbour will be trenched with the remainder of the pipeline laid on the seabed. Rock sourced from the local Mount Bundey quarry will be used to backfill the trench within nominated sections (refer **Section 2.5**).

2.4.1 Offshore pipelay

The DPD pipeline will be laid using a continuous assembly pipe-welding installation method. This involves assembling single pipe joints (approximately 12 m in length) in a horizontal working plane on-board the pipelay vessel. The pipes are welded together, inspected and then the welded area is coated on-board before being lowered behind the pipelay vessel. The pipelay process uses an 'S-lay' method (with the S notation referring to the shape of the pipeline catenary as it is lowered to the seabed). As the pipeline is lowered, it is supported on-board the pipelay vessel using a curved steel structure fitted with rollers known as a stinger. Pipelay in shallow water will be conducted using an anchored pipelay barge; while pipelay in deeper water will be conducted using a dynamically positioned deep water pipelay vessel. KP91.5 is the nominated handover point between the anchored pipelay barge and deep water pipelay vessel in approximately 20 m of water, but the actual handover point where the deep water pipelay vessel will take over will depend on operational requirements.

2.4.1.1 Dead-man anchoring

A dead-man anchor may be used during a midline start up with the dynamically positioned pipelay vessel. The dead-man anchor will 'dig' into the seabed to provide stability for the dynamically positioned pipelay vessel during pipelay initiation.

The base case is to sequentially install the shallow water section of the DPD pipeline followed by the deep-water section. However, subject to vessel availability and other operational drivers the deep-water vessel could commence pipelay requiring the need for a mid-line start-up.

If a mid-line start-up of the DPD pipeline is required, then a dead man anchor assembly shall be used to initiate pipelay and allow the pipeline to be tensioned. The dead man anchor assembly is essentially a drag anchor connected to nominally 1,500 m of wire cable.

If required, the dead-man anchor shall be installed adjacent to the DPD pipeline route and shall be removed on the completion of pipeline initiation.

2.4.1.2 Above water tie-in

The base case is for the Project pipeline to be sequentially laid, beginning at the shore crossing, moving through Darwin Harbour and progressing offshore through NT waters to the PLET in Commonwealth waters. For this to occur the last section of pipe laid by the shallow water pipelay barge will have a recovery head arrangement installed which will include a submersed pennant buoy, allowing this and the pipe to be recovered by the deep water pipelay vessel. Once retrieved the recovery head will be removed and recovered pipe welded to the new section of pipe to commence the deep water pipelaying process. The base case handover point will be at KP91.5 in approximately 20 m of water, in this case the shallow water pipelay barge will have laid approximately 31 km of pipe and the deep water pipelay vessel will lay approximately 69 km of pipe in NT waters.

An alternative to pipelaying sequentially from onshore to offshore may be to install the deep water portion of the DPD pipeline ahead of the shallow water portion, or to install both portions concurrently. In this scenario, the shallow water vessel would still commence at the shore crossing to facilitate the shore pull and an above water tie-in (AWTI) would be performed where the two sections of pipeline meet. The AWTI would occur using the shallow water pipelay barge and would involve recovery of pipeline end sections using davits and subsequent welding from a temporary work platform. This activity would involve the installation of buoyancy modules on the pipe tails to support the pipeline end sections and facilitate correct alignment for welding.

2.4.2 Shore pull

The DPD Project will utilise the shore pull method to bring the pipeline onshore.

The shore pull will be undertaken as follows:

+ A large wire will be connected onto the front end of the pipeline via a pullhead. The large wire could be pulled out to the vessel from shore along the seabed using a smaller pull-wire, or conversely it could be pulled from the vessel to the shore subject to the selected installation methodology. In either scenario the wire will be pulled along the seabed within the pipeline route disturbance corridor;
+ Pipeline will be assembled on the shallow water pipelay barge;
+ Pipeline will be pulled ashore from the shallow water pipelay barge using the winch spread located onshore through the pre-constructed trench to the onshore target box;

+ The pipe will be winched up to the shore pull onshore termination point, approximately 2 m above HAT which is the end of the shore pull; and
+ The pulling arrangement will allow for the shore pull to be completed as a continuous operation, which will take approximately two weeks.

2.4.3 Onshore pipeline installation

The installation of the pipeline between the shore pull onshore termination point and the upstream weld of the beach valve (approximately 200 m) will follow a different process to the offshore pipelay and shore pull. Pipe sections will be strung out alongside the trench, lifted onto temporary pipe supports and cut to length as required, end preparation works completed and aligned for welding. This will be followed by butt welding of the joint and non-destructive evaluation (NDE) until the sub-assembly is completed. The sub-assemblies will be lifted onto temporary pipe supports in the trench, aligned for welding and joints butt welded. The final NDE and coating will be completed after hydrotesting.

2.5 Rock installation

The primary method of maintaining pipeline stability on the seabed will be through the concrete weighted pipeline coating. However, rock installation is required for secondary stabilisation and/or protection for pipeline sections within Darwin Harbour where the concrete weighted coating alone is not considered sufficient to provide stability and/or protection.

The material that is removed from the trench is not considered to be viable for use as ‘fill’ back to the pipeline trenches. The seabed along the offshore pipeline route (KP0 to KP91) is predominantly sand. The seabed along the northern end of the pipeline route is gravelly silty sand (16% gravel; 9% silt), which becomes less gravelly and much siltier (39% silt; 0.2% gravel), with higher proportions of clay, towards the southern end of the offshore pipeline route. The pipeline route sediments within Darwin Harbour (KP91 to KP122.5) are composed of varied particle sizes. At the northernmost end of the pipeline alignment a very high proportion of silt (46%) and clay (10%) exists, similar to the southern offshore pipeline route. The sand wave area (refer **Table 2-2**) has very high proportions of sand (up to 93%),while the southern end of the pipeline route consists of gravelly silty sand (**Appendix 6**).

Trenched material is incompatible with re-use in pipeline stability and protection, therefore will be placed at the spoil ground. Using this trenched material would also require considerably more trenching (i.e. deeper trenches would be required) to guarantee stability and protection of the pipeline. This would increase the dredged volume considerably, resulting in a greater potential impact to the environment. The process and requirements of backfill must be to a minimum specification in order to ensure the pipeline is suitably protected and will not suffer any damage from installation activities. The process to provide the level of guarantee of the material would require significant qualification and testing. Furthermore, contingency rock sourcing and installation methods would be required to address the scenario where the required trench depth cannot be achieved to guarantee sufficient pipeline protection using backfill material.

In the referral, Santos had considered using material excavated from borrow grounds adjacent to the pipeline, this option is no longer being pursued as there is a lack of supporting evidence that the borrowed sand material would be adequate to address the technical requirements of backfill as discussed above. Instead, this Project will follow previous projects in Darwin Harbour that have used rock material for the required backfill.

The rock material required for subsea rock installations will be obtained from suppliers from the Mount Bundey quarry located about 115 km south-east of Darwin. Rock will be transported from Mount Bundey to East Arm Wharf, where it will be stored within the DLNG site, until it is then transported by truck for load out to vessels. Rock installation vessels will include a fall pipe vessel and BHD for rock installation at the shore crossing. Rock installation by BHD at the shore crossing will be supported by rock barges and onshore plant.

2.6 Flooding, cleaning, gauging and testing

2.6.1 Planned flood, clean, gauge and testing operations

Once installed, the Project pipeline internal surfaces will need to be cleaned, tested and preserved in preparation to carry hydrocarbons. Key activities involved with Flood/Clean/Gauge/Testing (FCGT) operations will include:

+ Pigging undertaken to clean and prepare the pipeline using pipeline inspection gauges (pigs);
+ Pig launcher/receivers installed on the Commonwealth waters PLET and at the shore crossing; and
+ Pigs pushed using chemically treated seawater with water 'won' (extracted) from Darwin Harbour;
+ Pipeline subjected to a hydrostatic pressure test; and
+ Pipeline dewatered, conditioned with monoethylene glycol (MEG) and purged with nitrogen.

In the marine environment, due to the corrosive nature of seawater, maritime industries use and rely on a range of chemicals including corrosion inhibitors, biocides, and oxygen scavengers to protect the integrity of assets and infrastructure and prevent microbial growth. For the DPD Project, such chemicals are required to be used to treat seawater (treated sweater) that will be used during pigging and to hydrotest the pipeline (i.e. confirm its integrity) prior to commissioning the pipeline and introducing hydrocarbons.

Treated seawater is typically a mixture of biocides (to prevent biofouling and bacterial corrosion on the internal surfaces), an oxygen scavenger (to control corrosion of the pipeline) and a dye (for leak detection during hydrotest). The planned chemical for treating seawater will be 'Hydrosure' or 'Hydro 3' or similar (for more detail on Hydrosure, refer to **Section 8.5.2**), however all chemicals will require assessment and be approved by Santos. The chemical concentration of the hydrotest water will be dependent on the required preservation period, which is the period of time the pipeline will be left filled with the chemically treated seawater before being dewatered for tie-in and commissioning (or repair in the case of a wet buckle event). Typically, a concentration of up to 550 ppm of the hydrotest package will be used for the planned duration.

Treated seawater will be used to separate each pig (during flooding) and will be discharged as each pig completes a run. A slug of filtered and chemically treated forewater will be injected ahead of the first pig to lubricate the polymer (typically polyurethane) sealing discs on the pig and control pig speed. There is potential that some debris remaining from pipeline installation activities within the pipeline may be discharged with this water.

There will be nominally five pigs separated by 500 m treated sea water slugs, plus 500 m of forewater in front of the first pig as shown in **Figure 2-7**. The total volumes are summarised in **Table 2-3**. These reflect an over-pump contingency of up to an additional 10% of the total volume of the pipeline.

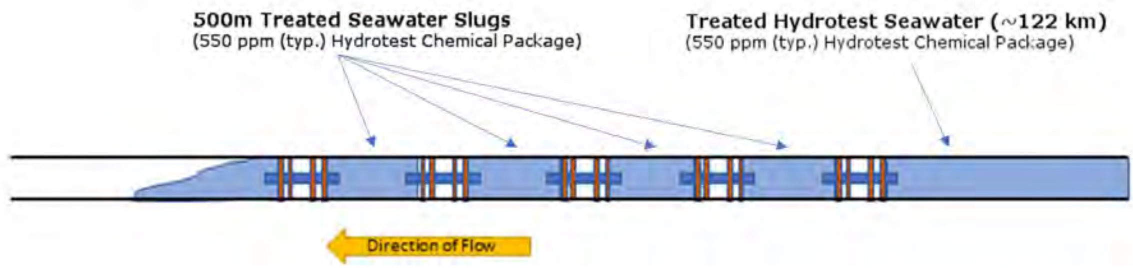


Figure 2-7 Schematic showing five pigs separated by 500 m

Once the pigging operations are completed and integrity tests met, the pipeline will be subjected to a hydrostatic pressure test (hydrotest). An additional volume of treated water is pushed into the line to raise the pressure of the pipeline. The hydrotest pressure will be held for a period as per the relevant standard to test the pipeline integrity. There will be small, localised discharges at the pipeline end termination (PLET) in Commonwealth waters as that infrastructure is tested and the GEP is depressurised.

Upon completion of FCGT activities, to dewater the pipeline, treated seawater will be discharged at the pipeline end termination (PLET) of the DPD pipeline, in Commonwealth waters, approximately 16 km west of the Commonwealth/NT waters boundary. The pipeline will be conditioned with 1000 m^3 of monoethylene glycol (MEG) and purged with nitrogen. The GEP will be dewatered using a train of dewatering pigs separated by MEG slugs. Approximately 1000 m^3 of MEG will be discharged at a final purity of >92%.

While activities in Commonwealth waters are out of scope for this assessment, the potential impact to NT waters from discharges related to FCGT operations in Commonwealth waters are considered and assessed for completeness (refer **Section 8.5.2.4**).

Dewatering is expected to take one week. Dewatering discharge will be at the seabed through a diffuser attached to the DPD pipeline PLET in Commonwealth waters.

The MEG could be discharged at the seabed or the surface, subject to the methodology adopted to sample the MEG in order to confirm that the pipeline has been correctly preconditioned.

Table 2-3 presents the estimated discharge volumes for each stage of FCGT.

Table 2-3 Estimated Volumes of Discharge at the Commonwealth waters PLET During the FCGT

Pipe Diameter	26-inch Length (m)	34-inch Length (m)	Treated Seawater Discharge volume (m^3)		
			Pre-hydrotest*	Hydrotest	Dewatering
26/ 34 inch hybrid	61,800	60,684	4,183	2,000	50,117

*Pre-Hydrotest - (5 off 500 linear metre slugs) +10% overpump

Each of the discharges (**Table 2-3**) will occur at separate times at the DPD pipeline PLET.

The pig train should typically travel at a rate of 0.5 to 1.0 m/s for efficient dewatering and operation Resulting in indicative discharge rates as presented in **Table 2-4**.

Table 2-4 Discharge rates [m³/hr] at the Commonwealth waters PLET based on pig speed and pipeline diameter

Pipeline Size	Pig Speed	
	0.5 m/s	1.0 m/s
26-inch	543 m^3/hr	1086 m^3/hr
34-inch	934 m^3/hr	1867 m^3/hr

Hydrotesting of the onshore DPD pipeline (between the onshore tie-in point (OTP) and the beach valve) will be done separately to the offshore DPD pipeline, whereby the hydrotest medium for the section between the OTP and the beach valve will need to be disposed of either within the DLNG facility, or through an external waste disposal site.

In the instance that the offshore DPD pipeline is hydrotested and pre-commissioned through tying into the onshore pipeline downstream of the beach valve, all hydrotest medium up to the point where the pipeline is tied in will be disposed of offshore. In this circumstance, the pipeline between the OTP and the beach valve, may have already been hydrotested (due to changes in design codes requiring higher test pressures), so therefore as above, the hydrotest medium will have been disposed of within the DLNG facility, or through an external waste disposal site.

2.6.2 Water extraction and filter flushing

To provide water for FCGT activities, water will be extracted (water winning) from Darwin Harbour. The current concept is that water winning will be via a pumping spread comprising four mesh-screened, submersible pumps supported on an anchored pontoon, with a water discharge manifold and hoses, power supply cables and a winch. It is anticipated that the pontoon and extraction hose will be positioned approximately 600 m from shore in approximately 15 m of water at LAT. Alternatively, water winning may occur through a similar spread located along the DLNG jetty or jetty head.

The total volume of water required will be dependent upon the nature of the FCGT and any contingency requirements (for example pipeline filling associated with responding to a wet buckle event). Planned FCGT water winning requirements are expected to require approximately 56,000 m^3 of water. Pumping rates are expected to be approximately 9-16 m^3/minute and water winning for FCGT activities is expected to take place over approximately three days (not including any contingency activities).

Water extracted from Darwin Harbour will be filtered prior to chemical treatment. In order to ensure the effectiveness of filters, regular backflushing is required. While the number of backflushes and volume of water associated with backflushing may vary depending upon the effectiveness of filters and level of clogging by suspended solids, it is estimated that approximately 580 backflush cycles will need to take place over three days, with each unit/cycle discharging 0.5 m^3 of backflush water. In total, approximately 300 m^3 of backflush water is expected to be discharged. Backflush water will have a higher suspended solids loading compared to water extracted (i.e., higher than ambient Darwin Harbour water suspended solid concentration). The concentration of total suspended solids (TSS) within backflush water will depend upon the ambient concentration within Darwin Harbour, which will vary with tidal state and season. Water during spring tides and over the wet season are expected to be more turbid (higher TSS concentration) than water during neap tides and over the dry season.

Backflush water will be discharged onto the existing disturbed shore crossing construction site, where it will then drain into the intertidal area and solids will disperse with tidal movements. Where possible, and dependent on the progress of shore crossing rock installation at time of FCGT activities, backflush water will be discharged onto installed rock, to baffle the flow of the discharged backflush water.

2.6.3 Contingency wet buckle operations

During pipelay activities, it is possible that an event may occur that requires remedial (pipeline) construction work, or in an unlikely, worst-case scenario, a pipeline wet buckle (i.e., failure in the pipeline) may occur resulting in raw/untreated seawater entering the pipeline.

Should raw seawater enter the pipeline during installation, it will need to be removed to prevent corrosion of the pipeline. To remove the raw seawater, a contingency pig would be launched with filtered seawater to flush the pipeline, followed by a second contingency pig which is pushed with compressed dry air. The pipeline end is then recovered from the seabed and pipelay can continue. Given only filtered seawater would be used to flush the pipeline, impact to the environment from this type of flushing is not expected. In this instance, a pig may be launched from either the DLNG facility or Commonwealth waters PLET to remove/flush the water from the pipeline, dependent on the location of where the raw sea water entered the pipeline.

In the event of an extended period before pipelay or rectification can recommence, the pipeline would need to be flushed with raw filtered seawater and then filled (from the DLNG facility end) with treated seawater in the intervening period before pipelay is recommenced. In this instance the seawater would need to be treated with a preservation chemical consisting of a biocide, corrosion inhibitor and oxygen scavenger to preserve the pipeline as described in **Section 2.6.1** for planned FCGT activities. If this is required, there is the potential for some of the treated seawater to be discharged as a result of overpump, which is required to make sure the entire previously laid pipeline is preserved to prevent corrosion. Once pipelay activities are ready to be recommenced, the treated seawater would need to be discharged (dewatering of the pipeline). The volume of discharge would depend upon the pipeline location where the wet buckle (or other pipeline breach) occurs, which would dictate the length of the pipeline that would require dewatering. This type of contingency discharge could occur in either Commonwealth or NT waters.

While this is an unlikely event, it has occurred elsewhere so is being carried as a contingency activity and the potential for impacts has been assessed.

2.7 Onshore site set-up

Site works within the onshore portion of the Project area will be required to support the DPD Project construction activities up to the beach valve location (**Figure 2-8**). Earthworks will be required to facilitate the set-up of the onshore site and allow positioning of equipment including removal of rock associated with an existing marine offloading facility (rock groyne), construction of a shore pull/ FCGT site pad and the creation of a temporary access road. The construction of the onshore site and onshore component of the shore crossing shall allow for shore pull activities, FCGT activities, limited rock placement, onshore trenching and pipelay activities, and equipment layout for contingency operations, including but not limited to allowing for wet buckle dewatering to be performed whilst the pull head is attached to the winch wire.

To facilitate parallel activities at the site pad and shore crossing areas during trenching and pipeline installation of the onshore section, a temporary road will be built through the DLNG site. This will allow access to the shore crossing from the south side of the proposed pipeline route. Approximately 200 m (from KP122.484 to KP122.69) of the onshore pipe will be installed once the offshore and intertidal sections of the DPD are complete (**Figure 2-8**). If the onshore portion of the pipeline is connected prior to completion of the offshore portion of the DPD pipeline, the combined onshore/offshore sections of the DPD could be FCGT in one event.

Figure 2-8 Indicative onshore site layout

2.8 Vessel activities

Table 2-5 shows the types of vessels proposed for the DPD Project, and their attributes relevant to potential environmental impacts. The number of transits and nominal transit speeds are estimates of what will occur during construction of the DPD pipeline, noting that all vessels will comply with harbour speed limits in accordance with the Darwin Harbour Handbook.

A comparison between predicted DPD Project vessel movements with historical Darwin Harbour commercial vessels visits is provided in **Figure 2-9**. This includes both 'harbour visits' (movements of DPD Project vessels in/out of Darwin Harbour) and 'intra-harbour' movements (movements of DPD Project vessels between locations within Darwin Harbour).

The use of vessels for pipelaying and trenching is predicted to increase the activity within the harbour area through an additional nominal 57 and 54 harbour visits respectively, during the construction period for the DPD Project. For 2020/2021 the number of recorded commercial vessel harbour visits was 1,416 so Project vessels would increase harbour visits by <8% from that year, or <5% based on the past 10 years (**Figure 2-9**). Within Darwin Harbour, DPD Project vessels are predicted to make an estimated nominal 243 movements between locations over the construction period. The scale of DPD vessel movements is within the range of annual variation seen in Darwin Harbour across the past 10 years (**Figure 2-9**).

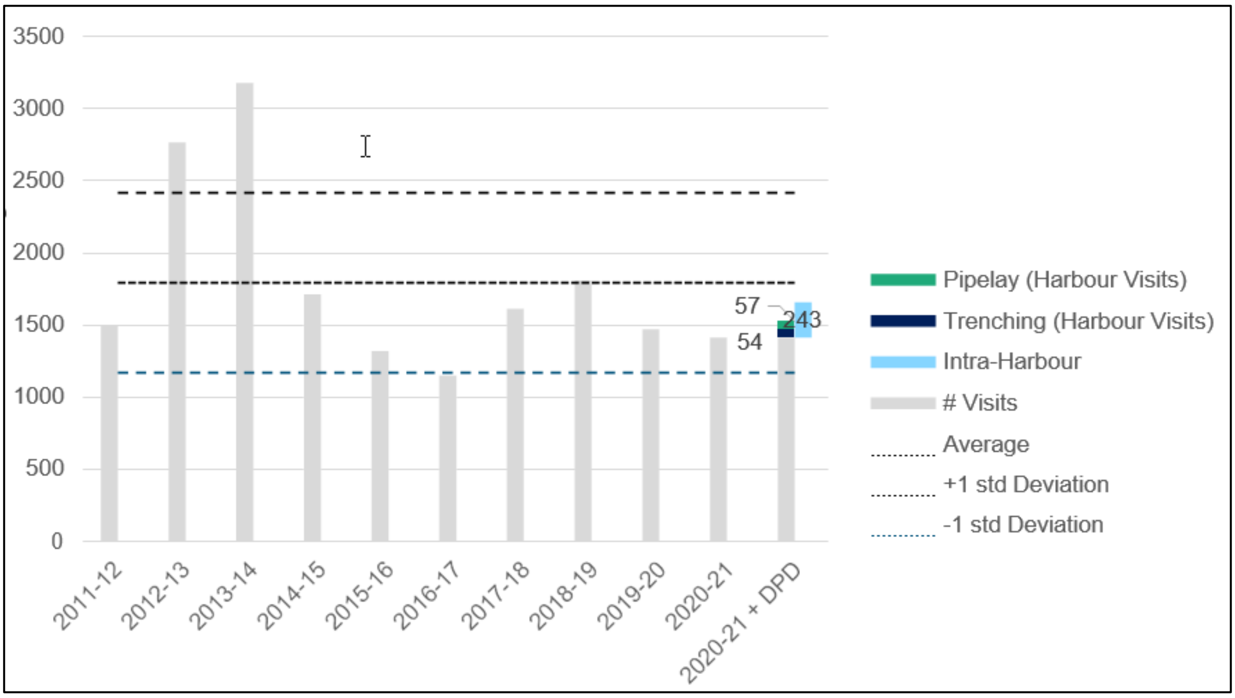


Figure 2-9 Annual harbour visits FY2011-12 to FY20-21

Table 2-5 Vessel description/summary

Vessel Type	Self-propelled	Lighting		Work speed (in field)	Nominal transit speed*	Nominal # of transits	Expected Duration
		Work	Navigation				
Trenching							
Backhoe Dredge (e.g. Peter de Groote)	No	✓	✓	Stationary (shift)	3 Kn	2	4 months
Split Hopper Barges (SHB) (e.g. Sloeber)	Yes	✓	✓	Stationary (shift)	10 Kn	17	4 months
Cutter Suction Dredge (CSD) (e.g. Amazone)	Yes	✓	✓	Stationary (shift)	12 Kn	5	5 weeks
Trailer Suction Hopper Dredge (TSHD) (e.g. Bonny River)	Yes	✓	✓	2 Kn	14 Kn	50	5 weeks
Pipelay and rock installation							
Pipelay Barge - Shallow water pipelay barge (SWPLB) e.g. Sandpiper + Tug)	No	✓	✓	300 m / day	3 Kn	2	4 months
Pipelay vessel – deep water pipelay vessel (e.g. Audacia)	Yes	✓	✓	3 km / day	16 Kn	1	30-45 Days
Pipe Supply Vessels (e.g. Alegria)	Yes	✓	✓	Stationary (1hr, 3/week)	10 Kn	54	4 months

Vessel Type	Self-propelled	Lighting		Work speed (in field)	Nominal transit speed*	Nominal # of transits	Expected Duration
		Work	Navigation				
Construction support Vessel/Survey (CSV) (e.g. Fortitude)	Yes	✓	✓	Stationary (shift)	14 Kn	2	4 months
Nearshore CSV/Survey (Span Rectification)	Yes	✓	✓	Stationary	14 Kn	4	4 months
Rock Installation (BHD)	No	✓	✓	Stationary	5 Kn	2	2 months
Fall Pipe Vessel (FPV) (pipeline route to wharf)	Yes	✓	✓	< 3 Kn	12 Kn	14	7 weeks
Rock Barge (pipeline route to wharf)	No	✓	✓	Stationary	5 Kn **	Unknown at this stage	2 months
Support Operations							
Multicat (shallow water anchor handling for SWPL barge and CSD)	Yes	✓	✓	0.5 Kn	9 Kn	N/A	6 months
Supply boat – trenching and rock installation	Yes	✓	✓	Stationary (1hr, 3/week)	10 Kn	27	Every 2 weeks
Crew Boat (Crew change for BHD, CSD, laybarge)	Yes	No	✓	Stationary (30 min, 2/day)	18 Kn	119	6 months

Vessel Type	Self-propelled	Lighting		Work speed (in field)	Nominal transit speed*	Nominal # of transits	Expected Duration
		Work	Navigation				
Survey vessel	Yes	No	✓	< 3 Kn	10 Kn	180	3 months
Environmental Monitoring	Yes	No	✓	Stationary 1 hr, 4/day)	10 Kn	57	As required

*Vessels shall keep within nominated harbour speed limits in accordance with Darwin Harbour Handbook

** 5 Kn is the typical towing speed

2.9 Project schedule

Santos is anticipating that all DPD regulatory approvals will be in place by Q4 2023 to ensure construction activities do not delay Barossa Development's first gas in the first half of 2025. A nominal DPD construction sequence and schedule is shown in **Figure 2-10** representing a start of construction activities at the beginning of the construction window. The construction activities will span a cumulative period of 15-months in the field.

The actual construction sequence and schedule will be subject to the timely receipt of all regulatory approvals and drivers such as vessel availability, operational matters, and weather.

Santos' regulatory approvals and stakeholder consultation consider construction activities may occur at any time between Q1 2024 to the end of Q2 of 2025.

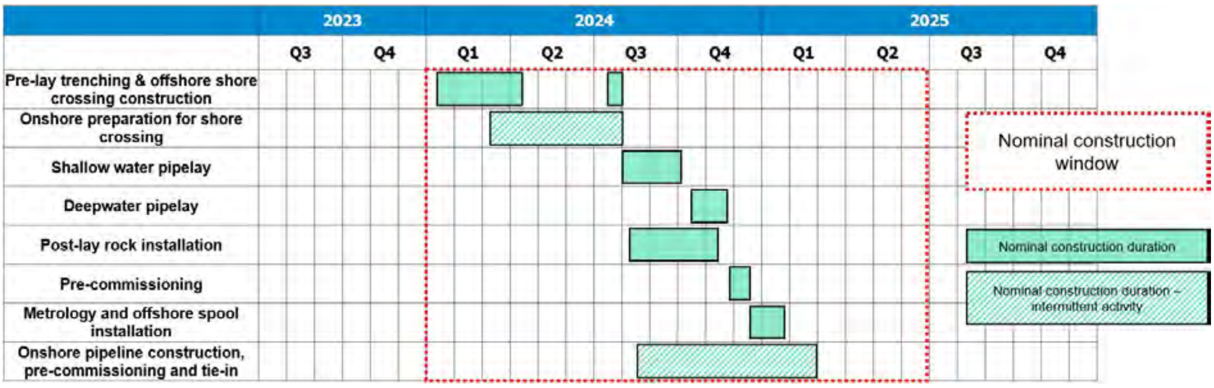


Figure 2-10 DPD Project execution schedule (Indicative)

3 Alternatives

3.1 Background: the Barossa Development

The Barossa Development involves the development of the Barossa gas field through the construction of subsea wells and infrastructure tied into a new offshore floating petroleum storage and offloading facility (FPSO) and the construction of a gas export pipeline to transport gas from the FPSO to the DLNG facility.

An Offshore Project Proposal (OPP) for the Barossa Area Development (ConocoPhillips, 2018) was submitted under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 and accepted by NOPSEMA in March 2018. The OPP outlined options for the development and commercialisation of the Barossa gas field. The options considered for the development of the gas resources in the Barossa area included:

+ An offshore FPSO located in the Barossa Development area with a gas export pipeline to tie into the existing Bayu-Undan to Darwin gas export pipeline to deliver the gas to the existing onshore liquefaction facilities at DLNG;
+ An offshore fixed platform facility (processing and wellhead platforms with a floating storage and offloading facility) with a gas export pipeline to tie into the existing Bayu-Undan export pipeline to deliver the gas to the existing onshore liquefaction facilities at DLNG; and
+ A new floating LNG (FLNG) facility located in the Barossa Development area, with integrated in-field hydrocarbon processing and gas liquefaction and export of LNG directly to LNG ships from this offshore facility.

These options were evaluated against a range of criteria including technical feasibility and safety, environmental impacts and risks, social and heritage, commercial and sustainability. Upon comparison of the FPSO and platform facility options, the FPSO option was preferred based on the advantages it provided, including the lower risk to people and the environment associated with drilling, the smaller seabed footprint and the increased operational flexibility associated with greater liquids storage.

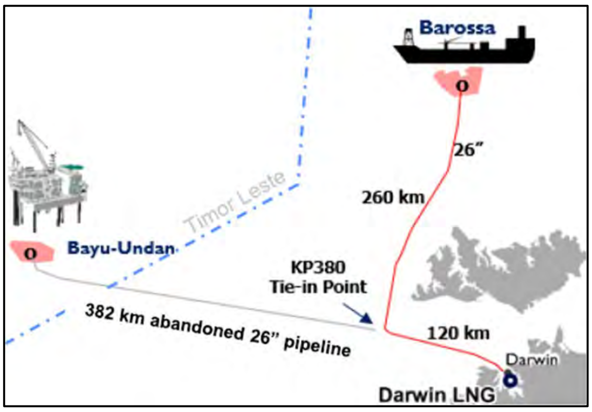
While the new FLNG facility option had some environmental benefits, primarily due to not requiring the construction, installation, and operation of a gas export pipeline from the field, there were also challenges associated with this option. These included a larger underwater noise footprint during operations, higher atmospheric emissions due to greater power demand to support the offshore processing and liquefaction facilities, and the potential for greater operational discharges, e.g. larger volume of cooling water. The FLNG was deemed uneconomic early in the project development phase with the required liquification facilities adding cost to the development. In conjunction with the above factors and the imperative for the project to provide replacement gas for the DLNG facility, as the most appropriate gas route to market, the FLNG option was screened out.

During ongoing assessment planning for the project, the first option utilising the FPSO and a gas export pipeline to the DLNG facility was further refined to enable the opportunity for CCS storage at Bayu-Undan to be developed. The extension of the proposed gas export pipeline all the way to the DLNG facility, rather than tying into the existing Bayu-Undan to Darwin pipeline would allow for the existing Bayu-Undan pipeline to be re-purposed for the transport of carbon dioxide (CO_2) from Darwin to the Bayu-Undan field to be injected into the reservoir for storage.

3.2 Justification for DPD Project

Santos has assessed options to use the existing Bayu-Undan to Darwin pipeline for either the Barossa Development's gas (i.e. tying into the Bayu-Undan to Darwin pipeline as shown in **Figure 3-1** (A)) or future CCS service (i.e. preserving the Bayu-Undan to Darwin pipeline and constructing a new duplicated pipeline, the DPD Project pipeline, as shown in **Figure 3-1** (B)) with the preferred option being preservation of the existing pipeline for potential future CCS and creating a duplicated pipeline for the purpose of carrying the Barossa Development's gas. The option to preserve the existing pipeline for CCS offers a range of potential environmental and other benefits as detailed below and summarised in **Table 3-1**.

(A) (B)



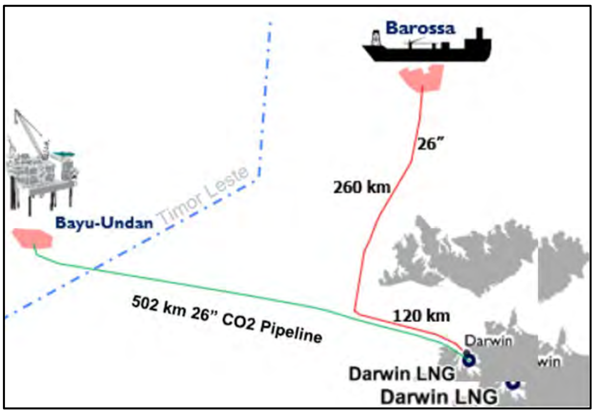


Figure 3-1 Options for the use of the existing pipeline for Barossa gas (A) or CCS service (B)

CCS is the process where CO_2 is captured from an emission source, then dehydrated and compressed for transportation via pipeline to a storage site. The CO_2 is then injected into a geological formation that provides safe and permanent storage deep underground. This process applies technology that has been used in the industry for decades, injecting the gas back into the depleted underground reservoirs.

The Bayu-Undan CCS project (**Figure 1-1**) would store CO_2 in the depleted Bayu-Undan field and, subject to all regulatory approvals, would offer safe and permanent storage of up to 10 million tonnes (Mt) of CO_2 per annum, equivalent to about 2 per cent of Australia's carbon emissions each year (or four times the Barossa Development's estimated annual Scope 1 emissions). Once approved, the project would be one of the largest CCS projects in the world and one of the many that will be critical to assist in meeting the world's climate goals. The International Energy Agency (IEA) Roadmap to Net Zero by 2050 (IEA, 2021b) envisages carbon capture, utilisation and storage growing to 7.6 billion tonnes of CO_2 per year by 2050 from around 40 Mt per year today.

Santos' Barossa Development is one of several potential CO_2 sources for Bayu-Undan CCS, but importantly the Bayu-Undan CCS project offers a 'whole of region' carbon solution delivered through a Darwin CCS Processing Hub (**Figure 1-1**). Potential CO_2 sources could also include existing and/or future NT industry along with international imports.

The Bayu-Undan CCS project is operated by Santos on behalf of the Darwin LNG joint venture: Santos (43.4%), SK E&S (25%), INPEX (11.4%), ENI (11.0%), JERA (6.1%) and Tokyo Gas (3.1%). The CCS project is currently working towards final investment decision (FID), with key activities including:

+ Front End Engineering & Design (FEED) studies, which will further define the scope of the Project along with the plan which will be used to deliver it; and

+ Engaging with a range of stakeholders (including the Timor-Leste, Commonwealth and NT Governments, as well as the various Joint Venture partners) to establish the necessary agreements and regulatory framework required for the Project.

CCS is proven technology, with more than 27 commercial CCS facilities operating around the world today, with a storage capacity of over 36 million tonnes of CO_2 per year (Global CCS Institute, 2021). The Bayu-Undan CCS project proposes to re-use existing infrastructure, which combined with economies of scale is expected to make the project highly competitive in terms of cost.

The Bayu-Undan reservoir is well understood and has the capacity to store large volumes of CO_2. Santos has a strong understanding of both reservoir seal and injectivity, supported by over 18 years of production data at Bayu-Undan. At Bayu-Undan Project start-up, over 1 bcf of gas a day was injected into these high permeability reservoirs.

As part of the FEED activities the Bayu-Undan pipeline is being assessed for feasibility in CCS service. These activities are being independently verified by De Norske Veritas (DNV), an independent verification body, who will be issuing a *Statement of Conformity* which Santos expects will confirm:

1. The design verification and requalification studies have been conducted in compliance with the correct and applicable Australian and International codes and standards;
2. The pipeline design along with the operating and maintenance strategies are suitable to maintain the safe operability of the pipeline in CO_2 service conditions until 2050; and
3. There are no impediments to the pipeline aspects of the project progressing from FEED to the Execute Project Phase.

Santos continues to work closely with the Timor-Leste regulator, ANPM, the National Petroleum and Minerals Authority (ANPM), towards the necessary agreements and regulatory framework that will be required for the Bayu-Undan CCS project, with a Memorandum of Understanding (MOU) having being signed between the two parties. With the signing of the MOU the ANPM President Florentino Soares Ferreira said: *"Despite Timor-Leste being one of the lowest emission countries in the world, and that the Paris Agreement provides waiver or concession to the developing and less developed nations such as Timor-Leste; we understand that carbon trading or carbon credits market is an integral part of our future economy. We don't want to miss this opportunity."*

Santos is firmly committed to CCS, with the DPD Project representing a commitment in excess of US $600M towards the CCS development.

A CO_2 transmission pipeline is a key piece of infrastructure required for the Bayu-Undan CCS project. By constructing the DPD pipeline to export gas from the Barossa gas field, the Bayu-Undan to Darwin pipeline (approximate 502 km) is left intact and preserved for future use in the potential Bayu-Undan CCS project. The key benefits of this include:

+ Earlier realisation of the CO_2 storage benefits from CCS (up to two years earlier), compared to having to construct a new CO_2 pipeline;
+ Health, safety and environmental risks associated with the subsea tie-in of the Barossa Development pipeline to the Bayu-Undan to Darwin pipeline are eliminated. This would typically be a high-risk activity involving the use of subsea saturation divers; and
+ The cost competitiveness of the Bayu-Undan CCS project is improved, strengthening the likelihood of future CCS environmental benefits being realised. This is largely due to the costs

associated with the subsea tie-in being eliminated along with eliminating future costs to construct a pipeline from the DLNG facility to a tie-in point.

3.3 Pipeline route environmental assessments

As part of the project design phase for the DPD Project, multiple pipeline routes were assessed against environmental, socio-economic and cultural heritage criteria as described in the DPD Project referral. A Darwin Harbour pipeline route was selected over a Cox Peninsula route or a Gunn Point route for a number of reasons, including that it eliminates the requirement for a long onshore pipeline which has the potential for additional environmental, culture and heritage, social, community and economic impacts. The Cox Peninsula route required a 116 km onshore pipeline and the Gunn Point route a 71 km onshore pipeline, including passing through the outer suburbs of Darwin.

The Cox Peninsula route was not considered suitable as the northern part of the peninsula, which belongs to the Kenbi Aboriginal Land Trust, has numerous sacred sites where access is not permitted, including some areas where there is no beach access, and anchoring or other seabed disturbance Is not permitted, e.g. at Charles Point. Consequently, further evaluation of potential pipeline routes was only conducted for the proposed Darwin Harbour route and the alternative Gunn Point route.

Table 3-1 provides a response to the NT EPA's direction *to provide a detailed analysis of the potential significant environmental impacts of alternative approaches methodologies or technologies for the action, demonstrating how the decision to proceed with the preferred option has been made with consideration of section 42(c) of the EP Act, the values associated with the NT EPA factors, principles of ecologically sustainable development, application of the environmental decision-making hierarchy and waste management hierarchy*.

Table 3-1 provides a detailed comparative analysis of the DPD Project using the Darwin Harbour pipeline route option (i.e. the option that was chosen and is the subject of this SER), the Gunn Point pipeline route option, the Bayu-Undan pipeline tie-in option. The table also sets out an evaluation of all options against section 42(c) of the EP Act and the outcomes of the application of the environmental decision-making hierarchy, waste management hierarchy and principles of ESD for each option.

The potential for significant environmental impacts for the Darwin Harbour and Gunn Point route options are associated primarily with the short-term construction phase of the projects. In comparing the two route options, the Gunn Point route is considered to have greater potential for significant environmental impacts to Marine Environmental Quality, Marine Ecosystems and Coastal Processes due to greater disturbance to coastal morphology, sensitive habitats (including seagrasses) and associated fauna and turtle nesting. The Gunn Point route also has greater potential for significant impacts to the NT EPA Factor of Terrestrial Environmental Quality and Terrestrial Ecosystems, with over 70km of the pipeline being constructed underground across land. By comparison, the Darwin Harbour route requires less than 1km of pipeline to be constructed onshore and its alignment allows the pipeline to cross the shoreline within the existing disturbance footprint of the DLNG facility. The Gunn Point route is also considered to have greater potential for significant impacts to Community and Economy through the required installation of underground pipeline through the Darwin suburban area.

On the basis of the assessment, which includes for the environmental benefits of the Bayu-Undan CCS project, the socio-economic benefits of continued gas supply to the DLNG facility, consideration of potentially significant environmental impacts to NT EPA factors in pipeline routing selection and consideration of section 42(c) of the EP Act, the DPD Project Darwin Harbour pipeline route is considered the optimal solution.

Further detail on how the DPD Project meets the requirements of section 42(c) of the EP Act, the environmental decision-making hierarchy, the waste management hierarchy and principles of ecologically sustainable development is provided in **Section 15**.

Table 3-1 Comparative assessment of potential environmental impacts, risks, benefits and adherence to EP Act principles from the proposed DPD Project Darwin Harbour pipeline route, the Gunn Point pipeline route, the Bayu-Undan pipeline tie-in option

<table>
<tr><th rowspan="2">Assessment topic</th><th colspan="3">Options for transmission of Barossa Development gas to Darwin LNG</th></tr>
<tr><th>DPD Project
Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)</th><th>DPD Project using Gunn Point pipeline route</th><th>Bayu-Undan to Darwin pipeline tie-in option</th></tr>
<tr><td colspan="4">Construction phase</td></tr>
<tr><td>Marine Environmental Quality</td><td>+ Trenching and rock installation required in NT waters to stabilise and protect the pipeline with associated impacts and risks to water quality and sediment quality.
+ Risk of impacts from treated seawater discharge in NT waters in the unlikely event of a pipeline wet buckle event.
+ Impacts in Commonwealth waters from the discharge of treated seawater during pipeline commissioning activities.
+ Vessel activities in NT waters has risk of IMS introduction.</td><td>+ This route has greater potential for impacts and risks to water quality and sediment quality in NT waters both along the pipeline route and at the spoil disposal site on the basis of:
- Trenching is required to allow pipelay vessel access given the shallow waters on the approach to Gunn Point shore crossing.
- Shallower water requires longer open cut trenching for shore approach.
- A significantly greater volume of sediment would need to be removed and disposed of compared to the Darwin</td><td>+ Localised seabed disturbance associated with subsea equipment used for pipeline cutting, tie-in and pre-commissioning activities in Commonwealth waters. No disturbance in NT waters.
+ Impacts in Commonwealth waters from the discharge of treated seawater during pipeline commissioning activities.
+ As no construction activities in NT waters, lower risk of IMS introduction.
+ Lower risk to Darwin Harbour shorelines and sensitive areas from a construction vessel hydrocarbon spill.</td></tr>
</table>

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
	+ Vessel based construction activities in NT waters with risk (albeit low) of hydrocarbon spill.	Harbour trenching requirements (assessed at approximately three times the volume) + Risk of impacts in NT waters from treated seawater discharge in the unlikely event of a pipeline wet buckle event. + Impacts in Commonwealth waters from the discharge of treated seawater during pipeline commissioning activities. + Vessel activities in NT waters has risk of IMS introduction. + Vessel based construction activities in NT waters with risk (albeit low) of hydrocarbon spill.	
Marine Ecosystem	+ Trenching required so seabed disturbance along the pipeline	+ Given the greater amount of trenching and longer open cut trenching for the shore approach,	+ Localised seabed habitat associated with tie-in activities in Commonwealth waters only.

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
	route and at the spoil ground will occur. + Impacts to sensitive benthic habitats such as seagrass and hard coral are not predicted and <0.12% of the macroalgae habitat found in Darwin Harbour may be impacted. + Vessel based construction activities in NT waters and within Darwin Harbour which may pose risk to marine fauna from light and noise emissions, or unplanned interactions. + Darwin Harbour overlaps dolphin BIAs (Australian snubfin, Indo-pacific humpback and spotted bottlenose dolphins).	greater impact to the seabed and benthic habitats is predicted, both along the pipeline route and at the spoil ground. + Habitat mapping by NT Government (Palmer and Smit, 2020) identifies seagrass beds in the shallow water which may be impacted from dredging. Similarly, hard coral present and may be impacted. + Dugongs also present in the area and may be impacted by any loss of seagrass. + Avoids the dolphin BIAs (Australian snubfin, Indo-pacific humpback and spotted bottlenose dolphins), but dolphins still present. + Greater potential for impact to flatback turtle nesting than Darwin Harbour route with turtle nesting at Gunn Point beaches.	Smaller disturbance footprint to seabed habitat than pipeline options. + Vessel based construction activities which may pose risk to marine fauna from light and noise emissions, or unplanned interactions in Commonwealth waters.

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
		+ Vessel based construction activities which may pose risk to marine fauna from light and noise emissions, or unplanned interactions in NT waters. + The intertidal flats present act as shorebird feeding grounds which may be impacted. + Shoal Bay site of Conservation Significance is adjacent to the pipeline route. + The Tree Point Conservation Area is located to the south of pipeline route and has mangrove habitat, tidal creek and coastal vine thicket and numerous bird species.	
Atmospheric Processes	+ Vessel-based construction activities will increase emissions in NT jurisdiction.	+ Vessel-based construction activities will increase emissions in NT jurisdiction.	+ Vessel-based construction activities will increase emissions in Commonwealth jurisdiction.

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
Coastal Processes	+ Not considered in NT EPA Notice of Decision/ Statement of Reasons to have potential significant impact to Coastal Processes. + Shoreline movement analysis (Geoscience Australia, 2020) demonstrates the coastline in the shore crossing area has remained net stable (no significant trend of growth or retreat of shoreline material) between 1988 and 2020, suggesting that no significant changes in coastal processes have been observed as a result of the construction of either the Bayu-Undan to Darwin pipeline or Ichthys pipelines and shore crossing works.	+ Given the greater amount of trenching and longer open cut trenching for the shore approach, there is greater potential to impact coastal processes than Darwin Harbour route. + Pockets of Monsoon Rainforest are present onshore and may need to be cleared which is not required for Darwin Harbour route. + Mangrove and salt flats are also present and may need to be cleared.	+ No potential for impact to coastal processes.
Community and Economy	+ Not considered in NT EPA Notice of Decision/ Statement of Reasons to have potential significant	+ Project activities, e.g. physical presence of vessels and infrastructure, noise and seabed	+ Lower potential for impacts and risks given construction further offshore in Commonwealth waters

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
	impact to Community and Economy. + Project activities, e.g. physical presence of vessels and infrastructure, noise and seabed disturbance may impact other Darwin Harbour users. + Unplanned project events, e.g. IMS, marine fauna interactions and a hydrocarbon spill may have impacts.	disturbance may impact other users. + Reduces activity in high vessel traffic area (Darwin Port). + Unplanned project events, e.g. IMS, marine fauna interactions and a hydrocarbon spill may have impacts. + Potential impacts and risks associated with installing the pipeline though the suburbs of Darwin, including land access.	
Culture and Heritage	+ Not considered in NT EPA Notice of Decision/ Statement of Reasons to have potential significant impact to Culture and Heritage. + Pipeline route through Darwin Harbour is in proximity to a number of maritime and heritage values, e.g. shipwrecks.	+ No known Indigenous sacred sites (though the area is under a perpetual lease to the Northern Land Council). + Only one shipwreck is present at some distance from the possible route into Gunn Point.	+ Low potential for impact to heritage values

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
	+ Project area is in vicinity of Darwin Harbour Indigenous sacred sites however compliance with AAPA Certificate will ensure the risk of potential impacts to cultural values associated with sacred sites will be appropriately minimised.		
Terrestrial Environmental Quality	+ Low potential for significant impact (short section of onshore pipeline within existing DLNG facility disturbance footprint).	+ Potential for significant impact (71 km of onshore pipeline) including coastal vegetation at Gunn Point.	+ No potential for impact.
Terrestrial Ecosystems	+ Low potential for significant impact (short section of onshore pipeline within existing DLNG facility disturbance footprint).	+ Potential for significant impact (71 km of onshore pipeline) including coastal vegetation at Gunn Point.	+ No potential for impact.
Operation phase			
Marine Environmental Quality Marine Ecosystem	+ Operational risks associated with a new natural gas conveyance through pipeline.	+ Operational risks associated with a new natural gas conveyance through pipeline.	+ No additional operational impacts or risks in NT waters beyond those related to the current and ongoing

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
Atmospheric Processes Coastal Processes Community and Economy Culture and Heritage	+ Ongoing operation of the DLNG facility with associated emissions. + Pipeline inspection, maintenance and repair activities required on both existing Bayu-Undan to Darwin pipeline and DPD pipeline. + Additional although infrequent vessel activities in NT waters.	+ Ongoing operation of the DLNG facility with associated emissions. + Pipeline inspection, maintenance and repair activities required on both existing Bayu-Undan to Darwin pipeline and DPD pipeline. + Additional although infrequent vessel activities in NT waters. + Additional pipeline inspection activities required for 71 km onshore section.	operation of the Bayu-Undan to Darwin pipeline. + Ongoing operation of the DLNG facility with associated emissions. + Ongoing pipeline inspection, maintenance and repair activities required on existing Bayu-Undan to Darwin pipeline only.
Decommissioning phase			
Marine Environmental Quality Marine Ecosystem Atmospheric Processes Coastal Processes	+ Decommissioning activities would be required for both existing Bayu-Undan to Darwin pipeline and DPD pipeline.	+ Decommissioning activities would be required for both existing Bayu-Undan to Darwin pipeline and DPD pipeline. + Additional decommissioning activities required for land-based section.	+ No additional impacts or risks in NT waters beyond those that may occur when the existing Bayu-Undan to Darwin pipeline is decommissioned.

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
Community and Economy			
Culture and Heritage			
Other impacts and risks	+ Safety risks associated with offshore construction and working in vicinity of existing live pipelines.	+ Safety risk associated with long, land-based construction and operation of gas pipeline in the suburbs around Darwin.	+ Safety risks associated with offshore construction. + Safety risk through use of saturation divers. + Delays Bayu-Undan CCS progressing. + Impacts viability of Bayu-Undan CCS through increased costs (e.g. tie-in + additional CO_2 pipeline). + No capacity within existing 26" diameter Bayu-Undan pipeline for gas additional to that from Barossa Development, limiting potential expansion capacity for DLNG facility.
Environmental benefits	+ Allows Bayu-Undan pipeline to be re-purposed for CO_2 transmissions	+ Allows Bayu-Undan pipeline to be re-purposed for CO_2 transmissions	+ Removes impacts and risks associated with the DPD Project

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	**DPD Project using Gunn Point pipeline route**	**Bayu-Undan to Darwin pipeline tie-in option**
	and therefore progresses Bayu-Undan CCS project. + Potential for Bayu-Undan CCS to store up to 10 million tonnes (Mt) of CO_2 per annum (~2% of Australia's emissions per year). + Enable future expansion of DLNG capacity through increased pipeline capacity (34") and installation of in-line tee. + Greater economic and local employment benefits than tie-in option. + Bayu-Undan CCS has the potential to be one of largest CCS projects in the world. + Potential additional CO_2 sources for CCS could also include existing and/or future NT industry along with international imports.	and therefore progresses Bayu-Undan CCS project. + Potential for Bayu-Undan CCS to store up to 10 million tonnes (Mt) of CO_2 per annum (~2% of Australia's emissions per year). + Enable future expansion of DLNG capacity through increased pipeline capacity (34") and installation of in-line tee. + Greater economic and local employment benefits than tie-in option + Bayu-Undan CCS has the potential to be one of largest CCS projects in the world. + Potential additional CO_2 sources for CCS could also include existing and/or future NT industry along with international imports.	pipeline construction in Commonwealth and NT waters over ~15-month period and associated supply chain activities.

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
	+ Economic benefits and job creation associated with low carbon industry development.	+ Economic benefits and job creation associated with low carbon industry development.	
EP Act - principles of ecologically sustainable development	+ Enables the long-term abatement of CO_2 from Barossa gas processing and future industries. + Promotes low carbon industry / fuels development. + Refer **Section 15.1** for DPD Project ESD assessment.	+ Enables the long-term abatement of CO_2 from Barossa gas processing and future industries. + Promotes low carbon industry / fuels development.	+ Reduces the risk of a negative impact within NT waters from construction activities. + Delays or prevents the ability for storage of up to 10 million tonnes (Mt) of CO_2 per annum by the Bayu-Undan CCS project.
EP Act – environmental decision-making hierarchy	+ Avoids sensitive features in NT waters and land through pipeline route selection and construction design. + Enables mitigation of GHG emissions through Bayu-Undan CCS.	+ Avoids sensitive features in Darwin Harbour but does overlap other sensitive receptors in NT waters and land. + Enables mitigation of GHG emissions through Bayu-Undan CCS.	+ Avoids infrastructure and construction disturbance within NT waters/ Darwin Harbour.

Assessment topic	Options for transmission of Barossa Development gas to Darwin LNG		
	DPD Project Darwin Harbour pipeline route (i.e. the option chosen and the subject of this SER)	DPD Project using Gunn Point pipeline route	Bayu-Undan to Darwin pipeline tie-in option
	+ Refer **Section 15.2** for DPD Project environmental decision-making hierarchy assessment.		
EP Act - waste hierarchy	+ Enables Bayu-Undan CCS to reduce GHG emissions going to atmosphere from Barossa gas processing (and potentially other industries). + Enable re-use of existing infrastructure (Bayu-Undan pipeline and facilities) for CCS. + Refer **Section 15.3** for DPD Project waste management hierarchy assessment.	+ Enables Bayu-Undan CCS to reduce GHG emissions going to atmosphere from Barossa gas processing (and potentially other industries). + Enable re-use of existing infrastructure (Bayu-Undan pipeline and facilities) for CCS.	+ Avoids trenching requirements (spoil disposal). + Reduces construction requirements and associated waste. + Re-use of existing infrastructure (Bayu-Undan pipeline and facilities) for Barossa gas.

3.4 Options for Darwin Harbour route alignment

Santos considered various routes (a northern, central and southern route) for the alignment of the DPD pipeline within Darwin Harbour, factoring in the positioning of existing pipelines and landfall locations. Other selection criteria included stakeholder risks, safety, constructability, avoidance of listed heritage areas and geotechnical conditions.

The selected route option is a hybrid of the northern and central routes and predominately lies parallel and north of the existing Bayu-Undan to Darwin pipeline and makes landfall immediately north of the Bayu-Undan to Darwin pipeline within the DLNG facility disturbance footprint. This route centreline is offset by approximately 100 m from the existing Bayu-Undan to Darwin pipeline for the majority of the route through Darwin Harbour, with a single, short section between the existing Bayu-Undan to Darwin Pipeline and Ichthys pipelines to avoid encroachment of the DPD pipeline into the Darwin Harbour shipping channel. The alternative options through Darwin Harbour consisted of routes wholly north of the Bayu-Undan to Darwin pipeline (northern route), between the Bayu-Undan to Darwin and Ichthys pipelines (central route) as well as a route to the south-west of the Ichthys pipeline (southern route). These options come with challenges associated with additional pipeline crossings within Darwin Harbour and outside the harbour, shore crossing challenges and constructability and safety challenges. The central route requires additional safety controls due to pipe handling and construction operations being required adjacent to two operational gas pipelines.

These other routes through the harbour were assessed as alternative options to the route presented herein, with the wholly northern route being favoured over the central route and the central route being favoured over the southern route due to the reduced number of pipeline crossings (up to four pipeline crossings for the southern route), reduced trenching requirements and a favourable shore crossing approach.

In conjunction with stakeholder engagement, the following factors were considered in finalising the route selection to ensure the impacts to stakeholders were minimised:

+ Consultation with DIPL and Darwin Port;
+ Shipping channel location (i.e., minimising/ avoiding channel encroachment as far as practicable);
+ Minimising route length;
+ Minimising the need for pre and post lay seabed intervention;
+ Minimising the number of pipeline free spans and span lengths;
+ Pipeline install-ability and trench constructability;
+ Environmental approvals requirements;
+ Avoidance of shallower waters with sensitive benthic habitats;
+ Limiting seabed disturbance to within or near pre-disturbed areas;
+ Crossing the shoreline within a previously cleared/disturbed area (DLNG facility disturbance footprint);
+ Avoidance of known heritage and native title areas;
+ Avoidance of dumping grounds and designated dangerous zones (e.g. military areas, UXOs);

+ Minimising the impact from unfavourable geotechnical conditions, rocky seabed, sand waves, seabed mobility;
+ Avoiding existing infrastructure, subsea equipment and wrecks;
+ Minimising crossings of other pipelines and cables;
+ Minimising third party interaction (e.g. existing pipelines, fishing/fish farms/oyster beds, military, shipping (Darwin Port), mining, recreational, tourism, etc.); and
+ Metocean conditions (both during construction and operation).

The preferred route selection was primarily driven by the following:

+ Maintaining sufficient separation from existing pipelines and minimising the impact to installation activities and the risk of dropping a pipe joint onto a live pipeline;
+ Avoiding shipwrecks and their associated protection zones;
+ Minimising the level of seabed intervention due to pipeline free spans;
+ Avoiding encroachment into the Darwin shipping channel;
+ Reduction of pipeline crossings to minimise cost and risk to other stakeholders, both during construction and operations; and
+ Minimising mangrove and marine flora disturbance at the shore crossing.

3.5 Pipeline route optimisation

The initial northern route design was the preferred route and applied a consistent offset of 100 m from the existing Bayu-Undan to Darwin pipeline, resulting in approximately 8.5 km of pipeline encroaching into the shipping channel.

Consultation with DIPL and Darwin Port across 2021 and 2022 has influenced and optimised the preferred pipeline route with the objective of minimising encroachment within the Darwin Harbour shipping channel and reducing the potential for future impacts of the route on Darwin Harbour development and shipping. An optimised northern route was proposed to DIPL and Darwin Port in October 2021 based on a reduced overall encroachment length into the shipping channel of 4 km with a maximum encroachment into the channel of 49 m, including the requirement to lower the pipeline below the seabed within the Shipping channel. Increased trenching was also agreed to by Santos across the Middle Arm Channel, at the request of DIPL, to ensure clearwater of 16 m across the entire channel width. Options for the pipeline route alignment are shown in **Figure 3-3** through to **Figure 3-10**.

Further consultation with DIPL through 2022 into 2023 focussed on options to mitigate the potential for third-party interaction with the DPD pipeline within the sand ensure the DPD pipeline does not limit future plans for the shipping channel. The optimum solution was to reroute the 4km section of the DPD pipeline that remained in the shipping channel up to approximately 135 m to move the route fully outside the shipping channel. The route adjustments are within the areas assessed in the referral as part of the central route assessment. This resulted in the route being moved to within approximately 30m of the Bayu-Undan to Darwin pipeline at the outer harbour and the inclusion of two crossings over the Bayu-Undan to Darwin pipeline in the inner harbour. Additional optimisation may include possible localised rock placement for pipeline stability and/or protection at the pipeline crossing locations. While additional rock may be placed over the pipeline, any requirements to trench within the areas where the pipeline originally encroached within the shipping channel has now been removed, reducing the trenching scope by 4 km, resulting in an overall reduction of trenching, subsequent spoil disposal and seabed disturbance.

Minor changes to the selected route may be made in line with ongoing detailed design to optimise pre-lay and post lay span rectification requirements. Any changes to the proposed route will lie within nominally 30 m of the selected route, within areas already assessed.

Counteracts may be used along the pipeline route within Darwin Harbour where tight radius bends are required to stabilise the bends during installation and operation. The counteracts could be constructed from concrete blocks, rock gabions, mattresses, steel structures or similar.

The risk of a pipeline damage event to existing pipelines within Darwin Harbour during construction and operation has been assessed for the selected and alternative routes with no differentiation when considering the implementation of construction controls with respect to the likelihood or consequence of credible pipeline failure events. Santos have engaged other pipeline operators and stakeholders during consultation to address the additional interfaces with other pipeline operators.

History of the DPD pipeline route optimisation from the preferred northern route detailed in the referral through the selected DPD pipeline route assessed herein is detailed in **Figure 3-3** to **Figure 3-10**.

Original Route

The original northern route was based on a 100 m offset to the Bayu-Undan to Darwin pipeline. This route encroached the shipping channel in two areas as marked below with a combined length of ~8,500 m.

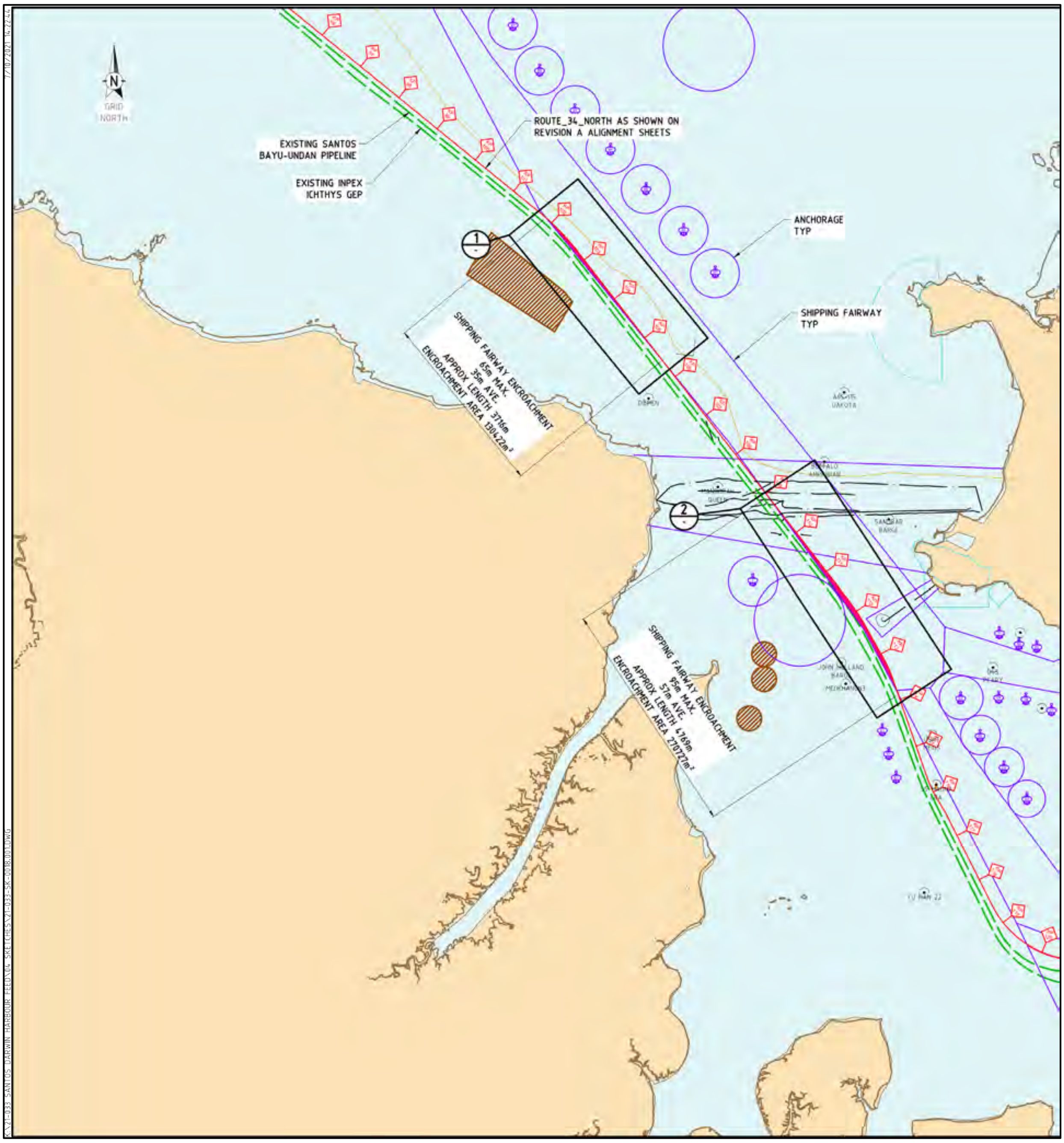


Figure 3-2 Section of the original DPD pipeline northern route, as described in the referral, showing shipping channel encroachment

Original Route
Close-up of the two shipping channel encroachment areas, showing ~8,500 m length of shipping channel encroached and a maximum penetration of ~95 m into the channel.

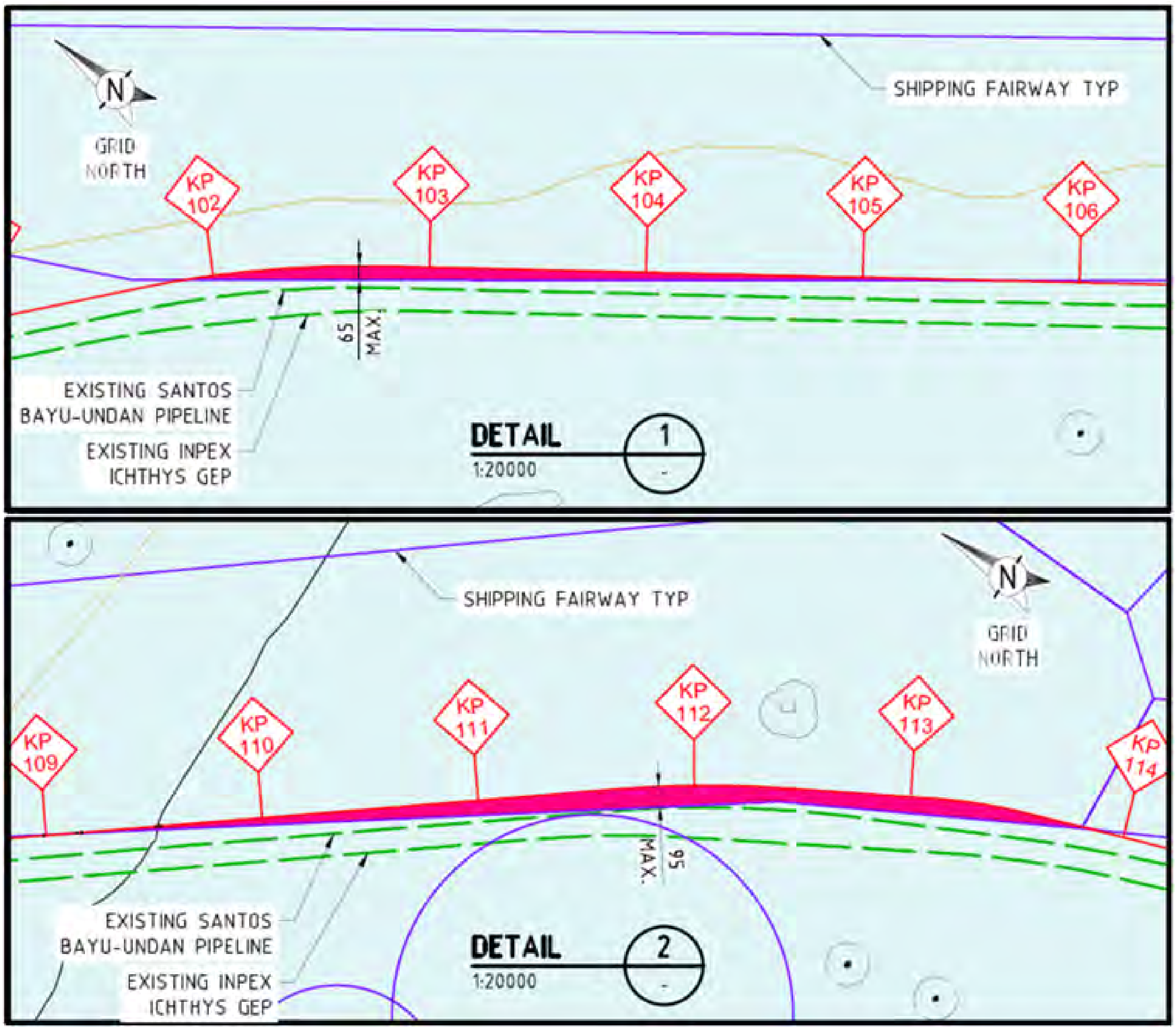


Figure 3-3 Sections of the original DPD pipeline northern route showing encroachment into shipping channel in two areas

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Revised Routing Option 1

A revised northern route option was considered following DIPL engagement which maintained where possible a 100 m offset to the Bayu-Undan to Darwin pipeline, however this could be offset ~50 m when in the shipping channel to minimise encroachment. Additional risk mitigation was considered necessary during construction for this option to ensure the Bayu-Undan to Darwin pipeline would not be impacted.

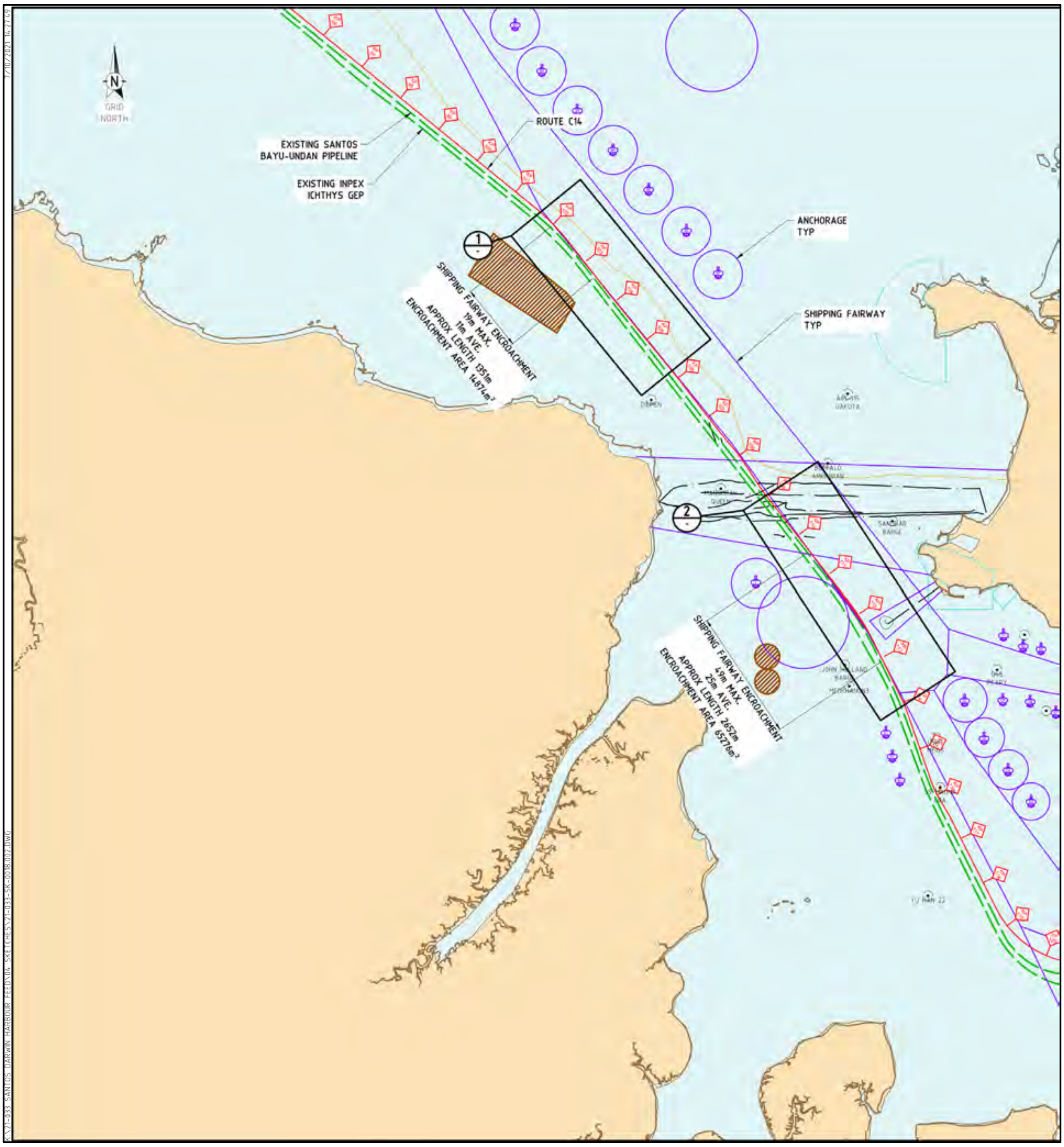


Figure 3-4 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 1), showing reduced shipping channel encroachment

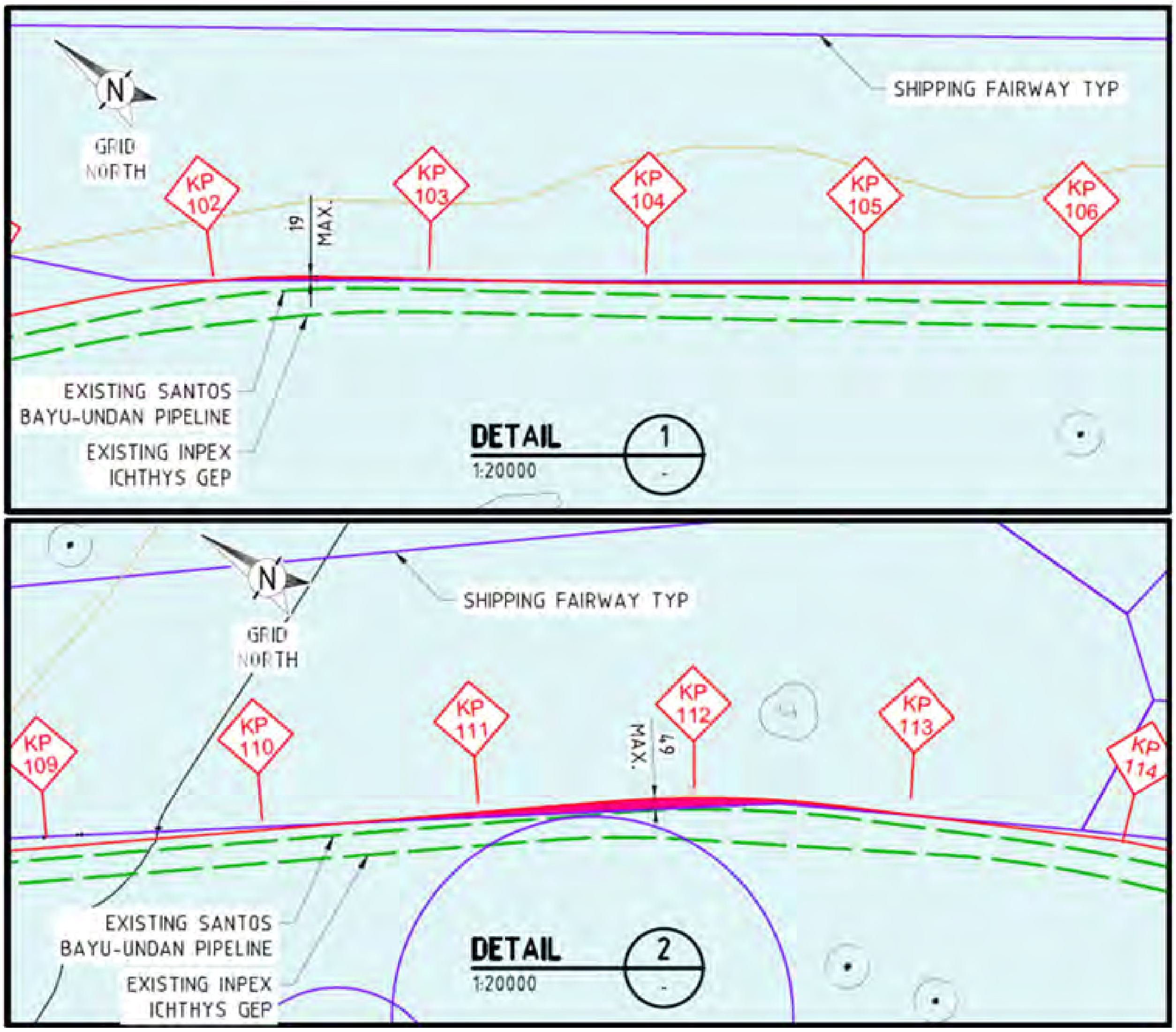
Revised Routing Option 1
Close-up of the two shipping channel encroachment areas of revised northern route (Option1). Total encroachment reduced to ~4,000 m length of shipping channel (a reduction of 4,500 m) and a maximum penetration of ~49 m into the channel (a reduction of 46 m).


Figure 3-5 Sections of the revised DPD pipeline northern route (option 1) showing reduced encroachment into shipping channel in two areas

Revised Routing Option 2

A revised northern route option (option 2) was considered following DIPL engagement which removed shipping channel encroachment in the north (outer harbour) and reduced encroachment in the shipping channel in the south (inner harbour). This option assessed installation of the DPD pipeline on the seabed and within a trench with rock protection where it remained within the shipping channel.

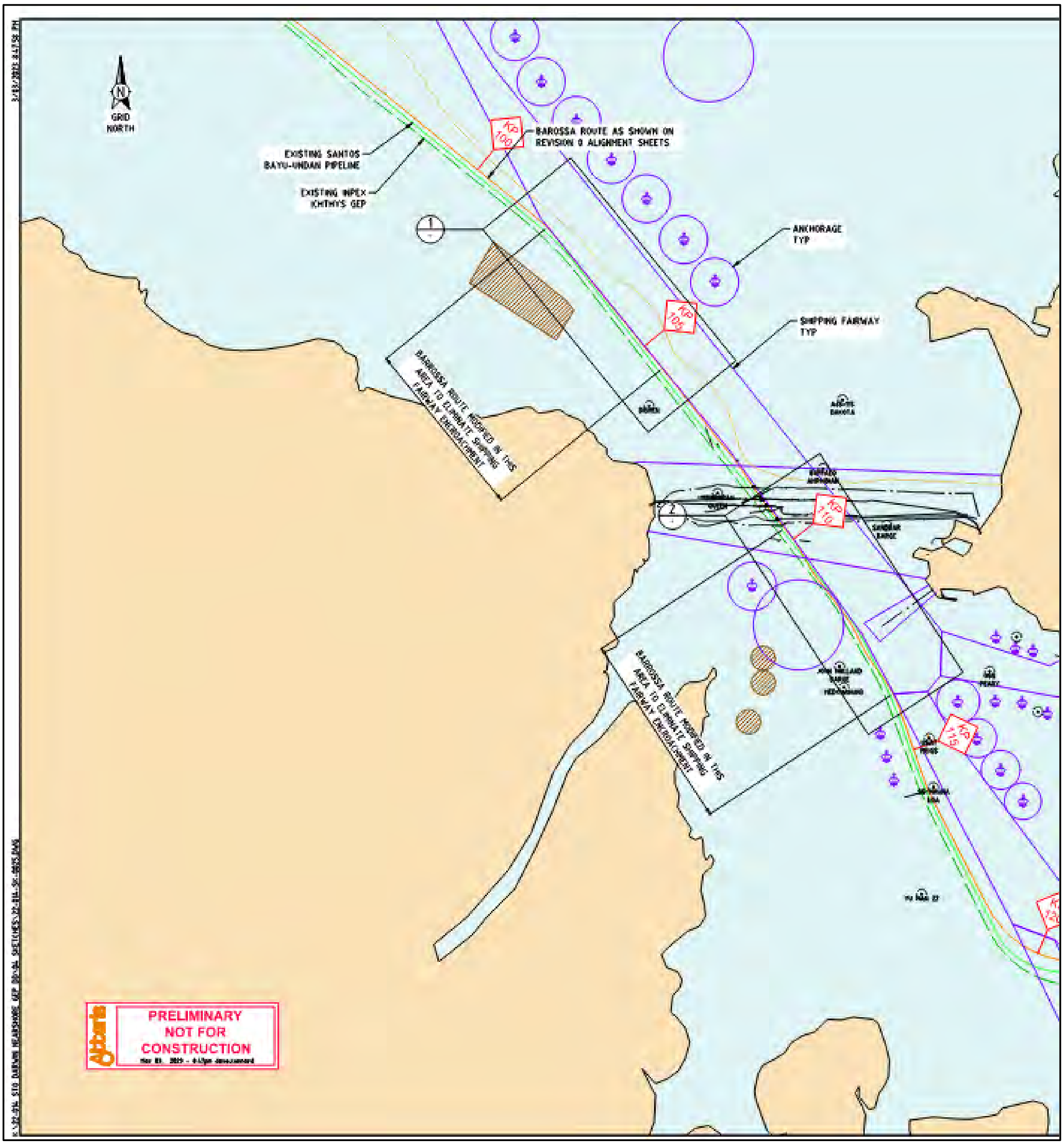


Figure 3-6 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 2), showing reduced shipping channel encroachment

Revised Routing Option 2

Close up of revised northern route (option 2) showing removal of the shipping channel encroachment in the north (outer harbour) and reduced encroachment in the shipping channel in the south (inner harbour). The encroachment length in the inner harbour is based on the pipeline being placed on the seabed. The inclusion of trenching and rock-dump requires the pipeline to be offset further from the Bayu-Undan to Darwin pipeline resulting in an encroachment of approximately 1.3km. This option was not preferred due to additional environmental impacts of trenching/rock dump, schedule impacts and cost impacts.

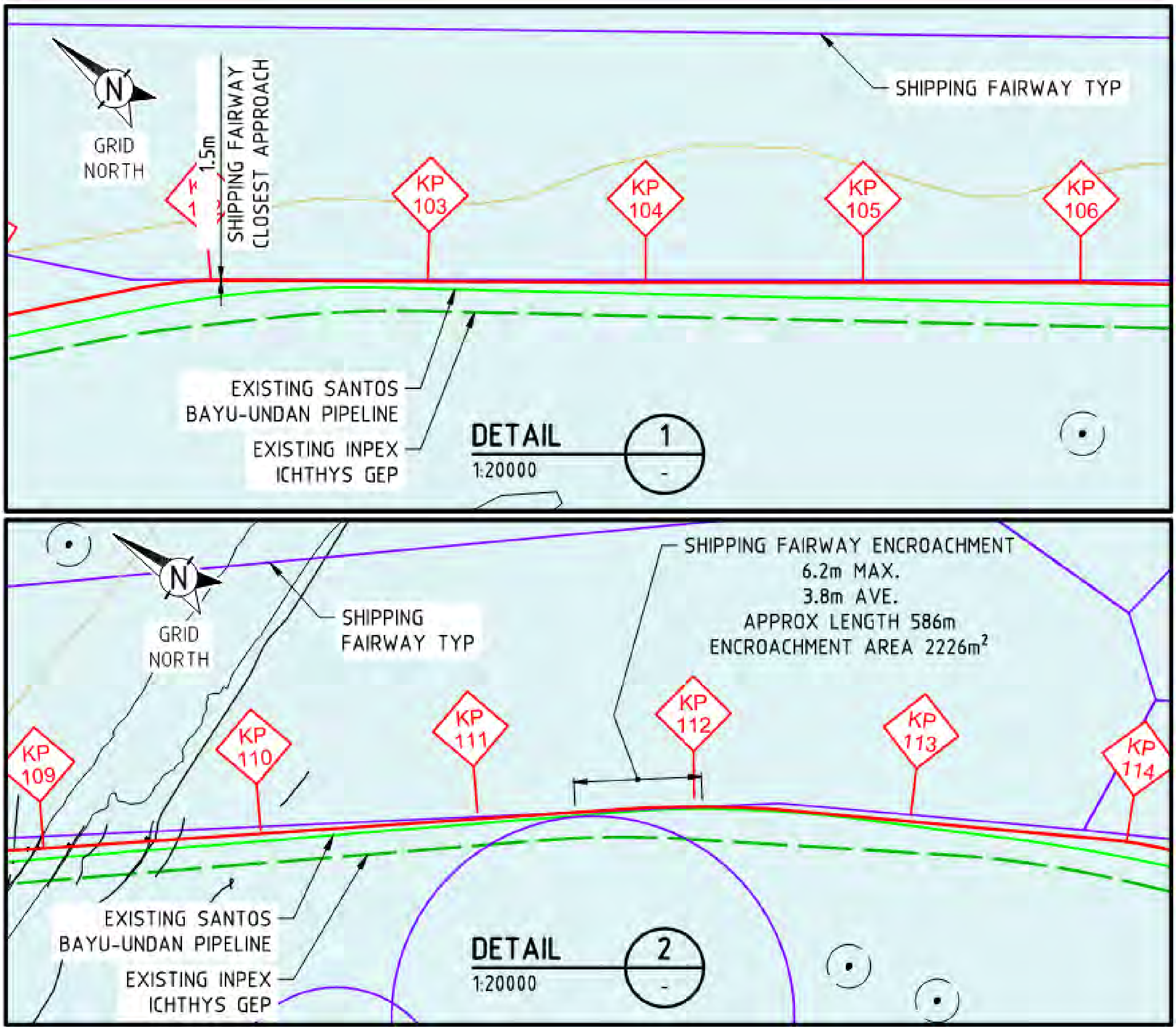


Figure 3-7 Sections of the revised DPD pipeline northern route (option 2) showing removed encroachment into shipping channel in the north and reduced encroachment in the south

Revised Routing Option 3 – Selected final route
Removal of the outer harbour shipping channel encroachment and avoidance of the inner harbour shipping channel encroachment (pipeline crossing option). This forms the selected route for the DPD pipeline.

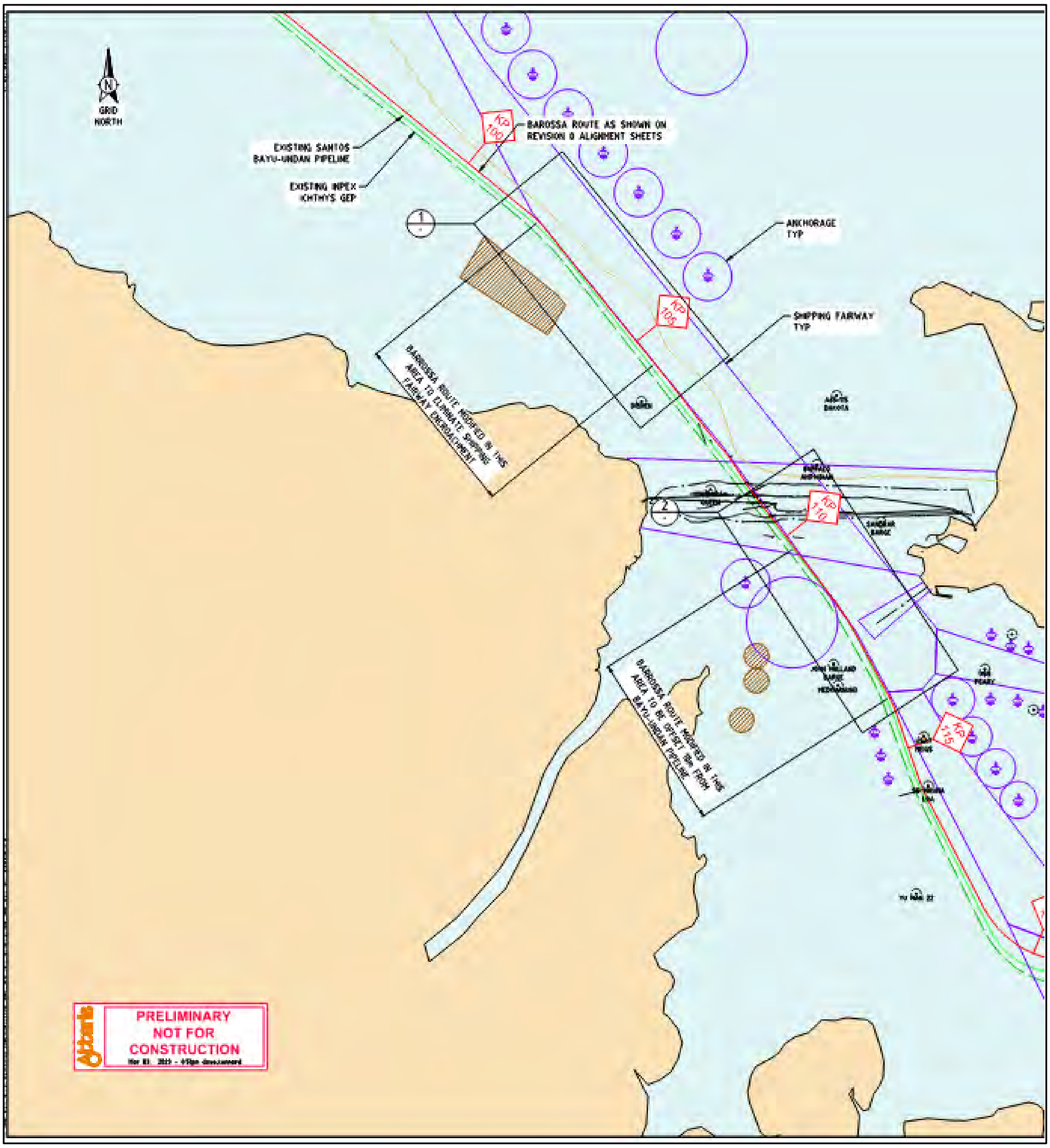


Figure 3-8 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 3), showing removal of all shipping channel encroachment. This represents the final selected route.

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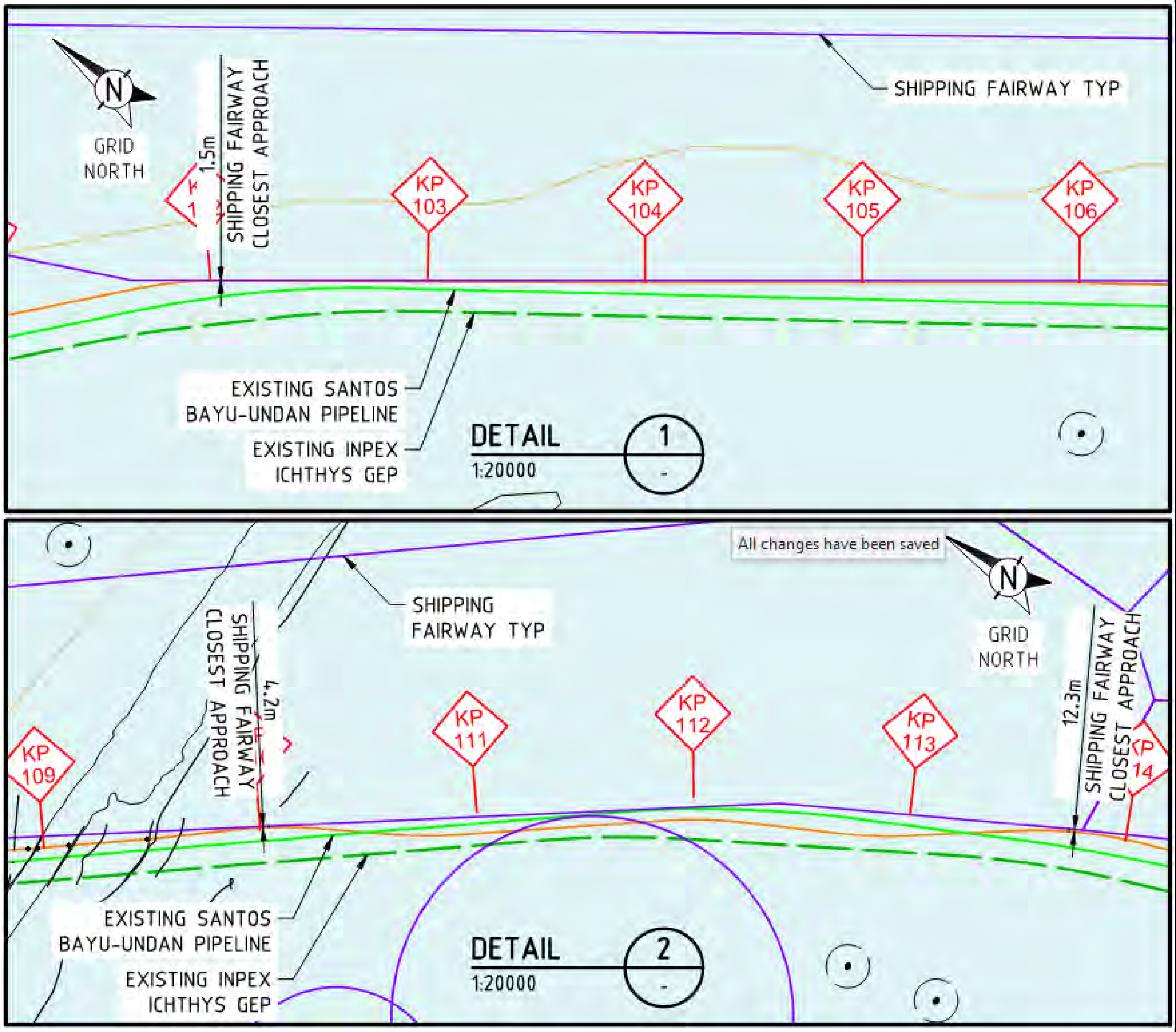
Revised Routing Option 3 – Selected final route
Close up of the removal of the outer harbour shipping channel encroachment and avoidance of the inner harbour shipping channel encroachment (pipeline crossing option). This forms the selected route for the DPD pipeline.


Figure 3-9 Sections of the revised DPD pipeline (option 3), following stakeholder engagement, showing removal of all shipping channel encroachment. This represents the final selected route.

4 Stakeholder Engagement

The purpose of this section is to provide details and outcomes of the stakeholder engagement undertaken by Santos since submittal of the DPD Project referral to the NT EPA on 8 December 2021, as per the requirements of section 43 of the EP Act.

This section also includes information on Santos' planned approach to engagement during the remainder of the assessment period, and in the lead-up to and during the execution of the proposed activities.

The stakeholder engagement approach is in accordance with Santos' corporate standards and practices and aligned with the NT EPA's Guidance for Proponents – Stakeholder Engagement and Consultation (NT EPA 2021a) and Guidance for Preparing a Supplementary Environmental Report (NT EPA 2021b) and the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement (IAP2 2015).

The Stakeholder Engagement Plan, including details of all engagement undertaken to date and planned future engagement, is provided as **Appendix 13**.

4.1 Engagement objectives

Stakeholder engagement is an open dialogue that continues through the full project lifecycle. It is an essential process supporting environmental impact assessment as it provides stakeholders with information about the Project's potential impacts and benefits on their activities, supports the early identification of issues and concerns in order to achieve better decision-making and outcomes.

The objectives of the engagement strategy used for the DPD Project are to:

+ Maintain an ongoing dialogue with stakeholders, keeping them informed of the Project details and impacts;
+ Update stakeholders on changes to the Project during each stage of engagement;
+ Notify stakeholders of commitments being made by Santos as part of the Project approval process;
+ Encourage stakeholders to provide comments and raise issues or concerns about the Project;
+ Identify new stakeholders during the engagement process;
+ Respond to stakeholder comments through the formal assessment process and directly as required; and
+ Continue to build on existing stakeholder relationships and trust to inform Santos' longer term-activities and community involvement.

4.2 Stakeholders

Santos has a long-standing presence in Darwin and the NT and has developed close relationships with a wide range of government, industry and community stakeholders. As Operator of the existing DLNG facility and the Bayu-Undan to Darwin pipeline, Santos has a strong understanding of the stakeholders and issues involved with developing and operating similar infrastructure.

Table 4-1 lists the stakeholders engaged to date, prior to and during the preparation of the referral and SER. The detailed engagement process undertaken is described in the Stakeholder Engagement Plan in **Appendix 13**. Stakeholders were initially identified based on Santos' knowledge and history of engagement in the Darwin area, their activities within the Project's footprint area, potential to be positively or negatively impacted by the Project or their general interest in the Project.

This stakeholder list was updated following the initial public comment period and during the engagement process. The number of stakeholders will continue to be updated as the Project progresses, recognising the SER will also be released for public comment and further stakeholders may be identified. The Stakeholder Engagement Plan (SEP) is treated as a live document that will be reviewed and updated by Santos on an ongoing basis throughout the life of the Project.

Table 4-1 Stakeholders groups and organisations

Sector	Stakeholder
Commonwealth Government	+ Department of Climate Change, Energy, the Environment and Water (formerly Department of Agriculture, Water and the Environment) + Department of Defence (including Australian Hydrographic Office and HMAS Coonawarra, Darwin)
NT Government Regulators / Agencies	+ Aboriginal Areas Protection Authority + Department of Environment, Parks and Water Security + Department of Chief Minister and Cabinet + Department of Industry, Tourism and Trade (Fisheries) + Department of Industry, Tourism and Trade (Energy) + Department of Industry, Tourism and Trade (Tenure) + Department of Industry, Tourism and Trade (Tourism) + Department of Infrastructure, Planning & Logistics (Planning) + Department of Infrastructure, Planning & Logistics (Middle Arm Sustainable Development Precinct Project) + Department of Infrastructure, Planning & Logistics (Darwin Ship Lift Project; Mandorah Ferry Project) + Department of Infrastructure, Planning & Logistics (Transport) + Department of Territory Families, Housing and Communities (Heritage) + NT Environment Protection Authority + NT Power and Water + Tourism NT
Indigenous Groups / Representative Bodies	+ Aboriginal Areas Protection Authority (also noted as agency above)

Sector	Stakeholder
	+ Larrakia Nation (including Larrakia Sea Rangers) + Northern Land Council + Tiwi Land Council (including some Clan Groups) + Wickham Point Deed Reference Group
Environmental Group Representatives	+ Australian Marine Science Association + Australian National University (individual) + Environment Centre NT + Sea Turtle Foundation
Fishing Representative Bodies	+ Amateur Fishermen's Association of the NT + NT Seafood Council (commercial)
Other Community Organisations	+ Darwin Harbour Advisory Committee
Industry / Tourism Operators	+ Darwin Aquaculture Centre + Darwin Port + Darwin Port + DLNG Pty Ltd + Eni Australia + INPEX + NT Guided Fishing Industry Association + NT Chamber of Commerce and Industry + Paspaley Pearling + Sea Darwin + Sun Cable + Telstra + Top End Tourism + Woodside

4.3 Engagement prior to referral submission to NT EPA

The first stage of the engagement process was undertaken from 8 October to 20 December 2021, prior to the initial submission of a Project referral to the NT-EPA.

During this period, Santos proactively sought meetings with a range of government agencies, private organisations and businesses that Santos had identified as key stakeholders with activities that would be relevant to the proposed activities in Darwin Harbour.

A total of 33 meetings were held with stakeholders during this period. Feedback was used to inform the referral and identify issues and concerns to be considered by Santos as part of the management framework and subsequent preparation of approvals documentation.

Details of the engagement undertaken during this period is provided in the SEP (**Appendix 13**).

Prior to the start of the formal consultation which commenced in late 2021, Santos identified the need to engage with other organisations proposing to undertake future benthic disturbance activities on an ongoing basis throughout the planning and assessment periods. The aim of this specific engagement was to share information and seek collaboration across a range of aspects including the undertaking of environmental studies, data sharing, spoil disposal and re-use, contracting of vessels and equipment and project schedule. The organisations are the NT Department of Infrastructure, Planning and Logistics (covering three projects), INPEX and the Commonwealth Department of Defence. This is further discussed in Section 12.3 of the TSDMMP (Refer to **Appendix 4**).

4.4 Engagement following referral of submission to NT EPA

Following submission of the referral, Santos continued to proactively engage with stakeholders to discuss their issues and concerns as well as the assessment process. From 12 January to 4 April 2022 a further 21 meetings were undertaken.

On 18 January 2022, the NT EPA published the referral and invited public comment until 15 February 2022. On the same day, Santos distributed information, via email, to government departments, community organisations and businesses that had been engaged by Santos to that date as stakeholders relevant to the DPD installation activities proposed to occur in NT waters.

Santos' email advised that the referral would be publicly available on the NT EPA website and explained how to provide formal comment to the NT EPA as well as offering further opportunity to discuss the Project directly with Santos.

An accompanying fact sheet provided an overview of the Project, a location map and information on the proposed works and timeframe and Santos' approach to environmental management, the statutory environmental approvals involved and the consultation process.

On 3 March 2022, the NT EPA provided Santos with the submissions on the referral that had been received from the public by the NT EPA's closing date of 15 February 2022. The overwhelming majority of the 318 public submissions were from environmental Non-Government Organisations and individuals using a pro-forma response.

On 7 April 2022, the NT EPA provided a Notice of Decision and Statement of Reasons determining that the DPD Project requires assessment under the EP Act at a Tier 2 level of assessment – assessment by Supplementary Environmental Report (SER).

On the same day, the EPA provided Santos with the submissions on the referral that had been received from NT Government departments.

Engagement by Santos during preparation of the SER, from 7 April 2022 to 31 January 2023, has focused on the following areas:

+ With specific government agencies or organisations to gather additional information and/or hold further discussion on matters raised in submissions on the referral;
+ With specific government agencies or organisations during preparation of information for the SER, e.g. development of Environmental Management Plans and monitoring programs;
+ With specific government agencies or organisations during execution of environmental studies/surveys providing information for the SER;

+ With proponents of other planned projects also involving dredging activities – NT Department of Infrastructure, Planning and Logistics, Department of Defence and INPEX;
+ With previously identified and/or new stakeholders to share information on the project, e.g. representative tourism groups, to understand their concerns and discuss how issues raised in submissions are/will be addressed; and
+ With specific Indigenous Groups and Representative bodies, e.g. Wickham Point Deed Reference Group, to share information and ensure two-way dialogue, and via the Aboriginal Areas Protection Authority's statutory, independent consultation process.

In preparing the SER, Santos has considered and assessed each submission individually and taken into consideration the issues raised.

A further 68 stakeholder meetings were undertaken between 7 April 2022 and 31 January 2023. A full list of the meetings is provided in the SEP (**Appendix 13**).

Section 5 provides a summary of the key issues raised in the submissions and the outcomes from engagement between Santos and key relevant stakeholders (after 7 April 2022), including matters raised in the submissions. A full register with all submissions and responses is provided in **Appendix 2**.

4.5 Ongoing and future engagement

Following the submittal of the SER, the SER is published in full by the NT EPA on its website and a further public comment period is held. As it did with the original referral submission, Santos will directly advise its stakeholder base via email when the SER is available for comment. Santos will also provide the opportunity for meetings with external stakeholders who have been actively involved in the engagement process for the SER to provide further opportunity for discussion on issues raised.

Following the public comment period, Santos will respond to any questions raised by the NT EPA and all issues and concerns raised in submissions provided by the public. In the meantime, and throughout the remainder of the NT EPA's assessment period, Santos will ensure stakeholders continued to be informed and have opportunity to raise and discuss their interests, issues and concerns. This will allow Santos to take this regular feedback into account in the finalisation of Environmental Management Plans, decision-making and project execution.

Santos is committed to continue with the engagement process throughout the life of the Project.

Prior to the commencement of construction, Santos will conduct meetings with external stakeholders to explain the activities and schedule, and how other users of the marine environment will be kept informed while the activities are occurring and how their impacts and concerns are being addressed.

Communication will occur via a combination of direct meetings, regular emails, public advertising and via organisations that have advised they are willing to also provide information or links to information on the activities via their dedicated communication channels to their own stakeholder databases.

Leading up to and during construction activities, all identified stakeholders will be kept regularly informed and aware of progress on current activities, pending activities, timeframes, how issues/concerns have been mitigated/are being managed, how complaints are being handled and ongoing communications process and contact points.

Further detail of the planned engagement following the assessment period, including leading up to and during the construction period, is provided in the Stakeholder Engagement Plan (**Appendix 13**).

5 Responses to Submissions

A total of 318 submissions were received in response to the publication of the referral. This included submissions from environmental organisations and/or research/volunteer groups, submissions from individuals and submissions from multiple government agencies. The public submissions included group public submissions by 284 individuals with the same wording (submissions 18-301).

Key issues raised during the public submission process can be summarised under the following themes:

- Increasing GHG/air emissions from the DPD Project and associated Barossa Development, and impacts to climate change;
- Feasibility of Carbon Capture and Storage (CCS);
- Impacts and supporting evidence used to assess impacts to the marine ecosystem, including:
  - Benthic habitats (including seagrass and hard coral habitats);
  - Protected marine megafauna (including dolphins, dugongs and turtles);
  - Fish and fisheries; and
  - Mangroves.
- Reliance on INPEX Ichthys data and the lack of evidence around long-term impacts;
- Impacts to Coastal Processes and Marine Environmental Quality, associated with trenching and rock placement;
- Assessment of potential impacts to cultural heritage;
- Industrialisation of Darwin Harbour and cumulative impacts;
- Santos' engagement with potentially affected communities and request for further details on the ongoing engagement plan;
- Impacts to recreational fishers (including use of the spoil ground) and existing shipping traffic; and
- Impacts to the broader community including job security, tourism and overall health impacts.

Key issues identified from each submission have been collated into a summary table (**Table 5-1**) identifying the stakeholder(s) who raised the issue and the most relevant NT EPA Environmental Factor associated with the issue. Corresponding responses have been provided with links where appropriate to sections of the SER for further detail. Where similar issues have been raised by multiple stakeholders these have all been addressed in the response.

There were a number of submissions that provided comment on the regulatory approvals process or on matters that were outside of the responsibility of Santos to address as part of its proposed activities. These comments have not been specifically addressed in the SER. They include the following matters:

- The level of assessment and nature of the assessment process under the NT EP Act;
- Comments directed to the NT EPA or other NT Government departments;
- Comments not related to the DPD Project activities, including activities related to the Barossa Development in Commonwealth waters (unless specifically requested by the NT EPA in **Table 1-1**);

+ Comments directed at the quality of historical monitoring programs not undertaken by Santos, unless information from these programs has specifically been used by Santos to inform its impact assessment; and
+ Comments calling for improvement to ongoing monitoring program/s not run by Santos, to monitor and assess biodiversity and ecosystem health across Darwin Harbour.

The majority of submissions did not raise concerns around the onshore works associated with the DPD Project within the DLNG facility footprint. Given that the onshore elements of the Project are located within the existing DLNG facility footprint, construction and operation of the Project has been assessed as posing a low risk to biodiversity and environmental values.

A submission from DIPL was received requesting further assessment on the implication of the DPD Project on vehicle traffic, with respect to vehicle movements associated with the Project but not included in the Project area (e.g. movement of personnel, equipment and material to the Project area). A Traffic Impact Statement (TIS) to assess the road traffic impacts has been undertaken in consultation with DIPL (**Appendix 10**).

All submissions received on the referral have been categorised by key issue and tabulated in **Appendix 2**.

Table 5-1 Summary table of submissions and responses.

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
Project description			
+ No detail is provided on the source of rock for infill of the trench or the quantity needed	Environment Centre NT (ECNT)	The Project design has been further progressed since publication of the referral and the SER now includes details for the proposed rockfill, including source of rock. Refer to **Section 2.5** for further details on these. The rock material will be obtained from suppliers from the Mount Bundey quarry.	Not Environmental Factor related
+ No detail is provided on the proposed cofferdam.	Environment Centre NT (ECNT)	The Project design has been further progressed since publication of the referral and the proposed cofferdams have been deemed unnecessary and since been removed from the Project design.	Not Environmental Factor related
+ Alternative pathway options need to be assessed, particularly for the nearshore areas once further benthic habitat survey is available.	Environment Centre NT (ECNT)	An assessment of possible alternative pipeline routes (pathways) was previously presented in the NT referral (Refer Section 5 of referral) which was published on 18 January 2022. Consultation with DIPL and Darwin Port across 2021, 2022 and into 2023 has progressed and optimised the final pipeline route, avoiding encroachment within the Darwin Harbour shipping channel and reducing the potential for future impacts of the route on Darwin Harbour development and shipping. Since the referral, Santos has undertaken engagement with DIPL and the Port of Darwin to discuss the basis for the nearshore pipeline route selection within Darwin Harbour with the intent to minimise environmental impacts with consideration of multiple engineering challenges. Potential impacts on seabed habitat as a result of the revised pipeline activities has been assessed in this SER (refer to **Section 8.5** for potential impacts and **Section 8.6** for proposed management measures). Refer to **Section 3** for further details on alternative route options, including route optimisations and the final route selection.	Not Environmental Factor related
+ More information about how trenching will cover the pipeline in rocky substrate habitats could be more explicitly explained to determine whether the pipeline will provide suitable artificial habitat	Environment Centre NT (ECNT)	The Project design has been further progressed since publication of the referral and the SER now includes details for the proposed trenching and rockfill. Refer to **Section 2.5** for further details on trenching activities. It is likely that the pipeline will provide artificial habitat in the same way as other operating gas pipelines in Darwin Harbour. This view is shared by a range of stakeholders consulted by Santos, including the NT Department of Fisheries, the Amateur Fisherman's Association of the NT (AFANT), the NT Guided Fishing Industry Association and marine-based tourism operators. As a result of consultation with AFANT on issues raised in its submission, Santos is discussing support for a potential study into the benefits of artificial habitats, including pipeline infrastructure, in the Darwin Harbour.	Not Environmental Factor related
+ More detail should be provided about the suitability of the proposed proximity to the Mauna Loa WW2 shipwreck (a good fishing area/habitat for jewfish) with consideration given to improving the buffer zone, and assurances given that side-casting will not be allowed in this immediate area.	Amateur Fisherman's Association of the Northern Territory (AFANT)	The proposed pipeline route has been designed to limit interaction with maritime heritage sites, other users and existing port and shipping activities. Santos has engaged with DIPL and the Port of Darwin to discuss the basis for the nearshore pipeline route selection within Darwin Harbour and the balancing of impacts with multiple engineering challenges. For further details on potential impacts to maritime heritage and proposed controls refer to **Section 11.3.4**. The pipeline route has been deliberately routed to avoid the Mauna Loa shipwreck and Santos confirms that there will be no side casting in proximity to the Mauna Loa shipwreck. The pipeline route is 15 m away from a 100 m exclusion zone, which is based on a 100 m radius around the centre of the Mauna Loa wreck.	Culture and Heritage
+ In shallower waters, the Project pipeline may require stabilisation due to exposure to waves, currents and tidal movement. Surely anchoring devices will suffice and trenching along with the associated blasting and dredging can be abandoned.	Grusha Leeman	No blasting is proposed for the DPD Project. Trenching is required for stability and to ensure that the pipeline plus any required rock protection has sufficient clearwater (depth of water above the pipeline and rock protection) so as not to restrict or interfere with current or future vessel use in Darwin Harbour (as determined in consultation with Darwin Ports and DIPL). Therefore, it is not possible to avoid trenching entirely. The amount of rock protection and the location of sections requiring rock protection, has been informed by a quantitative risk assessment which sought to understand the risk of potential external impact to the pipeline and required protection requirements. This has restricted rock protection to those areas where risk has dictated it is required. As a result, this has reduced the amount of trenching required to enable the pipeline and rock protection to meet clearwater requirements. Refer to TSDMMP (**Appendix 4**).	Not Environmental Factor related
+ No firm decommissioning plan	Bruce Robertson – Institute for Energy Economics and Financial Analysis	It is expected that advancements in pipeline decommissioning will be made by the time the DPD Project is due to be decommissioned (i.e. >2050). Santos will decommission the Project in accordance with regulatory requirements at that time. Current industry best practice would be to leave the inert, stabilised pipeline in place. Furthermore, a	Not Environmental Factor related

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
		Decommissioning Plan will be developed and will define closure objectives and agreed criteria, in consultation with all relevant stakeholders prior to commencement of any decommissioning activities.	
+ The referral Document expressly states (p 17) that processing gas from the Barossa field at the Facility is "excluded" from the referral and that the DLNG Extension was "approved by the NT EPA" under the previous *Environmental Assessment Act 1982* (NT) (EA Act). This is incorrect. The NT EPA decided not to assess the DLNG Extension, which is not the same as a completed assessment under the EA Act.	Environment Centre NT (ECNT)	Santos notes that the DLNG Extension was considered under the EA Act through the Notice of Intent (NOI) approvals pathways by the NT EPA. Santos acknowledges the NT EPA's decision on the Statement of Reasons – ConocoPhillips Pipeline Australia Pty Ltd Darwin Liquefied Natural Gas Transition Work Program where the proposed action, which was referred to the NT EPA by ConocoPhillips Pipeline Australia Pty Ltd, has been examined by the NT EPA and preliminary investigations and inquiries conducted. Based on the NOI, and additional information provided, the NT EPA decided that the potential environmental impacts and risks of the proposed action were not so significant as to warrant further environmental impact assessment by the NT EPA under provisions of the EP Act at the level of a Public Environmental Report or Environmental Impact Statement. This decision was published within a Statement of Reasons, date 6 May 2020, and was made in accordance with clause 8(2) of Environmental Assessment Administrative Procedures 1984 (EAAP).	Not Environmental Factor related
Baseline information			
+ The proponent should undertake a dedicated benthic survey for the pipeline corridor in Darwin.	Department of Environment, Parks and Water Security (DEPWS)	Santos commissioned further survey work, using a remotely operated vehicle (ROV) in June 2022 to build on previous benthic survey work of the pipeline route undertaken in October 2021 (and presented in the DPD Project referral). The objectives of the June 2022 survey were to obtain further benthic habitat coverage of the pipeline route, including within the Charles Point Reef Protection Area, ground-truth potential cultural heritage targets (as identified from maritime archaeological assessment) and to verify the presence of benthic habitats identified from AIMS 2021 Darwin Harbour habitat mapping (Udayawer et al. 2021) along and adjacent to the pipeline route. The survey targets within the Charles Point Wide RFPA was informed by engagement with the Department of Industry, Tourism and Trade (DITT) – Fisheries Division and as a result, included a fish aggregation area approximately 2.5 km from the pipeline route. Santos has made available raw benthic survey data collected during the October 2021 and June 2022 surveys to both DITT-Fisheries and DEPWS. Refer to **Section 9.4.3** for results of the additional benthic habitat survey and **Appendix 13** for details of consultation undertaken since publication of the NT referral.	Marine Ecosystems
+ Geotechnical investigations should occur to address uncertainties in the sediment characteristics	Environment Centre NT (ECNT)	A geotechnical survey of the pipeline route was completed in January 2022 and sediment sampling was also completed during that survey within Darwin Harbour. The survey results provide contiguous surfaces and sub-bottom profiles along the corridor with sediment sampling used to determine sediment characteristics. The laboratory analysis of the sediment samples has now been completed (refer **Appendix 6** for pipeline benthic survey report) and the results have been used to update the SER (refer **Section 8.4.2**). Sampling and analysis of sediments was done in accordance with principles within the Australian Government *National Assessment Guidelines for Dredging* (NAGD; CoA 2009). Sediment characteristics following the laboratory analysis have informed the dispersion modelling completed for the DPD Project.	Marine Environmental Quality
+ Full characterisation of the contamination of marine sediments in the Project area is required to obtain a greater understanding of recently accumulated sediments, and to assess the impact of proposed trenching on Marine Environmental Quality (i.e., geotechnical investigations).	Environment Centre NT (ECNT)	Laboratory results from the water and sediment sampling program undertaken in January 2022 as part of the geotechnical survey were not available to be included in the referral. These results are now presented in **Section 8.4** to provide a more complete characterisation of water quality and sediment quality within the Project area. The sampling methods used during the survey were in line with the Australian Government National Assessment Guidelines for Dredging (NAGD; CoA 2009).	Marine Environmental Quality
+ Updated data on marine megafauna populations, coral extent and seagrass health are essential to understand impacts + Data/information/advice from non-government sources, marine species experts or data from	Environment Centre NT (ECNT) Karen Edyvane – Australian National University	Santos considers that the level of existing data/information on marine megafauna distribution/abundance and benthic habitats within the Project area, supplemented with additional Project-specific studies, is adequate to inform the impact assessment and management measures represented in this SER. Additional studies have been undertaken using a risk-based approach, and consider NT EPA and NT Government feedback on the referral, focussing on receptors/activities with the greatest potential for impact. Additional data presented in the SER includes benthic survey habitat, sediment dispersion modelling, underwater noise modelling, treated seawater modelling and hydrocarbon spill modelling.	Marine Ecosystems

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
major NESP Hub activities (e.g. sawfish, sharks) should be sought		Data/information/advice from both government and non-government sources has been used within the impact assessment sections of this SER.	
+ Lack of baseline, ecosystem, understanding of Darwin Harbour with concerns that monitoring / management has not included the use of conceptual models, collation/integration of datasets and ecosystem modelling. + Concerns with reliance on information from the NT Government's Darwin Harbour Integrated Marine Monitoring and Research Program (IMMRP) – both, in assessing the medium and long-term impacts of the INPEX Ichthys Project and also, assessing the potential impacts of the current DPD Project.	Karen Edyvane – Australian National University	Santos has sought and reviewed a number of available data and information sources to improve the understanding of the existing environment within the Darwin Harbour, including the long-term Northern Territory-run offset program, the Integrated Marine Monitoring and Research Program (IMMRP). The IMMRP is a monitoring program run by the NT Government and INPEX Operations Australia Pty Ltd. Santos utilised information from the IMMRP to inform the impact assessment presented in the referral, and real time environmental monitoring undertaken during the construction phase of the INPEX Ichthys project considered relevant on the basis of similarity in types of activities conducted. In addition, Santos has engaged a number of technical studies since the referral to inform assessment of the DPD Project. Santos has further reviewed the INPEX Ichthys environmental monitoring reports to better understand conclusions drawn and the potential for longer term impacts to inform the DPD Project environmental monitoring program (refer to **Section 8.5** and **Section 11.1.4** for further detail on information utilised to inform the SER and additional impact assessment presented). The TSDMMP provided in **Appendix 4** provides details on the water quality and benthic habitat monitoring program developed for the DPD Project**.** Santos is committed to making all of its impact assessment study and monitoring data available to relevant NT Government agencies and the Darwin Harbour Advisory Committee (DHAC) as requested to support a greater understanding of the Darwin Harbour marine environment.	Marine Environmental Quality Marine Ecosystems
+ Deficiencies in the historical studies undertaken through the Darwin Harbour Integrated Marine Monitoring Research Program (IMMRP) and low level of NT Government support/ investment of the IMMRP.	Karen Edyvane – Australian National University	The studies previously undertaken as part of the Darwin Harbour Integrated Marine Monitoring Research Program (IMMRP) and NT Government support of that program are outside of Santos' control and therefore this issue is not responded to further in the SER.	Marine Environmental Quality Marine Ecosystems
+ There are currently gaps in baseline information for understanding the potential biological and biodiversity impacts of development, including: - Estuarine (and land-sea) ecosystem processes and function - Soft sediment communities, sessile epifauna (including shell-life) - Coral reef & seagrass communities - Fish nursery and feeding areas (particularly for commercial, recreational species (including crayfish)) - Movements and critical habitat (i.e., feeding, nursery, calving, breeding areas) of key marine megafauna (sharks/rays, sea snakes, turtles, saltwater crocodiles, dugongs, cetaceans)	Karen Edyvane – Australian National University Robin Knox	Santos considers that the project specific data collected and studies completed for the DPD Project, in conjunction with the existing information collected for similar projects such as the INPEX Ichthys project and the original Bayu-Undan to Darwin pipeline is adequate to inform the impact assessment which covers the potential biological and biodiversity impacts raised in the submissions. Further data has been collected specific to the DPD Project on a risk basis where there is a known impact or where there is the highest potential for impact (e.g. benthic habitat data). Information on potential biological and biodiversity impacts as a result of the Project activities are provided as follows: + Estuarine (and land-sea) ecosystem processes and function – Refer to Sections 8.5.1 and 9.5.1 + Soft sediment communities, sessile epifauna – Refer to Sections 8.5 and 9.5 + Coral reef & seagrass communities – Refer to Sections 8.5 and 9.5 + Fish nursery and feeding areas (particularly for commercial, recreational species) – Refer to **Section 11.2.5** + Movements and critical habitat of key marine megafauna – Refer to **Section 9.5.7** Santos has sought additional sources of data and reviewed the information available in the Commonwealth's Conservation Atlas (e.g. biologically important areas (BIAs), habitat critical to marine species, etc.) and revisited existing monitoring data and reports on key marine megafauna to improve the understanding of the existing environment within the Project area. Santos has continued to engage with stakeholders including the AFANT and DITT – Fisheries Division, to further understand popular recreational fishing locations within the Project area and broader surrounds including potential impacts to a fish aggregation area within the Charles Point Wide RFPA. Santos sought expert advice from Pendoley Environmental, a SME, to determine the presence and significance of marine turtle nesting activity on beaches within and surrounding Darwin Harbour and the potential impact of Project lighting. A technical note was prepared which considers regional marine turtle nesting and assesses the likely level of impact the	Marine Ecosystems Community and Economy

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
		DPD Project will have on the Arafura Sea genetic stock of flatback turtles (*Natator depressus*). A summary of the importance of turtle nesting beaches is provided in **Section 9.4.6** and the technical note is provided in **Appendix 14**. Santos commissioned further survey work in June 2022 to build on previous survey work (October 2021 and January 2022) and to verify the presence of benthic habitats in certain sensitive areas that could potentially be impacted by the DPD Project (refer **Appendix 6**). This work included the Charles Point Wide RFPA and Weed Reef which are considered key areas for commercial and recreational species.	
Water and sediment quality			
+ The proponent should rely on its own plume and sediment transport models to inform risk assessment + The proponent should undertake sediment transport modelling to establish the zone of influence of project activities to assess direct and indirect impacts against published thresholds/trigger values and inform management of activities + The proponent should clarify/ describe whether dredging is continuous or occurs in pulses + The Project/dredge disposal can have a significant impact on Marine Environmental Quality	Department of Environment, Parks and Water Security (DEPWS), including the Flora and Fauna Division Environment Centre NT (ECNT)	Santos has completed sediment dispersion modelling (refer to **Appendix 3**) to further understand the potential indirect impacts to Marine Environmental Quality from increased turbidity and sedimentation associated with trenching and spoil disposal activities. The sediment dispersion modelling approach, use of source terms and technical report was reviewed by AIMS and been informed by feedback, including that provided within an expert review report. Modelling was used to inform thresholds to establish a zone of influence along the pipeline and at the spoil disposal site. The sediment dispersion modelling considered multiple trenching scenarios during both wet and dry periods to capture different prevailing currents and conditions. The approach of applying thresholds to interpret sediment dispersion modelling has been done in consultation with DEPWS. **Section 8.5.1.1** presents the approach taken and method used for the sediment dispersion modelling, the results and subsequent impact assessment to evaluate if trenching and spoil disposal could have a significant impact on Marine Environmental Quality. Trenching will be a continuous operation throughout an expected campaign of 2-3 months. Depending on the final construction schedule, a maintenance trenching campaign may be required to ensure the trench is in specification for pipe lay. If required, it is expected that the works would be completed within a two-week period and would not commence until after the cyclone season in 2024. Further details on trenching activities are provided in **Section 2.3.1** and **Section 2.3.2**.	Marine Environmental Quality
+ Reliance on previous INPEX assessments to inform impact from this project	Department of Environment, Parks and Water Security (DEPWS) Environment Centre NT (ECNT)	At the time of the referral, Santos had not completed modelling studies to inform a more detailed impact assessment of the DPD Project. Consequently, the approach taken was to draw on the extensive studies and monitoring conducted for similar projects in Darwin Harbour, including construction of the original Bayu-Undan to Darwin pipeline and DLNG facility, and the more recent INPEX Ichthys project. In particular, the INPEX Ichthys project was used as a proxy to assess impacts on the basis that it undertook similar work activities within a similar area (including spoil disposal) but on a greater spatial and temporal extent. Santos has now completed a range of technical modelling studies since the referral to further understand the potential direct and indirect impacts to the environment from the DPD Project activities. Sediment dispersion modelling (**Appendix 3**), treated seawater modelling (**Appendix 5**), underwater noise modelling (**Appendix 8** and **Appendix 9**), hydrocarbon spill modelling (**Appendix 15**), additional benthic habitat surveys(**Appendix 6**), maritime heritage studies (**Appendix 16**), a lighting impact technical study (**Appendix 14**) and a traffic impact assessment (**Appendix 10**) have been completed and the results have been used to inform the updated impact assessment presented in the SER for each of the key factors. The impact assessment is presented against the relevant NT EPA factors in **Sections 8** to **Section 11**.	Marine Environmental Quality
+ The proponent should provide a Dredging and Dredge Spoil Placement Management Plan for review by appropriate experts before any dredging commences	The Flora and Fauna Division Department of Environment, Parks and Water Security (DEPWS)	Santos has engaged technical specialists to prepare the TSDMMP for the DPD Project as provided in **Appendix 4**. The TSDMMP along with the suite of management plans prepared of the DPD Project have been reviewed and endorsed by third-party technical specialists.	Marine Environmental Quality
+ Modelling the discharge of treated seawater and hydrocarbon spills is essential to understand impacts	Environment Centre NT (ECNT)	Treated seawater modelling (**Appendix 5**) was undertaken to consider the potential impacts to Marine Environmental Quality in the unlikely scenario of a wet buckle event occurring during construction that required treated seawater to be dewatered from the pipeline in NT waters, including Darwin Harbour. Refer **Section 8.5.2** for further details of the discharge modelling and subsequent impact assessment.	Marine Environmental Quality

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
		Hydrocarbon spill modelling (**Appendix 15**) was also undertaken to predict the potential impacts to the marine/coastal environment from the accidental release of marine diesel during Project activities. Refer to **Section 8.5.5** for further details of the spill modelling and subsequent risk assessment of how a spill may impact the Marine Environmental Quality.	
+ Assessment and monitoring protocols for sediment should consider the Australia & NZ WQ Framework (ANZG, 2018) and apply 'multiple lines of evidence' (Simon & Batley 2016).	Karen Edyvane – Australian National University	The environmental monitoring program will focus on real-time measurements of turbidity for the protection of sensitive receptors, as turbidity is the primary indirect stressor resulting from trenching activities. Other parameters including Photosynthetic Active Radiation (PAR), salinity and water temperature will also be collected to provide environmental context and evidence to trenching activity attributability assessment (Section 7.5.4 of **Appendix 4**). Baseline and responsive habitat monitoring will also be undertaken to assess the health of sensitive receptors. Prior to the commencement of trenching activities monitoring will be completed to develop/confirm an environmental baseline for water quality and benthic habitat condition. If appropriate, trigger values identified by INPEX will be updated to align with this baseline data. Post construction monitoring may be completed based on analysis of construction monitoring and any trigger exceedances.	Marine Environmental Quality
+ Impacts from gas leakage along the pipeline	Alice Nagy Anonymous (submission 17)	A quantitative risk assessment (INTECSEA, 2021) completed for the DPD Project pipeline was used to inform the SER with respect to the risk of pipeline rupture during operations from external impact and the release of dry gas. The risk assessment of dry gas release from the DPD Project Pipeline has been presented in **Section 9.5.8** and **11.2.5.1.7**.	Marine Environmental Quality
Conservation areas			
+ Potential impacts to Charles Point Wide reef fish protection area – important zone to the overfished stocks of Golden Snapper and Northern Mulloway	Environment Centre NT (ECNT) Anonymous (submission 14)	The Charles Point Wide RFPA is a temporary spatial enclosure established in 2015 by the NT Department of Primary Industry and Resources (NTDPIR) (now DITT) to aid recovery of stocks of golden snapper (*Lutjanus johnii*) and black jewfish (*Protonibea diacanthus*). The Charles Point Wide RFPA is approximately 88 km² and the DPD Project area overlap within the Charles Point Wide RFPA is approximately 0.06 km² based on an approximately 11.5 km long section of pipeline with a 5 m wide disturbance footprint, i.e., 2.5 m either side of the pipeline alignment (noting there is no pipelay vessel anchoring required to lay the pipeline through this area). Further survey work (**Appendix 6**) has been conducted within the Charles Point Wide RFPA to further characterise the benthic habitats under the pipeline route and at a jewfish aggregation site provided by DITT, over 2.5 km away from the pipeline route. The surveys of the pipeline route through the RFPA do not show presence of any habitat similar to that at the known aggregation area, nor any area of raised/ significant habitat, i.e. the pipeline route is a relatively featureless bare sand habitat. Refer to **Section 9.4.2** for further details on habitat mapping within the Charles Point Wide RFPA. Sediment dispersion modelling was completed (**Appendix 3**) to further understand the potential indirect impacts to the RFPA from trenching and spoil disposal activities. **Section 8.5.1.1** presents the approach taken and method used for the sediment dispersion modelling. The results show that the RFPA is not impacted by turbidity or sedimentation. Treated seawater modelling was undertaken (**Appendix 5**) to consider the potential impacts in the unlikely scenario of a wet buckle event occurring during construction that required treated seawater to be dewatered from the pipeline. Refer **Section 8.5.1.5** for further details of the discharge modelling and **Section 8.5.1.6** for the subsequent impact assessment. Hydrocarbon spill modelling was undertaken (**Appendix 15**) to predict the potential impacts to the marine/coastal environment from the accidental release of hydrocarbons during Project activities. Refer to **Section 8.5.5** for further details of the spill modelling and **Section 9.5.9** for subsequent impact assessment, including potential impacts to the Charles Point Wide RFPA. Santos has been engaging with the DITT – Fisheries Division to better understand the issues and potential impacts related to the RFPA. Prior to submittal of the DPD referral, Santos was advised by DITT-Fisheries that the new pipeline route to not be laid over, or in very close proximity to, an identified Jewfish Aggregation Area. Following the referral, In February and March 2022, Santos provided coordinates to DITT-Fisheries to show that the pipeline route and all pipelay activities would occur a significant distance from the aggregation area (over 2.5 km from the pipeline route). Santos has provided DITT Fisheries with benthic survey data from along the pipeline route and at the fish aggregation area. Refer to **Appendix 13** for details of consultation undertaken since publication of the referral.	Marine Ecosystems Marine Environmental Quality

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ The pipeline will pass through the Oceanic Shoals Marine Park, through the Charles point reef fish protection zone and within 6 km of the Tiwi Islands' western coast. + The Tiwi Islands western coastline is a biologically significant area for Olive Ridley turtles and green turtles.	Dina Rui - Jubilee Australia Research Centre Anonymous (submission 17)	Santos notes that the DPD Project pipeline will not pass through the Oceanic Shoals Marine Park and the section in NT Waters is ~27 kms from the Tiwi Islands at its closest point and therefore not within 6 km proximity to the Tiwi Islands. The DPD Project does transit the Charles Point Wide RFPA and Santos has completed further survey work and modelling studies to inform an updated assessment of the potential impacts to this area. Refer to **Section 9.5** and **Section 11.2.5**.	Marine Ecosystems
Benthic habitats			
+ The project should establish the zone of influence of project activities to assess direct and indirect impacts + Sediment transport modelling needs to be undertaken to determine if: - Suspended sediments and light availability will impact on neighbouring seagrass meadows - Whether the spatial extent of the declined water quality will impact availability of habitat for marine fauna - Whether sediment is likely to move from the dredge spoil ground into neighbouring areas (e.g. Lee Point) and to what extent this could impact benthic fauna (infauna) and conservation significant areas, like seagrass meadows	Department of Environment, Parks and Water Security (DEPWS)	Sediment dispersion modelling was completed (**Appendix 3**) to further understand the potential direct and indirect impacts to benthic habitats from trenching and spoil disposal activities. This included applying thresholds in consultation with DEPWS to establish a zone of influence along the pipeline and at the spoil disposal site. The sediment dispersion modelling considered multiple trenching scenarios during both wet and dry period to capture different prevailing currents and conditions. **Section 8.5.1.1** presents the approach taken and method used for the sediment dispersion modelling. The benthic habitat and marine fauna impact assessment is presented in **Section 9.5.**	Marine Ecosystems .
+ The most recent habitat mapping should be used to inform ecosystem values, e.g. completed by AIMS in 2021, including: - (i) Recent research mapping benthic communities in Darwin, which predicts a very high probability of extensive hard coral habitat in Darwin Harbour, including in the areas to be traversed by the Pipeline. - (ii) The referral Document suggests instead that Darwin Harbour comprises largely sand-mud and soft sediment communities, which is contradicted by the above research; - (iii) The baseline survey provided in the referral Document (Appendix D) is restricted to the Project area only, and does not refer to marine habitat studies of Darwin Harbour, or outer Darwin Harbour, which is the potential zone of influence of the Pipeline's construction and operation; + The described environmental values do not refer to, nor reflect the latest available studies	Department of Environment, Parks and Water Security (DEPWS) Environment Centre NT (ECNT) Karen Edyvane – Australian National University Kelly Lee Hickey Anonymous (submission 17)	Santos has reviewed and used the latest available environmental information to inform its impact assessment. This includes the latest benthic habitat mapping undertaken by AIMS (Udyawer et al., 2021) which focused on nearshore/intertidal areas (including East Point) and the previous AIMS 2019 mapping (Galaiduk et al., 2019) which included mapping habitats in the deeper water inside and outside Darwin Harbour which were not mapped in the 2021 outputs. Other habitat mapping data, including substrate mapping produced by Geoscience Australia (Siwabessy et al., 2021; Siwabessy et al., 2018) and habitat mapping undertaken by INPEX Browse Ltd (2011) and other published data have also been incorporated into the impact assessment. Santos also commissioned further survey work (completed in June 2022) to supplement the benthic survey work completed in October 2021. The benthic survey results were used to better understand the distribution of benthic habitats along and near the pipeline route and trenching locations, and to verify whether the habitats predicted by AIMS 2021 modelling (Udyawer et al., 2021) were present or not. As stated in AIMS 2021 report, the mapping outputs, "…represent the potential fundamental ecological niche for the habitats analysed based on environmental suitability derived from the model covariates, however, do not represent the realised ecological niche (i.e., whether a habitat will or will not be found at any location at any point in time)." (Udyawer et al., 2021, p.70). Consequently, the dedicated benthic survey was used to verify whether the habitats that AIMS 2021 mapping predicted might be present, were actually present or not. Refer to **Section 9.4.3** for a description of the benthic habitats (including predicted areas of hard coral) based on the available information and the results of the additional survey work. Refer to **Section 9.5.1** for impact assessment related to benthic habitats.	Marine Ecosystems

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ Referral maps do not show areas of hard coral, such as those in the reserve in East Point			
+ Potential impacts to Weed Reef – is regarded by Traditional Owners and eco tour operators as the primary location for Dugongs in Darwin Harbour.	Environment Centre NT (ECNT)	No tourist operators raised this issue through the submission process. Santos has consulted on the DPD Project with Traditional Owners through the Wickham Point Deed Reference Group, the Northern Land Council, the Tiwi Land Council, Larrakia Nation tourism organisations and relevant government departments (DEPWS and DITT-Fisheries). No specific issues with Weed Reef have been raised during any of these consultations. Santos has also reviewed and used the latest available environmental information to inform its impact assessment and undertaken an additional field survey work in June 2022 to build on previous survey work undertaken in October 2021 to verify the presence of benthic habitats, including those at Weed Reef. Refer to **Section 9.5.7** for impacts to marine mammals (including dugongs) and to **Section 9.5.1** for reef habitat and other primary production areas (including Weed Reef).	Marine Ecosystems
+ Up to date research and surveys must be undertaken by an independent expert in order to determine what the anticipated impacts will be on the animals themselves and their critical habitat areas (including mangroves).	Australian Parents for Climate Action Darwin and NT – volunteer group	Santos considers that the level of existing information collected for similar projects such as the INPEX Ichthys project and the original Bayu-Undan to Darwin pipeline in conjunction with additional technical studies specifically conducted by subject matter experts for the DPD Project is adequate to inform the impact assessment. Further data has been collected specific to the DPD Project on a risk basis where there is a known impact or where there is the highest potential for impact (e.g. collection of benthic habitat data). As per Section 7.2.3.3 of the referral, data was collected for mangroves at the shore crossing location adjacent to the DLNG facility to confirm the presence of mangroves and their condition. The survey confirmed only one species of mangrove in proximity to the Project pipeline, *Sonneratia alba*, of which there were only a handful of mangrove regrowth individuals within the existing disturbance footprint (i.e. less than 5 within 20 m either side). This species of mangrove is a common species that is well represented and characterised as part of the mangrove monitoring programme at DLNG. Santos considers this level of information adequate to support the impact assessment of the DPD Project. Santos sought expert advice from Pendoley Environmental to determine the presence and significance of marine turtle nesting activity on beaches within and surrounding Darwin Harbour. A technical note was prepared which considers regional marine turtle nesting and assesses the likely level of impact the DPD Project lighting will have on the Arafura Sea genetic stock of flatback turtles (*Natator depressus*). A summary of the importance of turtle nesting beaches is provided in **Section 9.4.6** and the technical note is provided in **Appendix 14**. Santos collected project specific water, sediment quality and benthic habitat data during across two separate surveys in October 2021 and January 2022 (**Appendix 6**). Santos commissioned further survey work in June 2022 to build on previous survey work and to verify the presence of benthic habitats in sensitive areas that could potentially be impacted by the DPD Project. Further details on the results of these surveys and impact assessment is provided in **Section 9.5.7** and **Section 11.2.5.1.9.** Santos considers the level of data collected for the DPD Project to be sufficient given the high volume of existing data available for Darwin Harbour following the extensive studies and monitoring conducted for similar projects including INPEX Ichthys project and the original Bayu-Undan to Darwin pipeline.	Marine Ecosystems
+ Concerns around impacts to important mangrove habitat, including dieback issues.	Alice Nagy	As per Section 7.2.3.3 of the referral, data was collected for mangroves at the shore crossing location adjacent to the DLNG facility to confirm the presence of mangroves and the condition of health. The survey confirmed only one species of mangrove in proximity to the Project pipeline; *Sonneratia alba*, of which there were only a handful of mangrove regrowth individuals within the existing disturbance footprint (i.e. less than 5 within 20 m either side). This species of mangrove is a common species that is well represented and characterised as part of the mangrove monitoring programme at DLNG. Santos considers the level of information in S**ection 9.5.1.6** and **Section 9.5.9.2** adequate to support the impact assessment of the DPD Project and does not consider the Project will significantly impact mangrove communities. The temporary and localised works at the shore crossing are unlikely to result in a elevated heat conditions sufficient to cause or exacerbate dieback in the nearby mangrove community.	Marine Ecosystems

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ The impact risk assessment should take into account: - The function of benthic habitats (infauna, epifauna and flora) rather than just a biodiversity perspective and consider seagrass meadows in Shoal Bay and Casuarina Coastal Reserve - The availability of habitat that are important for feeding or life stages of listed fish species (*Environment Protection and Biodiversity Conservation Act 1999* or *Territory Parks and Wildlife Conservation Act 1976*) and important commercial and/or recreational species - Whether the pipeline could destroy habitats of threatened species including whales, dugongs and turtles	Department of Environment, Parks and Water Security (DEPWS) Dina Rui – Jubilee Australia Research Centre	Santos has reviewed and used the latest available environmental information to inform its impact assessment. This includes the latest benthic habitat mapping undertaken by AIMS (Udyawer et al., 2021) which focused on nearshore/intertidal areas (including Shoal Bay and Casuarina Coastal Reserve) and the previous AIMS 2019 mapping (Galaiduk et al., 2019) which included mapping habitats in the deeper water inside and outside Darwin Harbour which were not mapped in the 2021 outputs. When identifying and describing the environmental values present within the Project area that may be impacted by Project activities, Santos recognises that in addition to being a value in its own right, benthic habitats play an important function and contribute to wider ecosystem processes. Consequently, the impact assessment has considered these values of different environmental receptors in conjunction with listed species and their habitat and has identified where DPD Project activities may result in an impact. **Section 9.4** identifies the environmental values present within the Project area and **Section 9.5** presents how Project activities may impact these values.	Marine Ecosystems
+ Trenching and spoil disposal: - Could impact seagrass and other seabed biodiversity as well as reef and pelagic fish habitat - Will further damage delicate marine plants and creatures and interfere with feeding and breeding grounds. - Is unacceptable as it is an area [Lee point] that has substantial areas of bottom structure where reef and pelagic species dwell	Grusha Leeman Anonymous (submission 14) Brooke Ah Shay – Doctors for the Environment Australia Anonymous (submission 17) Kelly Lee Hickey	Santos commissioned further survey work in June 2022 to build on previous survey work and to verify the presence of benthic habitats in certain sensitive areas that could potentially be impacted by the DPD Project, including at the spoil disposal ground. Refer to **Section 9.4.3** for details on the benthic habitat mapping results. Sediment dispersion modelling was completed (**Appendix 3**) to further understand the potential indirect impacts to benthic habitats from trenching and spoil disposal activities. This included applying thresholds in consultation with the DEPWS to establish a zone of influence along the pipeline and at the spoil disposal site. The sediment dispersion modelling considered multiple trenching scenarios during both wet and dry period to capture different prevailing currents and conditions. **Section 8.5.1.1** presents the approach taken and method used for the sediment dispersion modelling. The subsequent benthic habitats and marine fauna impact assessment is presented in **Section 9.5.1.**	Marine Ecosystems
Marine fauna			
+ The project should consider the following mitigation measures for incorporation into EMPs in relation to vessel traffic, dredging, pile driving and lighting: - Implementation of vessel speed limits during the construction and operation phase - Marine megafauna observation zones and exclusion zones - That the observation period for marine megafauna prior to commencing dredging and pile driving is 20 minutes and that the observer is solely dedicated to the task of sighting and recording marine megafauna interactions prior to, and during, dredging and pile driving operations - Lighting specifications follow national guidelines	Flora and Fauna Division of Department of Environment, Parks and Water Security (DEPWS)	Vessels will keep within nominated harbour speed limits (**Section 2.8**) and comply with Part 8 of the EPBC Regulations 2008. Standard management for Marine Fauna includes Observation Zones (150 m) and Exclusion Zones (50 m) zones for marine megafauna during trenching operations. A 10-minute observation period for megafauna prior to commencing routine trenching was considered sufficient for an observation zone of 150 m; an MFO will be solely committed to this task during the pre-trenching observation period. In the event that a hydraulic hammer is required to be used for rock breaking, larger Observation and Exclusion zones will be implemented, and a 30-minute observation period has been proposed. These underwater noise management measures are further detailed in **Section 12** and in the Marine Megafauna Noise Management Plan (**Appendix 7**). Pile-driving is not proposed for the DPD Project. Lighting modelling, impacts and management are covered in **Section 9.5.3** and **Section 12.** Lighting on vessels with be directional and have shielding to reduce impacts to the surrounding environment. The predicted impact to marine fauna is considered to be temporary and minor, and the mitigation measures to be employed on the DPD Project are considered to reduce impacts to as low as practicable.	Marine Ecosystems
+ The list of threatened species is inaccurate and is a significant underestimate. Only 7 marine	Environment Centre NT (ECNT)	Santos has revisited the likelihood of occurrence assessment for threatened species presented in the referral and updated the likelihood of occurrence rating. In addition, supplementary sources of data and information has been sought and reviewed to improve the understanding of the existing environment within the Project area. This included publicly	Marine Ecosystems

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
threatened species are listed, and 2 migratory species;		available papers and reports, including some prepared as part of the National Australian Science Program (NESP). Refer to **Section 9.4.4** for further details of the updated likelihood of occurrence assessment.	
+ Australian snubfin dolphins and Bottlenose Dolphins are well documented in Darwin Harbour and yet the referral only mentions the presence of Australian humpback dolphins. Other assertions about absence of whales from the Project area are also incorrect with recent sightings of Humpback Whales recorded along the west coast of Bathurst Island and Van Diemen Gulf	Environment Centre NT (ECNT)	Section 7.2.4.2 of the referral and **Section 9.4.5** of this document, considers all three dolphin species (Australian humpback (*Sousa sahulensis*), Australian snubfin (*Orcaella heinsohni*) and spotted bottlenose (*Tursiops aduncus*)) and that these are known to have resident populations within Darwin Harbour and surrounding waters. Since the referral, Santos has revisited the likelihood of occurrence assessment for threatened species presented in the referral and updated the likelihood of occurrence rating for seven species along with the inclusion of an additional eight species, including humpback whales. In addition, supplementary sources of data and information has been sought and reviewed to improve the understanding of the existing environment within the Project area. This included publicly available papers and reports, including some prepared as part of the National Australian Science Program (NESP). Refer to **Section 9.4.4** for further details of the updated likelihood of occurrence assessment. Humpback whales make an annual migration north from Antarctica to calve during the southern winter before heading back to Antarctica for a summer feeding period. The sighting near Van Diemen Gulf is seen as a rare circumstance and is likely to be one of 70,000 humpback whales spread across two large groups that migrate along the east and west coasts of Australia.	Marine Ecosystems
+ Comprehensive marine megafauna population assessments and applied research into the causes of population decline are required along with ongoing biodiversity monitoring.	Environment Centre NT (ECNT)	Santos considers that the level of existing survey data collected on marine megafauna within the Project area is adequate to inform the impact assessment. Further studies have been conducted specific to the DPD Project on a risk basis where there is a known impact or where there is the highest potential for impact (e.g. underwater noise modelling). Santos considers the risk to marine megafauna to be primarily from vessel activities associated with the temporary construction phase. Dolphin monitoring surveys in Darwin Harbour were conducted between 2011-2019, looking at population dynamics of three species: Australian humpback dolphin (*Sousa sahulensis*), Australian snubfin dolphin (*Orcaella heinsohni*) and spotted bottlenose dolphin (*Tursiops aduncus*). Initial surveys were conducted between 2011 and 2015 to cover the construction phase of the Ichthys LNG Project. This initial monitoring program was extended once construction was completed as part of a voluntary offset agreement between the Ichthys LNG Project and the Northern Territory Government. This second program commenced in 2016 and ended in 2019 (Griffiths et al. 2020). The surveys used capture-recapture methods to estimate population parameters for each of the three species. Individual animals were identified by unique markings on their dorsal fins and fluke markings. Final reporting for the monitoring program (Griffiths et al. 2020) found that all three species were shown to occur at low densities, exhibit substantial temporary emigration and have fluctuating population size. Results from the monitoring program highlight a negative trend in abundance for all three species over time. The monitoring program did not relate declining abundance to a particular anthropogenic event and ultimately the study was unable to explain the reasons for the observed year to year variation and overall decline. The conclusion from the final report (Griffiths et al. 2020) was the monitoring was unlikely to be suitable for long term surveillance monitoring due to the mobility of species and lack of reasons that could be attributed to changes in abundance. Santos has therefore not attempted to collect further baseline data for dolphins, and it is considered that the information collected as part of the Ichthys LNG project is adequate for use by the DPD Project. Santos sought expert advice from Pendoley Environmental to determine the presence and significance of marine turtle nesting activity on beaches surrounding Darwin Harbour. A technical note was prepared which considers regional marine turtle nesting and assesses the likely level of impact the DPD Project lighting will have on the Arafura Sea genetic stock of flatback turtles (*Natator depressus*). A summary of the importance of turtle nesting beaches is provided in **Section 9.4.6** and the technical note is provided in **Appendix 14**.	Marine Ecosystems
+ An assessment of underwater noise impacts during construction and operation are required	Environment Centre NT (ECNT)	Underwater noise modelling has been undertaken (**Appendix 8** and **Appendix 9**) to better understand the potential impacts to marine fauna from noise associated with DPD Project construction activities. Operational noise (infrequent vessel visits for pipeline surveys) is considered far less of an issue than construction noise (which was assessed as having only a minor impact) and has not been subject to specific modelling. Noise impact and effective ranges have been	Marine Ecosystems

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
		identified based on published thresholds for different marine fauna, to determine the potential scale of impacts and appropriate management measures. Refer to **Section 9.5.2** for further details of the noise modelling and impact assessment. Management actions for marine fauna are presented in **Section 12** and in the Marine Megafauna Noise Management Plan (**Appendix 7**).	
+ Potential impacts to sensitive Marine Ecosystems and threatened and vulnerable species, such as dolphins, whales, dugongs and marine turtles	Grusha Leeman Alice Nagy Robin Knox Kelly Lee Hickey	Santos has revisited the likelihood of occurrence assessment for threatened species presented in the referral and updated the likelihood of occurrence rating. Refer to **Section 9.4.4** for further details. Santos has used existing data on the abundance and distribution of marine megafauna within the Project area and has also completed a range of modelling studies to further understand the potential direct and indirect impacts to marine fauna from the DPD Project activities, including underwater noise modelling, sediment dispersion modelling, treated seawater discharge modelling and hydrocarbon spill modelling. The key impact and risk assessments for marine fauna, including dolphins, dugongs and marine turtles are presented in **Section 9.5.2, 9.5.3, 9.5.4, 9.5.7, 9.5.8** and **9.5.9.**	Marine Ecosystems
+ Concerns around the limited consideration of indirect impacts and need to establish the zone of influence for project activities.	Environment Centre NT (ECNT)	Santos has completed a range of modelling studies to further understand the potential direct and indirect impacts to the marine environment from the DPD Project activities including sediment dispersion modelling, underwater noise modelling, treated seawater discharge modelling and hydrocarbon spill modelling. Sediment dispersion modelling includes relevant thresholds for impact assessment analysis and establishes a zone of influence along the pipeline and at the spoil disposal site (refer **Section 8.5.1**).	Marine Environmental Quality Marine Ecosystems Coastal Processes Community and Economy
Fish and fisheries			
+ Further assessment into impacts within Charles Point Wide RFPA + Potential impact to an important subsea structure in the Charles Point Wide reef fish protection area + Potential social impact that could be realised if community perceives that support for the RFPA has been undermined by approval of pipeline construction + Construction of a gas pipeline through the Charles point reef fish protection area needs thorough investigation considering the importance of this zone to the overfished stocks of Golden Snapper and Northern Mulloway	Department of Industry, Tourism and Trade – Fisheries Division Amateur Fisherman's Association of the Norther Territory (AFANT) Anonymous (submission 14) Environment Centre NT (ECNT)	Geophysical survey data collected along the proposed pipeline route were used to identify locations within the Charles Point Wide RFPA where changes to bathymetry were apparent. These locations were then surveyed using a remotely operated vehicle (ROV) to determine the presence of habitat that could be important to fish including the black jewfish (*Protonibea diacanthus*). In addition, a known fish aggregation area, provided by DITT – Fisheries, over 2.5 km from the pipeline route, was surveyed by ROV. Refer to **Section 9.4.2** for an assessment of potential impacts to subsea structures in the RFPA which incorporated the additional benthic habitat survey data presented in **Section 9.4.3**. Engagement with DITT – Fisheries Division has been undertaken to better understand potential impacts from the DPD Project to the RFPA. Santos was advised by DITT-Fisheries that within the Charles Point Wide RFPA, the area of greatest value is a known jewfish aggregation site and that this area should be avoided by pipeline installation activities. Consultation with the Amateur Fishers Association of the NT (AFANT) reiterated that the main concern was potential impact on the recreational fishing species that the area was designed to protect.	Marine Ecosystems Community and Economy
+ Localised impacts from trenching will occur in the form of the removal of fish habitat that supports recreationally targeted species	Amateur Fisherman's Association of the Norther Territory (AFANT) Anonymous (submission 14)	An analysis of the habitat that will be directly and indirectly impacted from trenching and spoil disposal activities has been undertaken, including consideration of the function that the benthic habitats may provide, e.g. fish habitat. **Section 9.5.1** presents impact assessment to evaluate if trenching and spoil disposal could have a significant impact on benthic habitats and the marine fauna they support. Potential impact to recreational fishers is presented in **Section 11.2.5.1.3**, and details of engagement with the NT's peak recreational fishing body, AFANT, and DITT-Fisheries are provided in **Appendix 13.**	Marine Ecosystems Community and Economy
+ Further engagement with NT Fisheries should be required to better understand these factors, and if necessary, to mitigate the risk of interrupting	Amateur Fisherman's Association of the Norther Territory (AFANT)	Sinclair Knight Merz (SKM) carried out an assessment of potential impacts to mud crabs in Darwin Harbour for the Ichthys project, which is of a larger scale in terms of dredging than the DPD Project (SKM, 2011). The report described that mud crabs are adapted to live in and migrate within highly turbid environments, as experienced seasonally within Darwin	Marine Ecosystems Community and Economy

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
the Darwin harbour mud crab spawning migration.		Harbour. The Department of Fisheries also states that mud crabs are highly tolerant of variations in water salinity and temperature (Department of Fisheries, 2013). See **Section 9.4.7** for further details. DPD Project trenching and pipeline installation works may occur over a 15-month period, which would therefore coincide with mud crab migration during the wet season. However, migration of mud crabs occurs over a wider extent, with the DPD Project activities occurring in localised areas at any given time, therefore, are not expected to create any significant impact to mud crab behaviours. In consultation with Santos, DITT-Fisheries principal research personnel, advised Santos that the DPD Project was unlikely to lead to significant impacts to mud crabs in the area.	
Changes in seafloor topography and currents			
+ Potential impacts from trenching and backfill of the trench and reinforcement of the pipeline (rock installation) have not been adequately assessed, and changes in seafloor currents can change sediment transport, sediment deposition and erosion.	Department of Environment, Parks and Water Security (DEPWS) Environment Centre NT (ECNT)	Sediment dispersion modelling (**Appendix 3**) was completed to understand the potential spatial extent that sediment may be dispersed as a result of trenching and spoil disposal activities. The sediment dispersion modelling considered multiple trenching scenarios during both wet and dry period to capture different prevailing currents and conditions. **Section 8.5.1.5** summarises the approach and results for the sediment dispersion modelling. The impact assessment for trenching and spoil disposal is presented in **Sections 8.5** and **9.5**. An assessment of trenching and rock installation on Coastal Processes is included in **Section 11.1.4** This includes a third party review of the proposed trenching and rock installation design and historical shoreline movement imagery in the vicinity of the pipeline shore-crossing area to further assess the potential for the DPD Project to impact on Coastal Processes (RPS, 2022e).	Coastal Processes
+ Details of the cofferdam are required, as is an assessment of the shoreline erosion associated with it.	Environment Centre NT (ECNT)	The Project design has been further progressed since publication of the referral and the cofferdams proposed in the referral have been deemed unnecessary and since been removed from the project design.	Coastal Processes
Primary productivity and processes			
+ Primary production can be impacted by elevated suspended sediments in multiple ways; either by reduced light availability or suspended sediments trapping phytoplankton and zooplankton which are subsequently removed from the primary production cycle as the suspended sediments settle out on the seafloor. + Further, dredge spoil disposal and seabed mining have a direct impact on benthic fauna/infauna and the nutrient/trophic process within sediments. Changes to sediment composition from disposed sediment could also permanently change sediment chemical processes. + Primary productivity and nutrient cycling should be assessed as part of the risk assessment.	Department of Environment, Parks and Water Security (DEPWS)	INPEX Nearshore Environmental Monitoring Program (NEMP) monitored dredging-related impacts to marine plant productivity by measuring mangrove health, phytoplankton biomass and microphytobenthos biomass. No detectable dredging-related impacts were found during the monitoring program (Cardno, 2014). Given the DPD Project proposes similar types of work activities within a similar area (including spoil disposal) but on a much smaller spatial and temporal scale, it is expected that impacts associated with the DPD Project would be significantly less than potential impacts for the INPEX Ichthys project. It is therefore considered unlikely that trenching-related impacts from the DPD Project would significantly impact primary productivity within Darwin Harbour and/or surrounds. Potential impacts to primary productivity and nutrient cycling were considered in the risk assessment for the DPD Project. Refer to **Section 9.4.1** and **Section 9.5.1.8** for further details. Sediment dispersion modelling was completed (**Appendix 3**) to further understand the potential spatial extent that sediment may be dispersed as a result of trenching and spoil disposal activities as well as to identify where potential indirect impacts to primary producer habitats may occur. This included applying thresholds in consultation with DEPWS to establish a zone of influence along the pipeline and at the spoil disposal site. The sediment dispersion modelling considered trenching scenarios during both wet and dry seasons to capture different prevailing currents and conditions. **Section 8.5.1.1** presents the approach taken and method used for the sediment dispersion modelling. The subsequent impact assessment for benthic habitats, including primary producers, is presented in **Section 9.5.1**.	Marine Ecosystems
Greenhouse Gas emissions			
+ The Barossa gas field has a very high CO_2 content (16-20%). The development of the Barossa gas field will consume a significant portion of the global carbon budget.	Elizabeth Sullivan – Australian Conservation Foundation Bruce Robertson - Institute for Energy Economics and Financial Analysis	An emissions inventory has been developed for the life cycle of the Barossa Development (with DPD), including Scope 1, 2 and 3 emissions. The DPD Project's emissions comprise the installation and operation of ~100 km of pipeline infrastructure in NT waters which will facilitate the passive conveyance of produced Barossa gas to the DLNG facility for processing. The DPD Project's	Atmospheric Processes

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
	Jorgen Doyle - Central Australian Frack Free Alliance Environment Centre NT (ECNT) Brooke Ah Shay - Doctors for the Environment Australia The Australia Institute Grusha Leeman Anonymous (submission 17) Alice Nagy Naish Gawen (on behalf of many) (submissions 18-301) Anonymous (submission 302) Robin Knox Anonymous (submission 305) Dina Rui - Jubilee Australia Research Centre Kelly Lee Hickey	GHG emissions represent only a small fraction (~0.02%) of Australia's annual GHG emissions. Therefore, the construction and operation of the DPD Project will not represent a significant contribution to global GHG emissions. The Barossa Development (including DLNG and end-use customers) greenhouse gas emissions represent 0.042% of 2021 global energy GHG emissions. Therefore, the Barossa Development is not a significant contributor to global GHG emissions. For additional detail refer to **Section 10**.	
+ The development of the Barossa gas field is inconsistent with the NT Government's net zero 2050 target.	Bruce Robertson - Institute for Energy Economics and Financial Analysis Brooke Ah Shay - Doctors for the Environment Australia Julie Fraser – Australian Service Union Julie Fraser Anonymous (submission 302) Kelly Lee Hickey	Santos acknowledges the NT Government's net zero by 2050 target. Santos has a net zero by 2040 commitment as well as interim 2030 emissions abatement targets (Santos, 2022). The Barossa Development, including the DPD Project, will comply with all Commonwealth and NT Greenhouse Gas (GHG) legislative requirements. The Scope 1 GHG emissions from the Barossa Development are regulated by the Safeguard Mechanism. The Safeguard Mechanism establishes a GHG baseline. Baseline exceedance is required to be offset through the purchase of carbon credits, the cost of the carbon credits provide a cost stimulus to abate emissions consistent with the baseline. The current Safeguard Mechanism reform is "to deliver emissions reductions consistent with Australia's Nationally Determined Contribution under the Paris Agreement" (DCCEEW 2023), 43% below 2005 levels by 2030 and the long-term goal of net zero emissions by 2050, ensuring the Barossa Development supports the NT Government's net zero 2050 target. Under proposed Safeguard Mechanism reforms, the emissions baseline will gradually decline to limit emissions and achieve net zero by 2050. The decline rate is proposed to be 4.9% each year to 2030, with post 2030 decline rates to be set in predictable five-year blocks thereafter. On 27 March 2023, the government announced that new gas fields supplying existing liquefied natural gas facilities will effectively receive zero baseline coverage for reservoir CO_2 emissions. For additional detail refer to **Section 10.2.3**.	Atmospheric Processes
+ The DPD project is incompatible with keeping global warming below 1.5°C and avoiding the worst impacts of climate change. It could also mean that Australia would not be able to deliver on its commitments under the Paris Agreement. The International Energy Agency / IPCC have advised previously that to stay below 1.5°C of warming and avoid the worst impacts of climate change, no further fossil fuel developments should be pursued.	Bruce Robertson - Institute for Energy Economics and Financial Analysis Jorgen Doyle - Central Australian Frack Free Alliance Australian Services Union Environment Centre NT (ECNT) The Australia Institute Grusha Leema Julie Fraser – Australian Service Union	The Paris Agreement is the key in-force agreement for limiting global warming. Australia contributes to meeting global temperature goals under the Paris Agreement through its nationally determined contributions (NDCs). These NDCs were last updated in June 2022 and include: + A 2030 target to reduce emissions by 43% below 2005 levels and + Net zero emissions by 2050 commitment The Barossa Development, including the DPD Project, will comply with all Commonwealth and NT GHG legislative requirements. Through Australian legislative compliance the Barossa Development will contribute towards Australia's NDCs which in turn contribute towards meeting global commitments under the Paris Agreement. Further discussion on legislative requirements is provided in the comment above. With regard to the International Energy Agency and Intergovernmental Panel on Climate Change modelling, it is important to note that the scenarios modelled do not reflect a forecast or a definitive outcome. Scenario analysis relies on	Atmospheric Processes

Santos

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
	Julie Fraser Peta Bailee Dina Rui - Jubilee Australia Research Centre Anonymous (submission 307)	assumptions that may not be correct or occur. The scenarios may be impacted by additional factors not considered in the model and so may not eventuate. As such, these scenarios should not be confused with actual government policy or in-force legislative frameworks (such as the Paris Agreement). Notwithstanding the limitations of scenario analysis, Santos considers the IEA Net Zero (NZE) by 2050 scenario along with three other macro-economic scenarios to inform its climate change strategy and plans. In the NZE by 2050 scenario, an assumed rapid rise in low emissions fuels is one of the key reasons – along with greater efficiency and electrification – why the IEA claimed no new oil and gas fields would be required beyond those already approved. However, the IEA also noted that actual deployment of low emissions fuels is well off track. The IEA 2021 World Energy Outlook also states that "Oil and gas spending today is one of the very few areas that is reasonably well aligned with the levels seen in the NZE to 2030" and warns that the world is not investing enough to meet its future energy needs, and that uncertainties over policies and demand trajectories create a strong risk of a volatile period ahead for energy markets. Whilst it is too simplistic to assert that no new oil and gas developments will be required, the NZE scenario does recognise that projects already approved for development, such as the Barossa , are required to be developed to supply world gas demand.	
+ The NT has seen incidence of dieback of mangrove forests caused by marine heat waves. These kinds of dieback events are environmental disasters as well as social, cultural, and economic disasters, and they are caused by global warming.	Alice Nagy	Santos acknowledges the environmental, social, cultural and economic impacts of climate change including impacts to habitats and ecosystems (**Section 10.4** and **Section 10.5**). Australia contributes to meeting global temperature goals under the Paris Agreement through its nationally determined contributions (NDCs). The Barossa Development, including the DPD Project, will comply with all Commonwealth and NT GHG legislative requirements. The Scope 1 GHG emissions from the Barossa Development are regulated by the Safeguard Mechanism. The Safeguard Mechanism establishes a GHG baseline. Baseline exceedance is required to be offset through the purchase of carbon credits, the cost of the carbon credits provide a cost stimulus to abate emissions consistent with the baseline. The current Safeguard Mechanism reform is "to deliver emissions reductions consistent with Australia's Nationally Determined Contribution under the Paris Agreement" (DCCEEW 2023), 43% below 2005 levels by 2030 and the long-term goal of net zero emissions by 2050, ensuring the Barossa Development supports the NT Government's net zero 2050 target. Additional detail on the project specific emissions is provided in **Section 10.2.1.**	Atmospheric Processes
+ There is global scientific consensus that climate change contributes to many human health risks including, higher mortality and morbidity from heat stress, the transmission of diseases and mental health impacts. Climate change will also cause increasingly severe weather events and impact food production. Continued global warming risks making the NT unliveable due to oppressive heat and creates risks to health and wellbeing of workers	Australian Parents for Climate Action Australian Services Union Brooke Ah Shay - Doctors for the Environment Australia Julie Fraser – Australian Service Union Julie Fraser Australian Parents for Climate Action Darwin and NT - volunteer group Anonymous (submission 304)	Santos acknowledges the social impacts of climate change. Australia contributes to meeting global temperature goals under the Paris Agreement through its nationally determined contributions (NDCs). The Barossa Development, including the DPD Project, will comply with all Commonwealth and NT GHG legislative requirements. Through Australian legislative compliance the Barossa Development will contribute towards Australia's NDCs which in turn contribute towards meeting global climate commitments under the Paris agreement. Additional detail on the project specific emissions is provided in **Section 10.2.1**.	Atmospheric Processes
+ Santos' documents outline that two-thirds of the CO_2 from the Barossa offshore gas field will be vented directly into the atmosphere before the gas is piped to Darwin. This includes the greenhouse gas methane, which will be emitted throughout the life cycle of the project. There are also potential leaks of emissions associated	Environment Centre NT (ECNT) Alice Nagy Australian Parents for Climate Action Australian Parents for Climate Action Darwin and NT - volunteer group	Monitoring and reporting of emissions will be made in accordance with the *National Greenhouse Gas and Energy Reporting Act 2007* (Cth), this includes fugitive emissions and vented CO_2. Santos is committed to minimising fugitive emissions in its operations. As a proportion of Santos overall production volume, methane emissions are well below the Oil and Gas Climate Initiative 2025 intensity target of less than 0.2 per cent (Santos, 2022). Fugitive emissions surveillance and management will be embedded into facilities operations and maintenance procedures. Such programs involve the use of leak detection equipment to identify leaks for subsequent repair.	Atmospheric Processes

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
with the transport of gas along the pipeline. How will these be monitored? + Santos has not addressed how they will monitor for fugitive emissions along the pipeline and at each state of processing the gas from beneath the sea floor to the ships to the harbour		Furthermore, the design of the Barossa Development facilities has been optimised to reduce fuel, flare, vent and fugitive emissions, with design measures including: + Flaring limited to operation of the flare purge and pilots during steady state operations; + Vapour recovery units and flash gas compression systems designed to capture low pressure, continuous sources of vented gas that would be sent to flare and direct them to be processed into sales gas; + Full electrification of the facility, with highly efficient combined cycle power generation; + Process heating via waste heat recovery; + Destruction of methane emissions in the CO2 permeate stream by a thermal oxidiser; and + Connection of process vents to flare (recovered) where possible to minimise methane emissions.	
+ Santos has not determined the lifecycle GHG emissions associated with the pipeline and the broader Barossa Development. Santos does not make any reference to the indirect emissions associated with the combustion of produced LNG. + Santos should outline GHG emissions for the whole of the Barossa Development	Bruce Robertson - Institute for Energy Economics and Financial Analysis Julie Fraser - Australian Services Union Environment Centre NT (ECNT) Brooke Ah Shay - Doctors for the Environment Australia Australian Conservation Foundation - Elizabeth Sullivan	An emissions inventory has been developed for the life cycle of the DPD Project and the Barossa Development, including Scope 1, 2 and 3 emissions (which includes indirect emissions). An overview of the emissions inventory is provided in **Section 10.2.1**.	Atmospheric Processes
+ Santos has stated that its "role in the low-carbon future is built around natural gas, which produces half the GHG emissions of coal when used to generate electricity". Santos also states this fuel is a partner for renewable energy sources. This is misleading based on the peaking nature of power plants which support renewable energy grids.	Bruce Robertson - Institute for Energy Economics and Financial Analysis	In a 2020 National Press Club address titled *"The Orderly Transition to the Electric Plant"*, Australia's former Chief Scientist, Dr Alan Finkel, highlighted the role of natural gas as part of a lower emissions future. In Dr Finkel's address he discusses how natural gas is a suitable dispatchable power source that can support the increasing renewable share of energy supply by managing the intermittency issues of renewable energy. To quote Dr Finkel: "while these (renewable energy) technologies are being scaled up, we need an energy companion today that can react rapidly to changes in solar and wind output. An energy companion that is itself relatively low in emissions, and that only operates when needed. In the short-term, as the Prime Minister and Minister Angus Taylor have previously stated, natural gas will play that critical role."	Atmospheric Processes
+ CCS is a technology with questionable feasibility and a track record for not capturing the volume of GHG emissions proposed or intended. + It is untested in an offshore gas reservoir such as Bayu-Undan. + Santos has no comprehensive plan to capture the very high CO2 content of the Barossa gas (16-20% reservoir gas). + Santos claims CCS can make the gas at Barossa cleaner, this is misleading. + More detail is required from Santos on the CCS project and how this will help reduce CO_2 emissions	Amateur Fisherman's Association of the Norther Territory (AFANT) Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis Jorgen Doyle - Central Australian Frack Free Alliance Australian Services Union Brooke Ah Shay - Doctors for the Environment Australia The Australia Institute Grusha Leeman Julie Fraser – Australian Service Union Julie Fraser	CCS technologies have been in operation since the 1970s and are proven as a large-scale CO_2 storage solution. There are currently more than 20 large-scale CCS projects in operation around the world, storing about 40 million tonnes per year of CO_2 (Global CCS Institute, 2021). The IEA's Executive Director, Fatih Birol, has emphasised that reaching net-zero goals without CCS will be almost impossible. To reach climate goals, the world needs to capture and sequester more than 5.6 billion tonnes of CO_2 globally every year by 2050 (IEA, 2021b). The CCS system is not included in this DPD Project proposal as this is still undergoing technical and economic assessments. Should the CCS system be implemented, the infrastructure within NT jurisdiction will be subject to referral to the NT EPA.	Atmospheric Processes

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	Naish Gawen (on behalf of many) (submissions 18-301) Robin Knox Anonymous (submission 304) Anonymous (submission 305) Anonymous (submission 307) Anonymous (submission 308) Kelly Lee Hickey Australian Parents for Climate Action Darwin and NT - volunteer group Australian Conservation Foundation - Elizabeth Sullivan Dina Rui - Jubilee Australia Research Centre Bruce Robertson - Institute for Energy Economics and Financial Analysis Anonymous (submission 15) Peta Baillie		
+ The successful implementation of CCS may not reduce the overall GHG emissions from extracting and liquefying the natural gas from the Barossa gas field.	Bruce Robertson - Institute for Energy Economics and Financial Analysis Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis The Australia Institute	The CCS system is not included in this DPD Project proposal as this is still undergoing technical and economic assessments. Should the CCS system be implemented, the infrastructure within NT jurisdiction will be subject to referral to the NT EPA.	Atmospheric Processes
+ The environmental, economic or social effects of the CCS system are not defined.	Bruce Robertson - Institute for Energy Economics and Financial Analysis Environment Centre NT (ECNT) The Australia Institute Australian Parents for Climate Action	The CCS system was not included in this DPD Project proposal as this is still undergoing technical and economic assessments. Should the CCS system be implemented, the infrastructure within NT jurisdiction will be subject to referral to the NT EPA.	Atmospheric Processes
+ Request that the community see detailed modelling of how CCS component would work, including cost benefit analysis and risks. What impacts would occur should the climate risks come to bear.	Australian Parents for Climate Action	The CCS system was not included in this DPD Project proposal as this is still undergoing technical and economic assessments. Should the CCS system be implemented, the infrastructure within NT jurisdiction will be subject to referral to the NT EPA.	Atmospheric Processes
+ It is unjust to leave Timor-Leste with carbon pollution along with the uncertainty of how this will be stored and regulated in the future.	Julie Fraser – Australian Service Union	Santos will comply with all relevant regulatory requirements associated with the construction and operation of a CCS system in Timor-Leste and Australia. CCS at the Bayu-Undan field will not commence until all appropriate approvals are in place, including those required by the Timor-Leste Government.	Atmospheric Processes
Other users and the community			

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ The proponent to submit a risk assessment and associated mitigation measures to ensure the Harbourmaster can measure the proponent's acknowledgement of the risks associated with the works impact to marine transport networks and associated port users. A comparative risk analysis including likelihood of occurrence of leakage in the pipeline due to a marine incident and its impact on environment and other port users between alternative pipeline routes and giving consideration to future traffic needs.	Department of Infrastructure, Planning and Logistics – Transport and Civil Services Division	A quantitative risk assessment (QRA) (INTECSEA, 2021) of the pipeline route has been completed to inform protection requirements (i.e. trenching and rock armour) for the DPD Project and provided to DIPL with a peer review undertaken by Royal Haskoning DHV on behalf of DIPL. Following discussions with the Harbour Master on the future growth plans for Darwin Harbour, the QRA was updated with an addendum to reflect additional vessel movements within the Port and the pipeline trench across the Middle Arm Channel was increased in depth and length to accommodate future plans to deepen the channel over a width of 620 m. Key findings from the QRA are as follows: + Based on marine traffic and port management with the harbour, three zones have been highlighted where damage events from external impacts could occur. + The highest risk zone is planned to be trenched with rock installed for protection – KP104 to KP106. + The other zones are at risk from smaller, un-escorted cargo vessel anchor drag events although thorough analysis has shown no loss of containment is credible from external impact based on the pipeline's inherent mechanical integrity. + The QRA assessed current traffic levels within the Harbour as well as future traffic levels associated with port developments. Third-party vessel damage events have the potential to impact all the alternative DPD pipeline routes within Darwin Harbour. The pipeline risk profile and protection design is not impacted by the different route options assessed (i.e., southern, central and northern routes) which all fall within a nominal 250 m corridor. A full assessment of potential impacts to other marine users from DPD Project construction activities within Darwin Harbour has been provided **in Section 11.2.5**. Discussions with DIPL regarding encroachment of the DPD pipeline into the Navigation Channel and the risk of third party damage to the pipeline in these regions are ongoing, along with assessments to locally reroute the pipeline to avoid encroachment into the Navigation Channel (see **Section 3.3**).	Community and Economy
+ The project could put local livelihoods and Australia's fish supply at risk	Dina Rui – Jubilee Australia Research Centre	Santos has continued to engage with AFANT and DITT–- Fisheries Division to further understand popular recreational fishing locations within the Project area and broader surrounds. Santos also notes that there is no commercial fishing within Darwin Harbour. No stakeholder consulted by Santos, including DITT-Fisheries, AFANT and the NT Seafood Council, has suggested the DPD Project would put Australia's fish supply at risk.	Community and Economy
+ The project has potential to impact on the community, tourism and tourism related recreational activities in Darwin harbour and lifestyle, e.g. visual amenity from Mindil Beach markets + Tourism NT recommends the proponent identify and engage with tour operators who may be impacted by the project in the initial discussion stage as well as during the construction stage (pipe laying) to mitigate and minimise the negative impacts on tourism.	Department of Industry, Tourism and Trade Julie Fraser – Australian Services Union Julie Fraser Robin Knox Kelly Lee Hickey Naish Gawen (on behalf of many) (submissions 18-301) Anonymous (submission 307)	The DPD Project is located within a maritime and logistics precinct and will be visible from public recreational places. Additionally, the construction activities will only be primarily occurring adjacent to existing shipping channels in the Darwin Harbour. There is potential for visual amenity to be reduced during construction, however this would be short-term and localised. Santos predicts that vessel movement will not increase more than 5% on an annual basis as a result of the DPD Project (**Section 11.2.5.1.1**) and there will be no significant change to the visual amenity of the Darwin Harbour in the context of existing vessel traffic. Once operational, activities associated with the operation of the pipeline (e.g. routine inspections) will be infrequent. Consultation has occurred with a range of stakeholders including Tourism NT and Top End Tourism, the organisation representing marine-based tour operators in Darwin Harbour, and relevant government agencies. The stakeholders have advised Santos that the main impact will be caused by pipe-lay vessel activities potentially displacing tourism activities for some periods of time. The stakeholders acknowledge that the timeframe and scale of impacts is less in comparison to the Ichthys pipeline vessel-based activities and associated onshore construction activities. They have advised the key requirement of Santos will be to communicate as early in the process as possible, to provide regular communications during the activities and to provide a contact person who can coordinate immediate responses to any issues or concerns raised. Details of this engagement and the planned ongoing communications are in **Appendix 13.**	Community and Economy

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ It is reasonable to suppose that the proposed new spoil area, though smaller in scale [than the previous INPEX spoil ground] may eventually hold value as a fishing location + The proponent may wish to engage with fishers and AFANT to learn more about fishing activities in the borrow and spoil areas proposed. Further plans to better understand project impacts and recovery may also be warranted. Additionally, the INPEX spoil area may be investigated to better understand fish communities and habitat that has been created following the disposal of spoil + The proponent may wish to consider how augmenting the proposed spoil area (or another area) with additional purpose-built reef habitat structures may expedite potential offsets provided to recreational fishers in the form of improved fishing opportunities.	Amateur Fisherman's Association of the Norther Territory (AFANT)	Santos notes AFANT's view that the proposed spoil area may eventually hold value as a fishing location. Santos has consulted further with AFANT, DITT-Fisheries and INPEX on the outcomes beneficial to recreational fishing from the existing adjacent spoil ground created by INPEX for its Ichthys project. Santos' priority is to not cause impacts to those identified benefits. Santos has not committed to augmenting the proposed spoil disposal ground at this stage. As a result of consultation with AFANT on issues raised in its submission, Santos is discussing support for potential future studies into the potential benefits of artificial habitat to fish, including pipeline infrastructure, in the Harbour. Engineered backfill has now been assessed as not required and therefore collection from a designated borrow ground is out of the scope for the DPD Project. Rock will be sourced locally from Mt Bundey quarry, for trench backfill for pipeline protection/stabilisation.	Community and Economy
+ The proponent to submit a Traffic Impact Statement (TIS) to assess the road traffic impacts, to ensure the road authority can measure the proponent's acknowledgement of the risks associated with the works impact on NTG Roads, infrastructure and road safety.	Department of Infrastructure, Planning and Logistics – Transport and Civil Services Division	Impacts to traffic associated with the transport of rock from Mt Bundey to the Project area, as well as movement of equipment and personnel to the Project area has been assessed within a Traffic Impact Assessment (**Appendix 10**). The NT DIPL – Transport and Civil Services Division has received the assessment and advised Santos that it meets their requirements.	Community and Economy
+ CM&C recommends the upcoming assessment and any management conditions should detail workforce composition and how local employment and procurement opportunities will be maximised to satisfy the 'Community and Economy' environmental objectives.	Department of the Chief Minister and Cabinet (CM&C)	Opportunities will be available for the Greater Darwin Region's existing labour force to support construction of the Project. Due to the predominantly offshore nature of activities the impact on social infrastructure and short-term accommodation will be negligible. Information on the economic benefits of the DPD Project to Darwin and the NT and the employment and procurement process to be executed is provided in **Section11.2.4,** in response to the request from CM&C.	Community and Economy
+ The upcoming assessment by the Proponent and any approval conditions and management plans should carefully consider and address any potential economic impacts during the construction phase of the project. In particular, there should be no significant impact on existing commercial and recreational shipping in Darwin harbour, general harbour users and the offshore commercial fisheries in and adjoining the Project area.	Department of the Chief Minister and Cabinet (CM&C)	Since the referral, Santos has further advanced details on vessel requirements for the DPD Project to understand the impact of DPD Project vessels on Darwin Harbour marine traffic and consulted with Darwin Harbour regulators and marine users, including AFANT, tourism groups, the regional Harbour Master and Darwin Port. Refer to **Table 2-5** for details of DPD Project vessel activities and **Section 11.2.5** for related impact assessment. The movements of DPD Project vessels are not considered to significantly add to the annual movements of vessels in and out of the harbour or within the harbour and are considered unlikely to significantly impact existing commercial and recreation shipping movements. Additional vessel traffic associated with the DPD Project falls within the annual port traffic variability seen in the past 10 years (refer to **Section 11.2.5**).	Community and Economy
+ Extraction and processing of natural gas is known to have adverse public health consequences	Brooke Ah Shay – Doctors for the Environment Australia	Santos is required to monitor and assess emissions at DLNG in line with its Environment Protection Licence (EPL) 217-03. There has been no evidence of impacts to human health from the existing Darwin LNG facility and therefore impacts to human health from processing of the Barossa gas at the facility are considered unlikely. Santos will continue to monitor stack emissions (exhaust and GHG emissions) biannually at the facility to industry standard level. Ambient air quality analysis is also undertaken annually using NT EPA air quality data (particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide	Community and Economy

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
		(CO), oxides of nitrogen (NOX, NO and NO_2), sulfur dioxide (SO_2)) measured at Palmerston, Stokes Hill and Winnellie. Management of emissions from gas processing at DLNG will be in accordance with the existing DLNG facility operations, as per the DLNG Operations Environmental Management (OEMP) (DLNG/HSE/PLN/001), under which the facility has operated since 2006. Consequently, there is demonstrated experience mitigating and managing environmental impacts and risks from the processing of natural gas and it is considered unlikely that the DPD Project would result in adverse public health consequences related to processing of natural gas.	
+ No supporting evidence in the referral for how the project will create more jobs i.e., how many jobs, for how long etc. Further social impact assessment is required to determine potential impacts on the Darwin community.	Australian Parents for Climate Action Darwin and NT– volunteer group	Opportunities will be available for the Greater Darwin Region's existing labour force to support construction of the Project. Due to the predominantly offshore nature of activities the impact on social infrastructure and short-term accommodation will be negligible. Further details on employment opportunities and workforce composition are provided in **Section 11.2.4**.	Community and Economy
Cultural and maritime heritage			
+ Potential impacts on cultural heritage including sacred sites in Darwin Harbour perceptions of a healthy harbour, including by recreational fishers + Potential impacts to maritime heritage, such as the many shipwrecks in Darwin Harbour + The referral Document stops short of stating that the proponent will obtain an authority certificate under the Northern Territory Aboriginal Sacred Sites Act. This should be a precondition of any environmental approval.	Environment Centre NT (ECNT) Amateur Fisherman's Association of the Norther Territory (AFANT) Karen Edyvane – Australian National University Naish Gawen (on behalf of many) (submissions 18-301)	The proposed pipeline route has been designed to limit interaction with and impacts to a range of receptors including maritime heritage, other users and existing port and shipping activities (refer to **Section 3**). To increase confidence in the assessment of sensitive receptors, Santos undertook a Maritime Archaeological Heritage Assessment to further identify potential maritime heritage sites within the Project area. The impact assessment was informed by a recent ROV visual survey conducted in June 2022 to ground truth potential cultural sites identified from geophysical surveys. Refer to **Section 11.3.4** for impact assessment related to maritime heritage (including shipwrecks). Santos will continue to engage with AFANT throughout the DPD Project. Refer to **Section 4.5** for further details on Santos ongoing engagement strategy. The cultural value of a healthy harbour for recreational fishing has been acknowledged within **Section 11.3.1**. Santos has received an AAPA Authority Certificate (C2022/098) for the DPD Project and will comply with the conditions of the certificate and with requirements of the NT *Aboriginal Sacred Sites Act 1989* and the *Heritage Act (2011)* (refer **Section 11.3.5**)	Culture and Heritage Community and Economy
+ ECNT is concerned that the environmental factor of "Culture and Heritage" is not addressed in the referral Document.	Environment Centre NT (ECNT)	Culture and Heritage were considered in the referral in Appendix–G–- NT EPA Factors (Considered Not Significant). The factor of Culture and Heritage was not considered by NT EPA to be significantly impacted by the NT EPA DPD Project activities as per their Notice of Decision/Statement of Reasons on the DPD Project referral. Nevertheless, Project impacts to this factor has been further assessed in this SER (refer to **Section 11.3**).	Culture and Heritage
+ Hiscock and Hughes relate that there are significant prehistoric shell mounds throughout Darwin Harbour. Further, recent research indicates that submerged cultural heritage is common in northern Australia, but under threat due to a lack of information about it. + An extensive cultural heritage survey of marine and submerged areas in the vicinity of the pipeline, preferably in partnership with Larrakia people, is required	Environment Centre NT (ECNT)	The Hiscock and Hughes study focuses on 'Haycock Reach', a small portion of the Harbour coastline which demonstrates a rich archaeological record. The DPD Project area does not intersect with the Haycock Reach study area identified in Hiscock and Hughes (2015) and the pipeline route crosses the shoreline within the previously disturbed DLNG facility footprint. A specific assessment of indigenous sacred sites potentially impacted by the DPD Project including a consultation process with relevant traditional owners was conducted by the Aboriginal Areas Protection Authority (AAPA) through its certification process. The process was communicated by Santos to a range of government and indigenous stakeholders, including the Wickham Point Deed Reference Group, the Northern Land Council and Larrakia Nation. Further detail of this consultation is provided in **Appendix 13**. Santos has received an AAPA Authority Certificate (C2022/098) for the DPD Project and will comply with the conditions of the certificate and with requirements of the NT *Aboriginal Sacred Sites Act 1989* and the *Heritage Act (2011)*.	Culture and Heritage
+ The proponent is required to engage a maritime archaeologist to review remote sensing data of the project pipeline in order to locate targets that may indicate as yet unidentified Underwater Cultural Heritage.	Department of Territory Families, Housing and Communities – Heritage Branch	To increase confidence in its understanding of the occurrence of potentially sensitive areas, Santos undertook a Maritime Archaeological Heritage Assessment (**Appendix 16**), as per an archaeological scope of works provided by the Department of Territory Families, Housing and Communities – Heritage Branch, to further identify potential maritime archaeological sites within the Project area. The assessment was also informed by a recent marine survey conducted in June 2022 which	Culture and Heritage

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ The pre-referral tool located in the appendix does not appreciate potential impact to significant UCH sites not previously recorded.		included using a ROV to collect visual data of potential heritage sites identified from remote sensing data in the Project area. Refer to **Section 11.3.3** and **Section 11.3.6** for discussion of maritime heritage values and potential impacts. Santos will continue to engage with the Heritage Branch throughout the Project on matters relating to Culture and Heritage.	
+ Two errors in the referral noted by Department of Territory Families, Housing and Communities–- Heritage Branch 1) The Heritage Branch is the NT Heritage Branch, not the NT Heritage Commission and 2) *The Historic Shipwrecks Act* was superseded by the Underwater Cultural Heritage Act.	Department of Territory Families, Housing and Communities–- Heritage Branch	Santos notes the errors in the referral identified and has corrected these in the SER. Refer to **Section 11.3** for further details.	Culture and Heritage
+ The Authority confirms that Santos has engaged with us on this proposal and has lodged an appropriate application for an Authority Certificate (application 202203003). In the application, the pipeline corridor component of the Subject Land in the harbour/sea is about 2 km wide, narrower than this part of the Project area as defined in the referral (~4 km wide). + The Authority notes that the Authority Certificate will only apply to the land/sea within the Subject Land defined in the application. + The Authority considers that if Santos obtains and complies with an Authority Certificate issued to Santos for all activities proposed to be undertaken, then the risk of potential impacts to cultural values associated with sacred sites will be appropriately minimised	Aboriginal Areas Protection Authority (AAPA / the Authority)	Santos acknowledges that the subject land width in the harbour/sea is approximately 2 km as per Authority Certificate (C2022/098). The Project area width of approximately 4 km defined in the referral and this SER is indicative and does not represent a corridor of disturbance to the seabed. Disturbance to seabed as a result of the Project activities is within 1 km from the pipeline route (or within a 2 km wide corridor).	Culture and Heritage
Other considerations			
+ Cumulative Impacts + The referral has not taken into account the cumulative impacts nor assessed the zone of influence to support its impact assessment + Cumulative impacts of underwater noise, air quality and water quality need to be assessed + Cumulative impacts should consider the condition of previously disturbed benthos and the overall dredging/disturbance planned for the harbour, as well as the process of industrialisation occurring within Darwin Harbour.	Department of Environment, Parks and Water Security (DEPWS), including the Flora and Fauna Division Environment Centre NT (ECNT) Amateur Fisherman's Association of the Norther Territory (AFANT) Karen Edyvane – Australian National University Dina Rui – Jubilee Australia Research Centre Anonymous (submission 307)	Santos has been engaging with Proponents of other Darwin Harbour projects that have potential for concurrent or consecutive activities with the DPD Project, including the NT Department of Industry, Planning and Logistics (DIPL), the Commonwealth Department of Defence and INPEX. An overview of projects and existing activities that have the potential to impact cumulatively with the DPD Project is provided in **Section 13.** Santos has committed to working collaboratively with other proponents to address cumulative impacts including the development of a Communications Plan as described in **Section 4.5**. Through its consultation with DIPL, Santos is aware of plans for a harbour-wide dredging strategy and associated working group to facilitate information exchange and coordination between proponents. Santos commits to working within this framework when developed. Details of consultation undertaken with other Darwin Harbour proponents are provided in **Appendix 13**. **Section 13** provides the assessment of cumulative impacts and risks associated with DPD Project activities on EPA Environmental Factors. Further details on these cumulative impacts are presented at the end of each of the key factor sections of the SER.	Marine Environmental Quality Marine Ecosystems Atmospheric Processes Coastal Processes Community and Economy Culture and Heritage
+ The Project is part of the intensified industrialisation of Darwin Harbour, with the transported gas to be used as a feedstock for	Anonymous (submission 305) Naish Gawen (on behalf of many) (submissions 18-301)	Santos has no intentions at this stage to use the gas as feedstock for petrochemical industries.	Not Environmental Factor related

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
petrochemical industries in the harbour. This poses immense environmental, economic, cultural, and health risks for Darwin and surrounding areas and must be considered relevant to any assessment of the Project's impacts.			
+ The Pipeline will have very significant impacts on the three environmental factors identified by Santos in the Referral Document, namely Coastal Processes, Marine Environmental Quality and Marine Ecosystems	Environment Centre NT (ECNT)	Impacts from the construction and operation of the DPD Project pipeline to Coastal Processes, Marine Environmental Quality and Marine Ecosystems have been further assessed within the SER and presented within **Section 11.1.6**, **Section 8.7** and **Section 9.7**, respectively. Impacts from planned activities have been assessed as Negligible to Minor using the impact assessment process outlined in **Section 7.4**	Marine Environmental Quality Marine Ecosystems Coastal Processes
+ Onshore Impacts + The Flora and Fauna Division of DEPWS agrees with the proponent's assessment that construction activities will occur within cleared and disturbed lands within the existing Darwin LNG facility disturbance envelope and therefore the construction and operation has a low risk to biodiversity and environmental values.	Department of Environment, Parks and Water Security (DEPWS)	Santos acknowledges this submission from DEPWS Flora and Fauna Division.	Terrestrial Ecosystems Terrestrial Environmental Quality Refer to Onshore CEMP.
+ Concerns that insufficient information has been provided to assess the risks to land based transport networks. DIPL request that Santos submits a Traffic Impact Statement (TIS) to assess the road traffic impacts, to ensure the road authority can measure the proponent's acknowledgement of the risks associated with the works impact on NT Roads, infrastructure and road safety. The assessment should include: + Details on what materials will be transported and their loads, traffic volumes and types of vehicles used for the transportation including the haulage routes and duration of the haulage operation specific to onshore movements (i.e. impact at a local and regional level).	Department of Infrastructure, Planning and Logistics – Lands and planning Department of Infrastructure, Planning and Logistics – Transport and Civil Services Division	Impacts to traffic associated with the transport of rock from Mt Bundey to the Project area, as well as movement of equipment and personnel to the Project area has been assessed within a Traffic Impact Assessment (**Appendix 10**). The NT DIPL - Transport and Civil Services Division has received the assessment and advised Santos that it meets their requirements.	Community and Economy
+ Suggest that Santos is encouraged to contact DIPL to discuss planning requirements as further approvals may be required and prior to finalising the alignment of the pipeline in order to ensure it is optimally located in the context of other infrastructure within Darwin Harbour.	DIPL – Lands and planning, DIPL – Transport and Civil Services Division	Consultation with DIPL and Darwin Port on the alignment of the pipeline within Darwin Harbour and NT Waters was first initiated by Santos in August 2021 prior to submittal of the referral. Consultation has continued throughout the SER preparation period and shall continue into the construction and operation phase. Consultation with DIPL includes consideration of future developments at Middle Arm with adjustments made to the pipeline route and trench design to accommodate future traffic and potential DIPL dredging activities in the Middle Arm channel. Details of the consultation undertaken are provided in **Appendix 13**. Details of the final pipeline route selection and optimisation process is provided in **Section 3**.	Community and Economy
+ The NT EPA should have refused the DPD Project referral. + The DPD Project should be assessed at a higher level than a Supplementary Environmental	Environment Centre NT (ECNT) Amateur Fisherman's Association of the Northern Territory (AFANT)	These issues are not within the control of Santos. They are therefore not further discussed within the SER.	

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
Report under the EP Act (e.g. EIS, Public Enquiry). + The whole of the Barossa Development / DLNG Extension should be called in by the NT EPA for referral under the EP Act.	Australian Parents for Climate Action Darwin and NT - volunteer group Australian Conservation Foundation - Elizabeth Sullivan Karen Edyvane - Australian National University Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis Jorgen Doyle - Central Australian Frack Free Alliance Julie Fraser - Australian Services Union Brooke Ah Shay - Doctors for the Environment Australia The Australia Institute Grusha Leeman Julie Fraser – Australian Service Union Julie Fraser Anonymous (submission 14) Anonymous (submission 17) Alice Nagy Naish Gawen (on behalf of many) (submissions 18-301) Robin Knox Anonymous (submission 302) Anonymous (submission 303) Anonymous (submission 304) Anonymous (submission 305) Anonymous (submission 306) Anonymous (submission 307) Anonymous (submission 308) Anonymous (submission 309) Kelly Lee Hickey Dina Rui - Jubilee Australia Research Centre Bruce Robertson - Institute for Energy Economics and Financial Analysis Peta Baillie		

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
Consultation			
+ The stakeholder engagement plan provides a robust list of stakeholders and consultation format undertaken, however, lacks detail regarding the outcomes of the consultation process. The referral contains minimal detail regarding stakeholder feedback and specifically if any concerns were raised including any mitigation strategies. + A register of stakeholder feedback and strategies for addressing any concerns raised should be considered.	Department of the Chief Minister and Cabinet (CM&C)	Additional detail on the consultation undertaken is provided in the Stakeholder Engagement Plan (**Appendix 13)**. To date (prior to submittal of the SER) more than 100 external stakeholder meetings have been conducted. The SER (**Table 5-1**) contains detail regarding stakeholder feedback and specifically if any concerns were raised including any mitigation strategies. Details of ongoing consultation is outlined in the Stakeholder Management Plan (**Appendix 13**). A register of stakeholder feedback and attempts made to address issues and concerns is used by Santos.	Not Environmental Factor related
+ The extent of community engagement that has occurred in relation to the Pipeline is minimal and key stakeholders have not been properly engaged, including considering capacity of communities and individuals to access and understand information about the project and its impacts not adequately addressed in the referral + There has been poor consultation with Traditional Owners including the Tiwi Islanders and Larrakia	Environment Centre NT (ECNT) Australian Parents for Climate Action Darwin and NT – volunteer group Dina Rui – Jubilee Australia Research Centre	Additional detail on the consultation undertaken is provided in **Appendix 13**. To date (prior to submittal of the SER) more than 100 external stakeholder meetings have been conducted including Indigenous organisations and reference groups including the Wickham Point Deed Reference Group, Larrakia Nation, the Aboriginal Areas Planning Authority, the Northern Land Council and the Tiwi Land Council. A register of stakeholder feedback and strategies for addressing any concerns raised is used by Santos. The referral was subject to a public comment period and the information has been fully available on the NT EPA website since April 2022. The SER is also available on the NT-EPA website and will be subject to a further public comment period. This section of the SER (**Section 5**) contains detail regarding stakeholder feedback and specifically if any concerns were raised including any mitigation strategies. Details of ongoing consultation is outlined in the Stakeholder Management Plan (**Appendix 13**). Santos also provides notification to the stakeholders on its database when information is publicly available via the NT EPA website and public comment periods commence. The information continues to be available on the website following the closure of the public comment period.	Not Environmental Factor related
+ The proponent may wish to engage with fishers and AFANT to learn more about fishing activities in the spoil area proposed.	AFANT	Consultation with AFANT and DITT-Fisheries has included discussion related to the proposed spoil area. Santos notes AFANT's view that the proposed spoil area may eventually hold value as a fishing location. Santos has consulted further with AFANT, DITT-Fisheries and INPEX on the outcomes beneficial to recreational fishing from the existing adjacent spoil ground created by INPEX for its Ichthys project. Santos' priority is to not cause impacts to those identified benefits. Santos has not committed to augmenting the proposed spoil disposal ground at this stage. As a result of consultation with AFANT on issues raised in its submission, Santos is discussing support for a potential study into the benefits of artificial habitat structures as fish habitat, including pipeline infrastructure, in Darwin Harbour.	Not Environmental Factor related
+ The proponent is encouraged to contact DIPL (Development Assessment Services) at its earliest opportunity to discuss planning requirements as further approvals may be required.	DIPL – Lands and planning	Santos has contacted relevant sections of DIPL and sought advice relevant to secondary approvals required under planning legislation. Additional detail on the consultation undertaken is provided in **Appendix 13.**	Not Environmental Factor related

Santos

6 Matters of National Environmental Significance

A DPD Project referral under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) was lodged and subsequently determined to be a Controlled Action by the Department of Climate Change, Energy, Environment and Water (DCCEEW)on 6 December 2022 (EPBC 2022/09372). Further information was requested under section 95A(2) of the EPBC Act on 23 December 2022.

It was determined that the DPD Project may have a significant impact on the following controlling provisions under the EPBC Act and is to be assessed via Preliminary Documentation:

+ Listed threatened species and communities (sections 18 & 18A)
+ Listed migratory species (sections 20 & 20A)
+ Commonwealth marine areas (sections 23 & 24A)

The Preliminary Documentation is currently being prepared for submission to DCCEEW.

7 Environmental Impact and Risk Assessment

7.1 Regulatory assessment

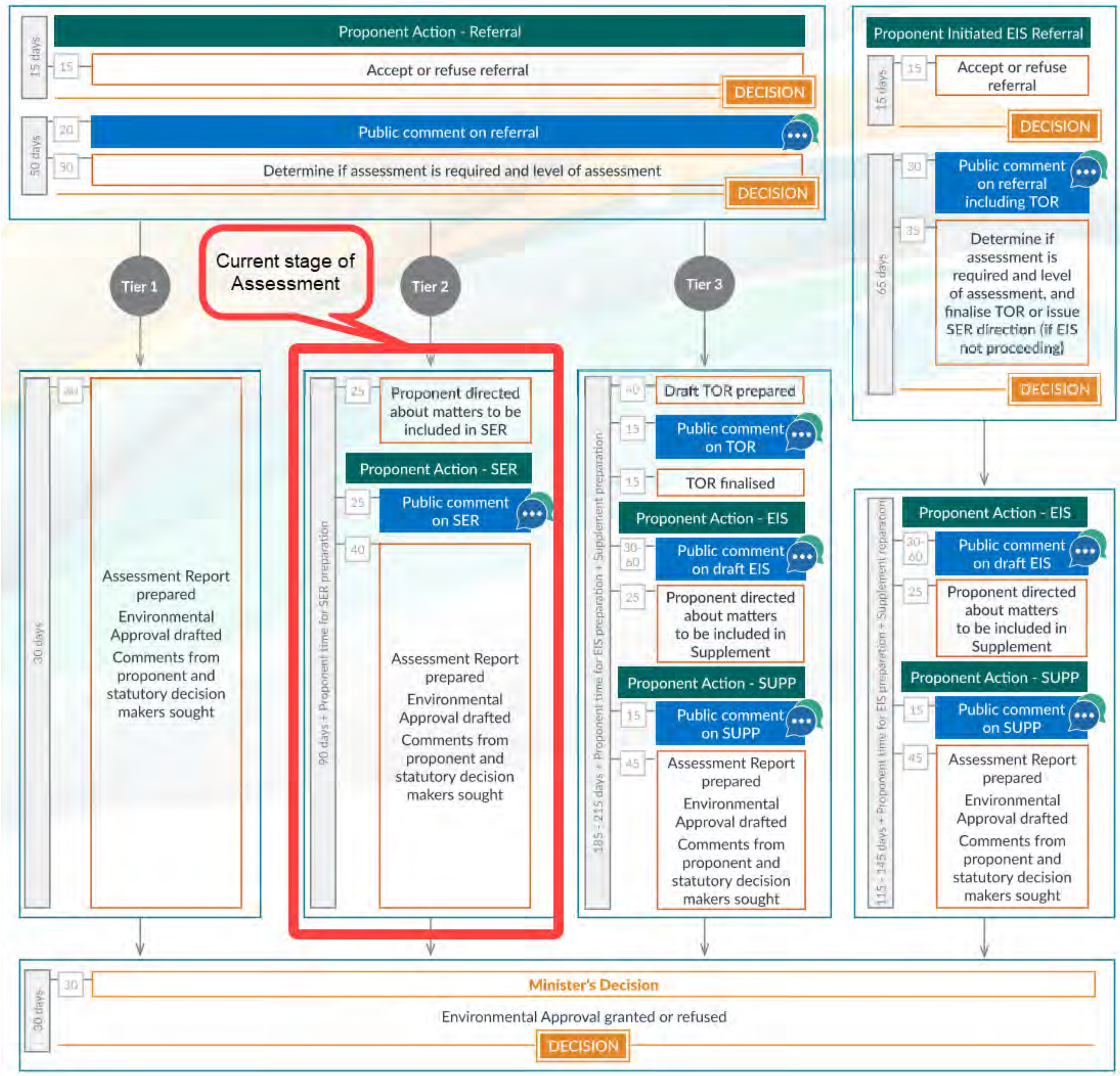
The DPD Project is being formally assessed under the NT EP Act and the Commonwealth EPBC Act (refer **Section 1.2**) Under the NT EPA Act the Project requires formal assessment through a Supplementary Environmental Report (SER) (Tier 2 assessment) (**Figure 7-1**).

This SER includes an environmental impact and risk assessment for the DPD Project, which builds on that provided in the referral, and covers the key environmental factors of Marine Environmental Quality, Marine Ecosystems and Atmospheric Processes, as required by the NT EPA within their Notice of Decision and Statement of Reasons for the DPD Project. The impact and risk assessment covers additional information requirements as requested by the NT EPA on 12 January 2023 (**Table 1-1**) and also, where relevant, covers key issues raised through submissions on the referral by government departments and the public (**Table 5-1**). The impact and risk assessment also considers new information and studies, where relevant, that have been undertaken by Santos for the purpose of better defining Project impacts and risks. In addition to the three environmental factors raised by the NT EPA through their Notice of Decision and Statement of Reasons on the DPD Project, additional NT EPA environmental factors have been included, in order to demonstrate relevant issues raised by government departments and the public have been assessed. The level of detail included in the impact and risk assessment sections is considered commensurate to the level of impact and risk being described.

In accordance with the guidance for preparing an SER (NT EPA, 2021b), a risk assessment has been developed for the DPD Project. The impact and risk assessment framework as described in **Section 7.4** has been used to identify and assess the potential impacts and risks associated with the DPD Project and has informed the development of management measures detailed in the SER and within Environmental Management Plans located within the Appendices.

The NT EPA (NT EPA, 2021c) defines cumulative impacts as 'impacts that can accumulate as a result of additive or interactive processes and actions, interactions among multiple management measures (past, present and future), a combination of multiple minor impacts over time, and activities conducted over a wider area than the proposed action, such as the activities of multiple projects operating in a region.'

The SER considers cumulative impacts from the DPD Project and other projects and/or activities by identifying the potential for compounding effects from other projects or reasonably foreseeable activities that are either proposed or currently under development. **Section 7.5** describes the cumulative impacts assessment process.



Key
Tier 1 - Assessment on Referral Information
Tier 2 - Assessment by Supplementary Environmental Report (SER)
Tier 3 - Assessment by Environmental Impact Statement (EIS)
TOR - Terms of Reference
SUPP - Supplement

Notes
Documentation is published at each stage of the assessment process
Reasons for decision are also published at each decision point
All timeframes are expressed as business days
Public Comment - period may be extended in consultation with the proponent
Range of 30-60 business days (determined by NT EPA) applies to public comment on draft EIS

Figure 7-1 NT EP Act environmental approvals flowchart showing DPD Project position

7.2 Environmental factors

The NT EPA considers that the DPD Project has the potential to have a significant impact on environmental values associated with Marine Environmental Quality (**Section 8**), Marine Ecosystems (**Section 9**) and Atmospheric Processes (**Section 10**). The NT EPA considered other environmental factors during its consideration of the referral, however, the impact on those factors was not considered to be significant.

The SER considers each of the relevant environmental factors and how these interact and connect both indirectly and cumulatively as relevant to the DPD Project. Other environmental factors raised by public and/or NT Government submissions, and considered relevant for further assessment, are addressed in **Section 11** and include Coastal Processes, Community and Economy and Culture and Heritage factors.

7.3 Additional studies

Since the referral was submitted, additional studies have been undertaken to further understand the baseline environment and assess the significance of potential impacts from the DPD Project. The additional work undertaken is described in **Table 7-1**.

Table 7-1 Additional studies undertaken since the referral

Study	Description / Summary of study
Maritime Heritage Assessment	Santos commissioned Cosmos Archaeology to undertake a maritime heritage assessment of the DPD Project area following a scope of works provided by the NT Department of Territory Families, Housing and Communities–- Heritage Branch. An initial assessment was conducted using desktop information and geophysical, MBES, side scan sonar (SSS) and magnetometer survey data collected by Santos. Santos commissioned a targeted ROV survey (based on initial desktop data assessment) which was completed by Cosmos Archaeology to visually inspect targets with potential cultural heritage significance. Refer to **Appendix 16** for the Maritime Heritage Assessment report which documents the findings of the surveys and assessment and subsequent recommendations. The report was presented to the Heritage Branch on 20 December 2022

Study	Description / Summary of study
Baseline Habitat Assessment	Baseline surveys were completed in October 2021, January 2022 and June 2022 by environmental consultancy RPS to collect data on marine water quality, sediment quality and composition (including contaminant concentrations), macroinvertebrate (infaunal) assemblages and benthic habitats, along the DPD Project pipeline route and spoil ground location. The survey results have been used to inform the environmental values and impact assessment sections presented in this SER (refer to **Section 8** (Marine Environmental Quality) and **Section 9** (Marine Ecosystems)). The survey conducted in June 2022 (ROV survey) was used to expand the benthic habitat survey data along the proposed pipeline route (including within the Charles Point Wide Reef Fish Protection Area), ground truth areas of potential sensitive habitat adjacent to the pipeline route (as predicted by AIMS 2021 and 2019 habitat mapping) and ground truth potential heritage items identified from a maritime archaeologist assessment of remote sensing data. Refer to **Appendix 6** for the benthic survey report.
Turtle Nesting and Lighting Impact Desktop Assessment	A desktop assessment was undertaken by Pendoley Environmental, marine turtle subject matter experts, to determine the presence and significance of marine turtle nesting activity on beaches within and surrounding Darwin Harbour (**Appendix 14**). The technical note considers regional marine turtle nesting and assesses the likely level of impact the DPD Project vessel lighting will have on the Arafura Sea genetic stock of flatback turtles (*Natator depressus*). A summary of the importance of turtle nesting beaches is provided in **Section 9.4.6**. Findings of the lighting assessment are summarised in **Section 9.5.3**.
Traffic Impact Assessment	Santos engaged the consultancy AECOM to complete a Traffic Impact Assessment (TIA) in accordance with requirements from DIPL. AECOM engaged with DIPL Transport and Civil Services Department during preparation of the TIA. Refer to **Appendix 10** for the assessment.

Study	Description / Summary of study
Sediment Dispersion Modelling	Sediment dispersion modelling of the trenching and spoil disposal activities associated with the DPD Project was completed by RPS to quantify the potential magnitude, intensity and spatial distribution of suspended sediment concentrations (SSC) and sedimentation that would be expected. Outcomes of the modelling study have informed the potential field of effect on water quality and benthic habitats, resulting from the release of sediments during trenching and spoil disposal activities. The sediment dispersion modelling simulations were conducted using hydrodynamic and wave data drawn from the 2019-2020 period, with nominal start dates for model simulation purposes being chosen as 1 April 2019 (winter/dry) and 1 October 2019 (summer/wet). A total of eight scenarios were modelled. In response to an expert review of the modelling completed by AIMS, additional modelling and assessment (including a spoil ground stability assessment) was conducted. Refer to **Appendix 3** for the full sediment dispersion modelling report. The modelling report includes an appendix detailing how comments from AIMS expert review report have been addressed in the final version of the report.
Underwater Noise Modelling	Underwater noise modelling has been completed by specialist underwater noise modelling consultancies Talis Consultants and JASCO Applied Sciences to model predicted underwater noise levels from construction activities. The focus of the study was trenching activities by trenching vessels, including rock breaking, as this was identified as the most significant sources of underwater noise for the DPD Project. Four noise source locations in Darwin Harbour including six scenarios were modelled as described in **Section 9.5.2.** The study looked at temporary threshold shift (TTS), permanent threshold shift (PTS) and behavioural effect thresholds of marine fauna for each of the modelled scenarios to determine if exceedances were predicted. Refer to **Appendix 8** and **Appendix 9** for the full underwater noise modelling reports.
Treated Seawater Modelling	Treated seawater modelling was completed by RPS to determine the potential impacts and area of exposure from the discharge of treated seawater if an unplanned 'wet buckle' event was to occur and if dewatering of treated seawater was required within the Project area. Both pipeline over filling (overflow) and dewatering scenarios were considered for three locations (two within Darwin Harbour) and both near-field and far-field modelling results over 12 hr, 24 hr and 48 hr exposure periods were completed. The extent and area of predicted exposure of the discharge were reported against established No Observable Effect Concentrations (NOECs) and calculated species protection levels (refer to **Section 8.5.2)**. Refer to **Appendix 5** for the full treated seawater modelling report.

Study	Description / Summary of study
Hydrocarbon Spill Modelling	Hydrocarbon spill modelling was undertaken by RPS to determine potential environmental impacts in the unlikely event of a vessel-based spill during Project activities. The following four scenarios were considered: + Scenario 1 – An offshore pipelay vessel fuel tank rupture at KP91.5 resulting in the release of 700 m^3 of marine diesel oil (MDO) on the surface over 6 hours; + Scenario 2 – A vessel fuel tank rupture at KP114 resulting in the release of 87.5 m^3 MDO on the surface over 6 hours; + Scenario 3 – An instantaneous surface spill of 10 m^3 of MDO due to a vessel to vessel refuelling incident within the harbour at KP114; and + Scenario 4 – A vessel fuel tank rupture at KP114 resulting in the release of 300 m^3 of MDO on the surface over 6 hours. The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for wet (November to April) and dry (May to October) seasons. A summary of the modelling approach is provided in **Section 8.5.5** with the full report provided in **Appendix 15**.

7.4 Environmental impact and risk assessment methodology

7.4.1 Overview

In accordance with Table 1 of the NT EPA *Preparing a supplementary environmental report (SER) Environmental Impact Assessment Guidance for Proponents* (Rev1) (NT EPA, 2021d), the impact and risk assessment framework for the Project was developed and implemented in accordance with international best practice standard methodologies including:

+ Australian/New Zealand Standards (AS/NZS) ISO 31000:–018 - Risk management— Principles and guidelines (Standard); and
+ HB 203:2006: Environmental risk management — Principles and process (Guide).

This impact and risk assessment was also developed with consideration of the NT EPA Environmental Factors and Objectives (NT EPA 2021b), with the aim of identifying and assessing the environmental aspects and potential impacts and risks for DPD Project activities during all work phases associated with construction, pre-commissioning and operation.

7.4.2 Santos environmental impact and risk assessment process

Santos' environmental impact and risk assessment process sets out a method to:

+ Identify the potential environmental impacts of key Project activities (planned and unplanned events);
+ Identify and evaluate the likelihood and consequence of the environmental impacts from planned (consequence only) and unplanned events identified to determine the inherent risk with standard mitigation (e.g. statutory compliance);
+ Identify avoidance and mitigation measures to avoid or reduce impacts and risks to a level that is acceptable and as low as reasonably practicable; and

- Determine the residual level of risk after application of management measures and controls.

The assessment of impacts and risks requires a level of understanding of the nature of activities and how they may interact with the environment, and examines the causal effect between the aspect (e.g. hazard) and the identified receptor. Impact mechanisms and impacts are determined and described, using scientific literature and modelling where required.

The consequence level of the impact is then determined for each aspect using the NT EPA Factors relevant to the SER including:

- Marine Environmental Quality;
- Marine Ecosystems;
- Atmospheric Processes;
- Coastal Processes;
- Community and Economy; and
- Culture and Heritage.

The level of information required to complete the impact or risk assessment depends on the nature and scale of the impact or risk. This process determines a consequence level based on set criteria for each receptor category and considers the duration and extent of the impact, receptor recovery time and the effect of the impact at a species' population, ecosystem or industry level. Impacts to social and economic values are also considered based on existing knowledge and feedback from stakeholder consultation. As the result of consultation with stakeholders, the social and economic values in the region that are of interest are considered.

As planned events are expected to occur during the activity, the likelihood of their occurrence is not considered during the risk assessment, and only a consequence level (**Table 7-3**) is assigned.

For unplanned events, the consequence level (**Table 7-3**) of the impact is combined with the likelihood of the impact occurring (**Table 7-2**), to determine a residual risk ranking using Santos' corporate risk matrix (**Table 7-4**).

Inherent risks were determined by ranking the likelihood and consequence of the impact with only industry standard mitigation measures and controls, giving a worst-case scenario outcome. Avoidance and mitigation measures were established for inherent risks to minimise the risk as far as practicable. Avoidance and mitigation measures were developed with reference to environmental guidelines, professional and/ or academic experience of technical specialists engaged to work on the SER and supporting studies, and personnel designing and developing the DPD Project. A summary of residual impacts and risks, following application of avoidance and mitigation measures is provided at the end of each NT EPA environmental factor section of the SER. A summary of all avoidance and mitigation measures applicable to the DPD Project is provided in **Section 12**.

Table 7-2 Likelihood description

No.	Matrix	Description
F	Almost Certain	Occurs in almost all circumstances OR could occur within days to weeks
E	Likely	Occurs in most circumstances OR could occur within weeks to months
D	Occasional	Has occurred before in Santos OR could occur within months to years
C	Possible	Has occurred before in the industry OR could occur within the next few years
B	Unlikely	Has occurred elsewhere OR could occur within decades
A	Remote	Requires exceptional circumstances and is unlikely even in the long term

Santos

Table 7-3 Consequence categories adopted in the risk assessment

Consequence Level		I	II	III	IV	V	VI
Acceptability		Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Consequence Level Description		**Negligible** No impact of negligible impact	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors Localised effect	**Moderate** Significant impact to local population industry or ecosystem factors	**Major** Major long-term effect on local population industry or ecosystem factors	**Severe** Complete loss of local population industry or ecosystem factors AND/OR extensive regional impacts with slow recovery	**Critical** Irreversible impacts to regional population industry or ecosystem factors
Environmental Receptors	**Marine Ecosystems** Fauna, habitat, conservation significant areas and ecological function, processes and integrity	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of habitat critical / disruption to the breeding cycle/ vales of a protected area. No introduction of disease and no reduction in habitat area/function.	Detectable but insignificant decrease in local population size and threat to local population viability. Insignificant disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area. Detectable but insignificant loss of area/function of habitat with rapid recovery within 2 years.	Moderate. Significant decrease in local population size but no threat to overall population viability. Significant behavioural disruption or disruption to the breeding cycle of local population / Significant reduction in area of occupancy of species / loss of habitat critical to survival of a species. Modify, destroy, remove or decrease availability of quality habitat to the extent that a long-term decline in local population or function of habitat is likely with recovery over medium term (2-10 years) Introduction of disease likely to cause significant population decline	Long term decrease in local population size and threat to local population viability. Major disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area Fragmentation of existing population / Loss or change of habitat to the extent that a long-term decline in local population and function of habitat is likely with slow recovery over decades Introduction of disease likely to cause long term population decline	Complete loss of local population, habitat critical to survival of local population or protected area/conservation significant area Widespread (regional) decline in population size or habitat critical to regional population Extensive destruction of local habitat with no recovery or long term (decades) or widespread loss of area or function of primary producers on a regional scale	Complete loss of regional population Complete loss of habitat critical to survival of regional population
	Marine Environmental Quality Water quality, sediment quality, ecosystem health and parameters that support fishing, aquaculture, recreation, aesthetics and cultural/spiritual values	Negligible. No or negligible reduction in physical environment nor decrease in ecosystem function/health. No or negligible loss of value to socio-economic activities	Detectable but localised, short term and insignificant impact to physical environment or ecosystem function/health or value to socio-economic activities. Rapid recovery evident within ~ 2 years.	Significant wide-scale medium term impact to physical environment, decrease in ecosystem function/health or value to socio-economic activities. Recovery over medium term (2-10 years).	Wide-scale, long term impact to physical environment, long term decrease in ecosystem function/health or value to socio-economic activities. Slow recovery over decades.	Extensive impact to/destruction of physical environment with no recovery or shutdown of socio-economic activities Long term (decades) and widespread loss of ecosystem function/health on a regional scale that damages value to socio-economic activities.	Complete destruction of regional physical environment / habitat with no recovery Complete loss of area or function of primary producers on a regional scale

Consequence Level		I	II	III	IV	V	VI
	Coastal Processes Geophysical processes, primary productivity/ nutrient cycling, conservation significant areas/coastal landforms and cultural, aesthetic or recreation values	Short term changes to local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale	Detectable but insignificant loss or change to local geophysical/hydrological processes, area or function of primary producers/nutrient cycling or conservation significant areas with rapid recovery within 2 years.	Moderate. Significant modification, destruction, removal or change of local geophysical/hydrological processes, wide-scale loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with recovery over medium term (2-10 years).	Long term loss or change of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with slow recovery over decades	Extensive destruction of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with no recovery or long term (decades)	Complete loss or change of geophysical/hydrological processes. Complete loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale.
	Community and Economy Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping	No or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry. Significant medium-term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry. Permanent loss of key natural features or populations supporting the local industry.	Permanent shutdown of local or regional industry Permanent loss of key natural features or populations supporting the local or regional industry
	Culture and heritage Includes: Indigenous heritage and maritime heritage (i.e. shipwrecks)	No or negligible impact on the area's cultural or heritage values. No or negligible alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Detectable but insignificant impact on one or more of the area's cultural or heritage values. Detectable but insignificant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Significant impact on one or more of the area's cultural or heritage values. Significant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Major long-term effect on one or more of the area's cultural or heritage values. Major alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Complete loss of one or more of the area's cultural or heritage values.	Permanent loss of one or more of the area's cultural or heritage values with no recovery.

Table 7-4 Santos' Risk matrix

		Consequence					
		I	II	III	IV	V	VI
Likelihood	F	Low	Medium	High	Very High	Very High	Very High
	E	Low	Medium	High	High	Very High	Very High
	D	Low	Low	Medium	High	High	Very High
	C	Very Low	Low	Low	Medium	High	Very High
	B	Very Low	Very Low	Low	Low	Medium	High
	A	Very Low	Very Low	Very Low	Low	Medium	Medium

7.5 Cumulative impact assessment

In accordance with the NT EPA Environmental Impact Assessment Guidance for Proponents (NT EPA 2021a), the impact assessment has identified and considered potential cumulative impacts from the Project and other activities at varying spatial extents from the Project. The objective of the assessment is to identify the potential for the Project to have compounding or additive effects with similar impacts from other projects or foreseeable activities that are either proposed or currently under development.

Cumulative impact may be described as the total impact on environmental factors that is caused from the proposed Project activities in conjunction with past and future activities. These are impacts of the action when combined with the impacts of other (related and unrelated) actions.

7.5.1 Cumulative assessment methodology

This section provides an overview of the methodology adopted for assessing the Project's potential cumulative impacts. Cumulative impacts can include:

+ Environmental changes including effects on the marine environment, water quality, hydrology and biodiversity;
+ Impacts on local, regional and Territory traffic, transport, vessels and road users; and
+ Changes to local and regional amenity, including noise, vibration and air quality.

The following methodology was applied to assess cumulative impacts, as described further in the key environmental factor sections:

+ Identify the impacts of the Project on baseline conditions (as detailed in the key environmental impact sections and technical reports);
+ Identify significant additional projects proposed:

- Onshore: within a 25 km radius from the Project; [1]or
- Offshore: within the Darwin Harbour or within a 25 km radius from the Project; and

+ Screen significant additional projects (located >25 km radius from the Project) to identify those with the greatest potential to interact (on a temporal basis) cumulatively with the DPD Project.

The identified projects and assessment of cumulative impacts is discussed in **Section 13**.

[1] A 25 km radius has been selected for as the range to assess cumulative impacts from the DPD Project, based on 25 km being used by Santos in the past and is thought to encompass the furthest potential extent of effects from the DPD Project and other project for assessment of direct and indirect cumulative impacts.

8 Marine Environmental Quality

This section provides further assessment of DPD Project impacts and risks to the NT EPA environmental factor of Marine Environmental Quality since the referral submission. It addresses relevant additional information requirements requested by the NT EPA and submissions received on the referral from government departments and the public, using additional data and studies, conducted since the original submission of the referral.

8.1 Environmental objective

The NT EPA environmental objective for Marine Environmental Quality is to protect the quality and productivity of water, sediment, and biota so that environmental values are maintained.

8.2 Additional information required

As described in **Table 1-1**, the NT EPA requested additional information to further understand the magnitude of potential impacts on Marine Environmental Quality and the effectiveness of environmental management and mitigation measures, specifically:

+ Provide interpreted outcomes of proposal-specific sediment dispersion/plume modelling;
+ Revise the impact assessment for sedimentation in the context of:
  - Proposal-specific data,
  - Sediment dispersion/plume modelling outputs, and
  - Updated habitat data.
+ Provide a draft DSDMP for sub-sea trenching activities, including:
  - A survey program to establish the baseline (pre-construction) condition of habitats within the zone of influence of the proposal (as required above) and relevant parameters to be monitored to detect impacts;
  - Quantitative trigger levels for relevant parameters (and description of their derivation) corresponding to investigative and/or adaptive management actions that must be taken in the event that monitoring indicates trenching/dredging activities are likely to impact sensitive receptors;
  - Quantitative limit values relevant parameters (and description of their derivation) corresponding to stop work, recommencement and/or investigative actions if sensitive receptor monitoring results exceed limit values;
+ Provide details of any infrastructure required for construction of the pipeline at the shore crossing;
+ Identify and map potential impacts (including cumulative impacts) and proposed measures that would be applied to ensure construction impacts are not significant;
+ Demonstrate how Marine Environmental Quality would be protected in the event of discharge of hydrotest water in NT waters;

+ Demonstrate that any discharge of hydrotest waters in Commonwealth waters would not cause an exceedance of the 99% species protection level in any NT waters e.g. if a discharge were to be near the jurisdiction boundary; and
+ Describe the proposed mitigation measures to manage potential impacts of hydrostatic test water discharges to the marine environment. Include detail about hydrostatic test water discharge characterisation, dispersion modelling, physical and toxicity impacts, marine fauna impacts, chemical selection and dosing, discharge volume and rate, and criteria for toxicant concentrations in discharge water. Include consideration of how the 99% species protection concentration (ANZG) would be met for high conservation ecosystems or chemicals that have a tendency to bioaccumulate; and
+ The monitoring program for the DSDMP (referred to as a TSDMMP) must provide for the assessment of cumulative impacts for trenching/dredging and spoil disposal, including:
  - A communications strategy for engaging with government authorities and other proponents undertaking or proposing to undertake dredging in the harbour; and
  - A proposed approach to managing dredging in coordination with other proponents/dredging projects to avoid significant cumulative impacts to Darwin Harbour from dredging activities.

Interpreted sediment dispersion modelling results are presented in **Section 8.5.1** with the modelling report presented in **Appendix 3**. The TSDMMP for managing trenching and spoil disposal activities is provided in **Appendix 4**. Details of infrastructure to support trenching and pipeline construction at the shore crossing is provided in **Section 2.3.4** and impact assessed in **Section 9.5.1.5**. Contingency treated seawater discharge modelling and impact assessment is presented in **Section 8.5.2** with the modelling report provided in **Appendix 5**.

8.3 Legislation, policy, and guidance

The following Commonwealth and NT legislation and other policies and guidance documentation apply to the Project.

Commonwealth

+ *Environment Protection and Biodiversity Conservation Act 1999.*

Northern Territory

+ *Waste Management and Pollution Control Act 1998*
+ *Environment Protection Act 2019*
+ *Water Act 1992*
+ *Waste Management and Pollution Control Act 1998*
+ *Marine Pollution Act 1999*

Other Relevant Policies and Guidelines

+ NT EPA Environmental Factors and objectives: Environmental impact assessment general technical guidance (NT EPA, 2021c);

- Anthropogenic Pressures on Darwin Harbour: An IMMRP Monitoring Plan (Version 1). Technical Report No. 11/2020 (Radke and Fortune, 2020);
- Guidelines for the environmental assessment of marine dredging in the Northern Territory (NT EPA, 2013);
- Darwin Harbour Strategy (DHAC, 2020);
- Darwin Harbour Water Quality Protection Plan (DLRM, 2014);
- National Assessment Guidelines for Dredging 2009 (DEWHA 2009).
- ANZECC/ARMCANZ Sediment Quality Guidelines (Simpson et al. 2019);
- National Acid Sulfate Soils Guidance: Guidelines for the dredging of acid sulfate soil sediments and associated trenching dredge spoil management (Simpson et al. 2018);
- Australian Ballast Water Management Requirements 2001 (DAWE 2020); and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018).

8.4 Environmental values

This section provides additional information on existing environmental values within the Project area, including for some which were not included in the referral. Further studies on water and sediment quality have been undertaken after the submission of the referral with the results included in the SER to confirm the existing environmental values within and surrounding the Project area. The following studies have been reviewed and findings included in the SER:

- Environmental Referral Report – New Marine Facilities to Service Mandorah and Cox Peninsula (Cardno, 2022a);
- Santos Barossa DPD- Pipeline Benthic Survey Report (RPS 2022a) (full report provided in **Appendix 6**).

A summary of the findings of these studies is provided in the following subsections.

8.4.1 Water quality

Santos Barossa DPD- Pipeline Benthic Survey Report RPS (2022a, see **Appendix 6**) conducted water column profiling and collected water samples in November 2021 from different sampling locations along the pipeline footprint, as identified in **Figure 8-1**. Water samples were analysed for the parameters identified in Table 8-1 and water column profile recorded the following parameters:

- Pressure (to derive depth);
- Conductivity (to derive salinity);
- Temperature;
- pH;
- Dissolved oxygen; and
- Turbidity.

Table 8-1 Water Quality Sampling Parameters

Analyte	Sample # (Spoil Ground)	Sample # (Offshore)	Total Samples
Total Suspended Solids (TSS)	14	20	34
Nutrients (TP and TN)	14	20	34
Orthophosphate (PO_4^{-3})	14	20	34
Nitrite and nitrate (NO_2 and NO_3)	14	20	34
Ammonium (NH_4^+)	14	20	34
Phytoplankton pigments (Chlorophyll-a and Phaeophytin-a)	14	20	34
Unfiltered Metals and metalloids (As, Ca, Cr, Co, Cu, Pb, Ni, Zn)	14	20	34
Unfiltered Hg	14	20	34
Filtered Metals and metalloids (As, Ca, Cr, Co, Cu, Hg, Pb, Ni, Zn)	14	20	34
Filtered Hg	14	20	34
TRH and BTEXN	14	20	34
PAH (where TRH above LORs)	0	0	0
NORMs (Ra226, Ra228, Th228)	7	10	17

The sampling identified that water temperature within column profiles along the offshore pipeline route and at the proposed spoil ground was either consistent with depth or decreased slightly with depth. Salinity was either consistent or varied marginally over depth except at the two westernmost offshore pipeline route sites, where an increase in salinity was recorded over the 0 – 10 m depth range. Turbidity at 4 sites along the offshore pipeline route decreased from surface to 15 – 20 m depth, then gradually increased with depth. Elsewhere along the pipeline route, turbidity was either relatively consistent with depth or increased with depth. At the proposed spoil ground turbidity generally increased with depth.

Oxygen levels tended to increase with increasing depth in both study areas except at two sites along the offshore pipeline route. Oxygen levels decreased with depth below 20 m and at one site oxygen levels decreased below ~10 m, then remained fairly consistent at the other site. For pH there was a decrease with depth at the majority of sites along the offshore pipeline route but increased with depth at two sites and at one site was consistent with depth except at ~15 – 20 m and ~35 – >50 m where there was a relatively large drop from 11.5 to 9.5. Overall, the in-situ data indicate that there was no evidence of a halocline or thermocline and showed no indications of stratification of the water column.

Filtered and unfiltered cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni) and mercury (Hg) were generally below the Limit of Reporting (LoR) at both offshore pipeline and spoil ground locations, with the exception of one site, which had filtered Ni and unfiltered Cr concentrations that were above the LoR but well below the relevant guideline values in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018). The filtered and unfiltered arsenic (As) concentrations were very similar in both offshore pipeline and spoil ground samples and were below the relevant ANZG (2018) Default Guideline Value (DGV).

Filtered and unfiltered copper (Cu) concentrations at 3 sites were above the relevant ANZG (2018) DGV. The Cu concentration in 1 sample (OP2S) was much higher than in other samples therefore it is likely that this sample is an outlier and sampled a potential contaminant. Filtered and unfiltered lead (Pb) concentrations ranged from <0.1 to 5.4 µg/L in the offshore pipeline samples but were much lower in the spoil ground samples (<0.1 to 0.4 µg/L). One sample had a filtered Pb concentration above the relevant ANZG (2018) DGV. Unfiltered zinc (Zn) concentrations were at or above the relevant ANZG (2018) DGV of 8 µg/L in two samples, filtered zinc concentrations were at or above the DGV at 6 sites at the western end of the offshore pipeline route (between OP1 and OP5) and across the proposed spoil ground area (sites SG4, SG7 and SG12), with no clear trend in exceedances between surface and bottom waters.

The results of the analysis of metals and metalloids identified DGV exceedances in Cd, Cr, Co, Cu, Ni, Hg and Zn in the surface waters of site OP1, though the source was not identified. OP1 is located approximately 5 km north from the end of the DPD Pipeline.

Nitrite and nitrate were recorded at concentrations at or above LoRs in bottom water samples only, at concentrations of up to 15 µg N/L. DGV in bottom waters is 106.46 µg N/L. Ammonium was detected in 14 samples, with 13 of those being bottom (near seabed) samples and were below the relevant ANZG (2018) DGV. The peak concentration of ammonia was 13 µg N/L at the proposed spoil ground. Total nitrogen concentrations ranged from 80 to 150 µg N/L; 35 samples were at or exceeded the relevant ANZG (2018) DGV. Nineteen orthophosphate (filterable reactive phosphorus) concentrations samples exceeded the relevant ANZG (2018) and total phosphorous concentrations in 35 samples were at or exceeded the relevant ANZG (2018) DGV. Nutrients (nitrogen, phosphorus, and organic carbon) are released in the decay of organic matter, and the increased concentrations of nutrients in near-seabed samples likely correlate with decaying organic matter on the seabed at those locations.

Chlorophyll-a concentrations were used as an indicator of the level of phytoplankton biomass across the offshore pipeline area. Chlorophyll-a concentrations ranged from 0.4 to 1.5 µg/L. All concentrations were below the relevant ANZG (2018) DGV. Phaeophytin-a is a breakdown product of chlorophyll-a and can be used to indicate if phytoplankton are blooming or declining. Phaeophytin-a was only detected in 10 samples of the offshore pipeline sites, the majority of which were surface samples.

TSS concentrations ranged from 1.7 to 8.6 mg/L. There was no correlation between depth and TSS, and no clear difference found in the TSS between surface and bottom samples. There is no ANZG (2018) default guideline value for TSS.

Hydrocarbon concentrations were below LoRs for all samples at all sites. Radium-226 was detected at above LoRs in near-seabed samples at two of the offshore pipeline sites but none at the spoil ground sites.

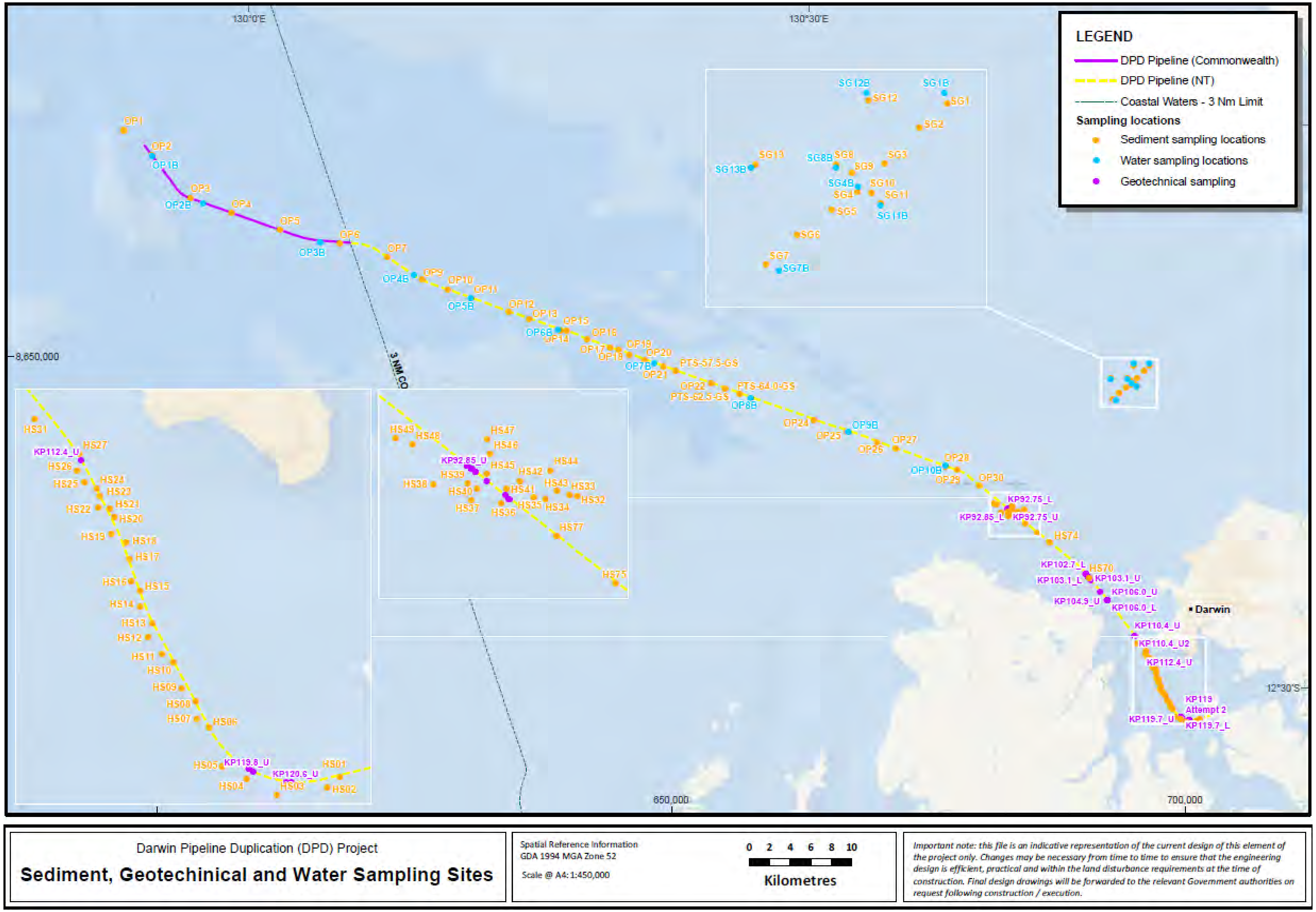


Figure 8-1 Sediment and water quality sampling sites (November 2021) and geotechnical sampling sites (January 2022) along the proposed Barossa Development pipeline route and at the proposed spoil ground (SG).

8.4.2 Sediment quality

8.4.2.1 Santos Barossa DPD – Pipeline Benthic Survey

As part of the survey scope, sediment samples were collected using a Van Veen grab at 30 offshore pipeline locations, 13 spoil ground locations and 53 Darwin Harbour locations (RPS, 2022a). Samples were also collected at an additional three offshore pipeline locations but only analysed for particle size distribution. During the January 2022 survey, sediment cores were collected from 17 Darwin Harbour core sample locations (refer to **Appendix 6** for detailed information on sampling methodology and results). All sampling locations are identified in **Figure 8-1** . Sediment samples were analysed for the following parameters:

- Particle Size Distribution (PSD);
- Infauna (offshore pipeline and spoil ground only);
- Total Organic Carbon (TOC);
- Metals and metalloids (Al, Sb, As, Ca, Cr, Co, Cu, Fe, Pb, Mn, Hg, Ni, Ag, Zn);
- Nutrients (Total Phosphorous (TP), Total Kjeldahl Nitrogen (TKN));
- Total Recoverable Hydrocarbons (TRH) & Benzene, Toluene, Ethylbenzene, Xylenes and Naphthalene (BTEXN);
- Polycyclic Aromatic Hydrocarbons (PAH), where TRHs were above limits of detection; and
- Naturally Occurring Radioactive Materials (NORMs; Ra226, Ra228 and Thor228).

The following additional analytes were included in laboratory analysis for Darwin Harbour grab and core samples:

- Tributyltin (TBT);
- Acid Sulphate Soils (ASS);
- Organochlorine pesticides; and
- Polychlorinated biphenyls (PCBs).

The results (refer to RPS (2022a)**; Appendix 6** for detailed results) show that seabed sediment PSD data identified a transition in sediment grain sizes along the offshore pipeline route, with the percentage clay and silt contributions increasing from around 3% and 9%, respectively, at the offshore OP1 (slightly silty gravelly sands; near KP0) end of the survey area, to up to around 7% and 39%, respectively, at the OP30, near the Darwin Harbour limits (gravelly muddy sands; at ~KP90). The increase in silt from offshore (~KP0) to Darwin Harbour is likely due to the riverine input of fine material from the Darwin harbour catchment area and mudflats/mangrove areas. The PSD data for the spoil ground indicated some local heterogeneity in sediments but were generally gravelly sands and muddy gravelly sands (3 – 5% clay, 12 – 23% silt, 51 – 73% sand and 9 – 29% gravel).

Darwin Harbour sediments ranged from sandy muds to muddy sandy gravels, with most sediments being muddy gravelly sands. There was also a sediment gradient from the Harbour limits (KP92) to near the shore crossing, with silty and slightly silty slightly gravelly sands at KP92 transitioning to silty sandy gravels from around KP102 to muddy sandy gravels and sandy muddy gravels near the shore crossing at KP120. Gravels in the study area comprise material from both geogenic (i.e. local rock formations) and biogenic (e.g. shell and potentially coral fragments) sources.

Comparison of the sediment composition of the offshore pipeline route, the spoil ground, the sand wave area in Darwin Harbour and the pipeline route south of the sand wave area to the shore crossing identified significant differences between all of these areas. Sediments at the offshore sampling sites (offshore pipeline and spoil ground) were generally dominated by sands (average >50 %), with pebbles (~27 %), silt (11-15 %) and clay (3-4 %). There was no recorded hard substrate from subsea video survey, so the coarser fragments (pebble) are more likely to be of biogenic origin (e.g. shell fragments). The main difference between the offshore pipeline route and the spoil ground is the increased relative silt content tending towards KP0, and subsequent reduced sand content. This outcome may well be due to a combination of factors, such as the smaller survey area (relative to the offshore pipeline route) and hence reduced potential heterogeneity), the more eastern location of the spoil ground, and the greater potential for the influence of open ocean environmental conditions on seabed substrates at the western end of the offshore pipeline route (e.g. potentially greater energy and potential increased near-sed bed currents, increasing potential for winnowing of finer particle sizes).

The sediments inside the Harbour were generally coarser and more characteristic of mixed sediments rather than the silty coarse sands recorded outside of Darwin Harbour. This is likely to be due to a combination of factors, including the local geology and differences in hydrodynamic conditions of the semi-enclosed Darwin Harbour versus the more open ocean-influenced Beagle Gulf. However, the mobile sediments of the sand wave area were distinct with respect to the very low silt content. This is likely due to the sorting of sediment particle sizes during transport along the seabed and the winnowing (removal through resuspension) of the finer silt particles. It is also likely that the seabed underlying the mobile layer was more similar to nearby seabed substrates in Darwin Harbour.

Laboratory results of the metals and metalloid concentrations from all sites (RPS, 2022a; **Appendix 6**) demonstrated a general trend for many of the metals analysed with an increasing concentration towards and within Darwin Harbour, though with much lower concentrations (except manganese) recorded in the proposed sand wave trenching area towards the mouth of the Harbour. This trend correlates with the silt content of sediments, which increased towards and within the Harbour, with the exception of the mobile sand waves from which the finer components were likely winnowed away by near seabed currents. Metals and metalloids are commonly associated with smaller particle sizes (Martincic et al., 1990).

The concentrations were compared to the relevant NAGD screening levels (CoA, 2009) to evaluate suitability of spoil for offshore disposal (refer **Figure 8-2**). The results identified that metals and metalloid concentrations in the sediment were all below the NAGD screening levels, except for arsenic at four sample locations. The highest concentrations of arsenic were recorded in the southerly section of the Darwin Harbour pipeline route, closest to the shore crossing. Arsenic is considered to have become concentrated in sedimentary rocks through sedimentation processes with the fine-grained clastic sediments having higher arsenic concentrations than the coarse-grained sediments. Geophysical data (both historic and contemporary), historic habitat mapping surveys and subsea video collected during the present study in Darwin Harbour have identified areas of emergent bedrock, often with a relatively thin veneer of sediment. An observed correlation between arsenic and iron concentrations in this area suggests that the underlying bedrock is likely the source of arsenic, which has previously been recorded in Darwin Harbour and is a well-known natural source in north-west Australia (e.g. INPEX Operations Australia Ltd 2014, DEC 2006). Arsenic in Darwin Harbour sediments is considered unlikely to be bioavailable to any significant extent, and therefore unlikely to cause toxic impacts to biota (INPEX Operations Australia Ltd 2014). Based on this, the naturally occurring arsenic levels are not considered a cause of concern from either resuspension as a result of trenching, or for offshore disposal of trenched material from Darwin Harbour.

This conclusion is further supported by the results of sediment sampling from the proposed spoil ground. Arsenic concentrations from the spoil ground were lower than those from Darwin Harbour and based on an increasing transition in arsenic concentrations to the north/north-west of the spoil ground across the sampling array, the source of the arsenic (as the nearshore bedrock was for samples within Darwin Harbour) is likely to be outside the spoil ground. Consequently, the source of arsenic is unlikely to be dredged Darwin Harbour seabed material disposed of at the adjacent INPEX Ichthys spoil ground to the east of the proposed DPD Project spoil ground.

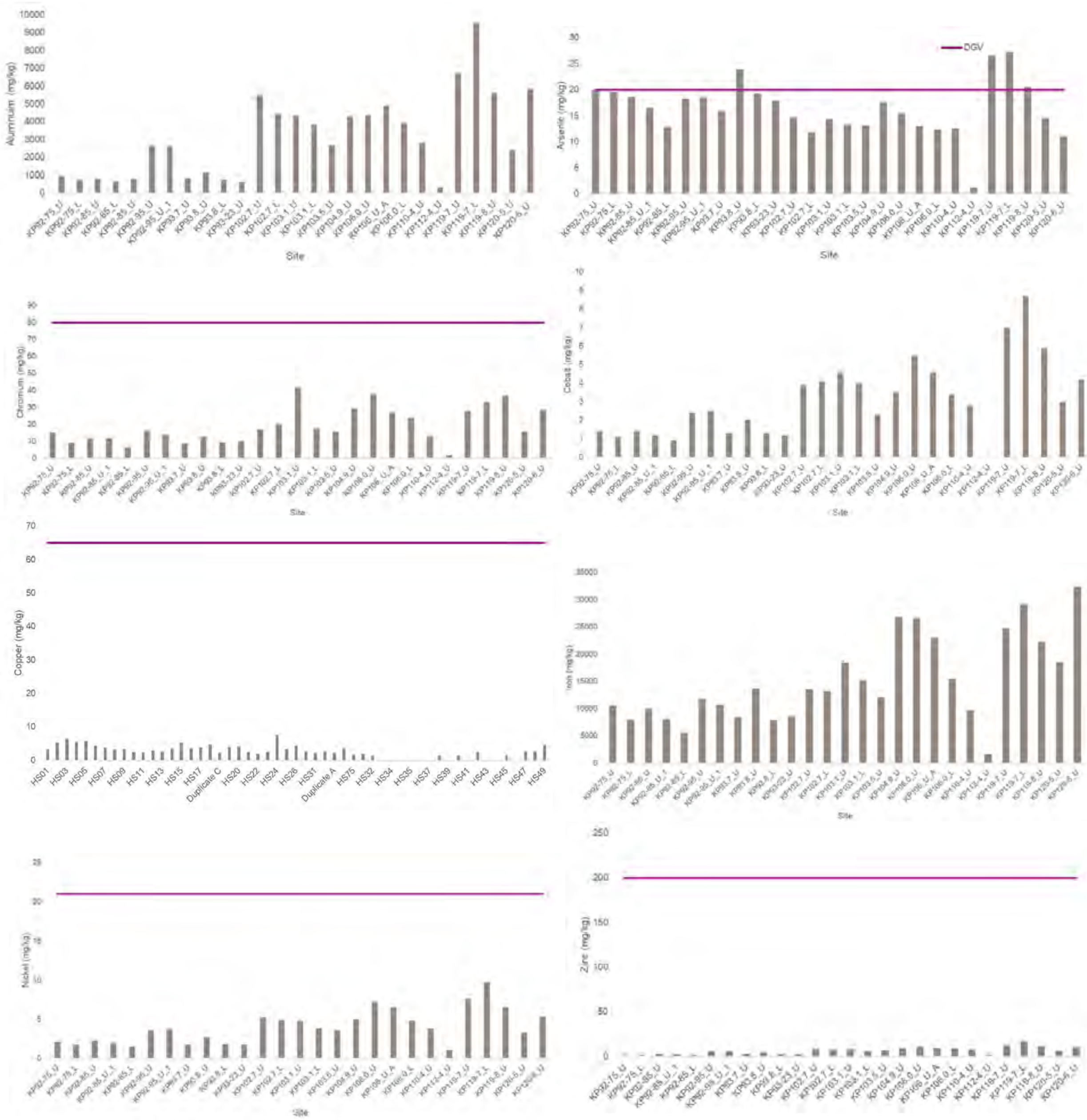


Figure 8-2 Metal concentrations in comparison to the screening levels presented in the National Assessment Guidelines for Dredging, 2009 (CoA, 2009) (refer RPS, 2022a; ***Appendix 6*** *for full details)*

TPH, TRH and BTEXN concentrations were below the laboratory LORs in sediment samples at all offshore pipeline and spoil ground sites. Consequently, no analysis of PAHs was required at these locations. TPH and TRH were detected at 35 of the 53 Darwin Harbour sites at low levels. Normalised TPH and TRH concentrations were well below the ANZ (2018) DGV of 280 mg/kg across all sites, and were below NAGD screening levels (CoA, 2009) with the highest recorded concentration of C10-C36 (sum) being 45 mg/kg at site HS09. All PAH concentrations at these 35 sites were below the LoR.

NORMs were recorded above LoRs for all sediment samples along the offshore pipeline route. Levels of rad226, rad228 and thor228 were generally below 31, 33 and 37 Bq/kg, respectively, except at sites HS27 and HS31 in Darwin Harbour main channel between KP110 and KP112, where peak levels of 51.7 – 79.1, 46.8 – 59.5 and 43 – 63.8 Bq/kg respectively were recorded. The combined value for rad226, rad228 and thor228 ('combined NORMs') were below the NAGD guideline value of 35,000 Bq/kg at all sites, even when considering upper confidence limits.

Pesticide concentration in all 27 of the Darwin Harbour sediment core samples were below the LoR.

TBT concentrations were below the LOR in all samples from Darwin Harbour. No samples were analysed for TBT outside of the harbour.

Although inorganic sulfur is present in the sediments, the potential for ASS is low as there is significant acid neutralising capacity (ANC) available.

The conclusion drawn was that no contaminants of concern were found in the sediments along the pipeline route, nor at the spoil disposal ground, with the elevated levels of arsenic considered to be naturally occurring and unlikely to impact the spoil ground. Therefore, sediments along the pipeline are considered suitable for unconfined ocean disposal as per the NAGD (CoA, 2009).

8.4.2.2 Environmental Referral Report – New Marine Facilities to Service Mandorah and Cox Peninsula

DIPL, on behalf of the NT Government, proposes to construct a new ferry berthing facility at Mandorah to improve transport connectivity between Cox Peninsula and Darwin (Cardno, 2022a). This new ferry berthing facility is located near the eastern tip of the Cox Peninsula within the Darwin Harbour and it is located approximately 1.5 km from the Project. Due to its proximity to the DPD Project, the ferry berthing facility sediment quality results have been considered in the SER to inform the DPD trenching impact assessment.

Marine sediment samples were collected within the ferry berthing facility dredging footprint area and analysed for physical and chemical properties as per the NAGD (CoA, 2009) and the results were:

+ Metals and metalloids concentration were recorded below all assessment criteria for offshore and onshore disposal of sediments;
+ Tributyltin (TBT) concentration was recorded above the LOR at two locations, one of these was outside of the proposed dredge footprint;
+ The 95% upper confidence level (UCL) for TBT corrected for 1% TOC (9.5 µg/kg), for samples collected within the proposed dredge footprint, marginally exceeded the NAGD low screening level of 9 µg/kg;
+ No other samples recorded concentrations of organotin compounds above the LOR;
+ Additional investigations were undertaken at 12 samples sites surrounding the site with elevated TBT found to be below the LOR. This suggested the previous detection was an

isolated occurrence, not representative of a contamination hotspot. The recalculated 95% UCL for TBT, incorporating the additional sampling, was well below the NAGD low screening level;

+ No organic compounds were detected, with all BTEX, TRH, PAH and organochlorine pesticide concentrations below their respective LORs in all samples; and
+ Two samples were found to have Net Acidity values above the recommended management action criteria (Simpson et al., 2018) for the dredging of sands to loamy clays; > 1000 tonnes.

The Cardno (2022a) report concluded that the potential for contaminants in sediments resuspended during dredging or in the dredge return water to bio-accumulate in aquatic organisms was considered to be negligible. Additionally, only low levels of contamination were recorded and the potential for the proposed works to increase the risk to aquatic biota over a long period was considered to be very low.

Cardno (2022a) concluded that marine sediment to be dredged by the project presented low risk of contamination and it was suitable for offshore disposal. 70,000 m^3 of the 85,000 m^3 to be dredged is rock and will be reused for the project, which the remaining material will be disposed offshore approximately 1 kilometre.

8.5 Potential significant impacts

The risk assessment process considered all planned and unplanned events resulting from DPD Project activities and identified those events that have the potential to significantly impact the Marine Environmental Quality. For the planned or unplanned events that were determined not to have the potential for significant impact, and which were presented and assessed in the NT referral, no further assessment is presented here. The following sections only present those events that have been determined to have the potential for significant impact, or events which were not presented and assessed in the NT referral. These include:

+ Seabed disturbance – Section 8.5.1;
+ Treated seawater discharge – **Section 8.5.2**;
+ Discharging water from onshore backflushing activities during FCGT – **Section 8.5.3**;
+ Invasive marine species – **Section 8.5.4**; and
+ Hydrocarbon spill – marine diesel oil **Section 8.5.5**.

While noise emissions can be viewed as impacting Marine Environmental Quality it was considered more appropriate to include noise emissions under Marine Ecosystems section since they have been specifically assessed with respect to impacts to key marine fauna.

8.5.1 Seabed disturbance

Activities related to the DPD Project will both directly and indirectly impact the seabed.

As detailed in **Section 2.3**, the majority of the pipeline will be laid directly on the seabed while sections making up approximately 16.5 km of the proposed pipeline route within the Darwin Harbour will require pre-lay trenching (with associated disposal of sediment and an offshore spoil disposal ground) to install the pipeline.

Figure 8-3 presents the locations of pre-lay trenching works to be carried out along the pipeline route and the location of the spoil disposal ground outside Darwin Harbour.

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Other activities that will impact the seabed include installation of the foundation, if required, for the in-line tee (ILT), installation of concrete mattresses to support where the pipeline crosses existing telecommunications cables, and temporary causeways at the shore crossing location (refer **Section 2.3**).

While all pre-lay works have the potential to have a localised and temporary impact to Marine Environmental Quality (including water quality and sediment quality) from laying infrastructure on the seabed, trenching is the activity that has the greatest potential to have a significant impact, from the generation of suspended sediments leading to increased turbidity and sedimentation.

To understand and evaluate the potential impacts to Marine Environmental Quality from trenching and spoil disposal, Santos commissioned sediment dispersion modelling which quantified the potential magnitude, intensity and spatial distribution of SSC and subsequent sedimentation that would be expected for the trenching and disposal operations proposed for the DPD Project. The predicted outcomes have been used to inform the assessment of the potential for influence or impact upon water quality and benthic habitats in the region. The modelling report, presented in **Appendix 3**, contains a summary of the sediment dispersion model inputs, methods and assumptions, and the model outcomes following analysis of specified threshold criteria. The modelling report was improved through comments received from an expert review by AIMS. Refer **Appendix 3** for details.

It is important to note that finalisation of the DPD pipeline route and associated trenching requirements occurred after sediment dispersion modelling was completed. The expected trenched spoil volume of ~255,000m^3 (refer **Table 2-2**) is lower than that modelled (306,000m^3) due to a reduction in trenching requirements. Trenching within zones labelled as trench zones 4, 5 and 7 within Section 5.4.2.1 of the modelling report (**Appendix 3)** and in **Figure 8-5** to **Figure 8-14** within this SER, is no longer required. Given the removal of some trenching zones and the lesser expected spoil volume required to be disposed at the offshore spoil disposal ground, the modelling results and subsequent interpretation are considered to provide a conservative representation of effects and impacts from trenching and spoil disposal.

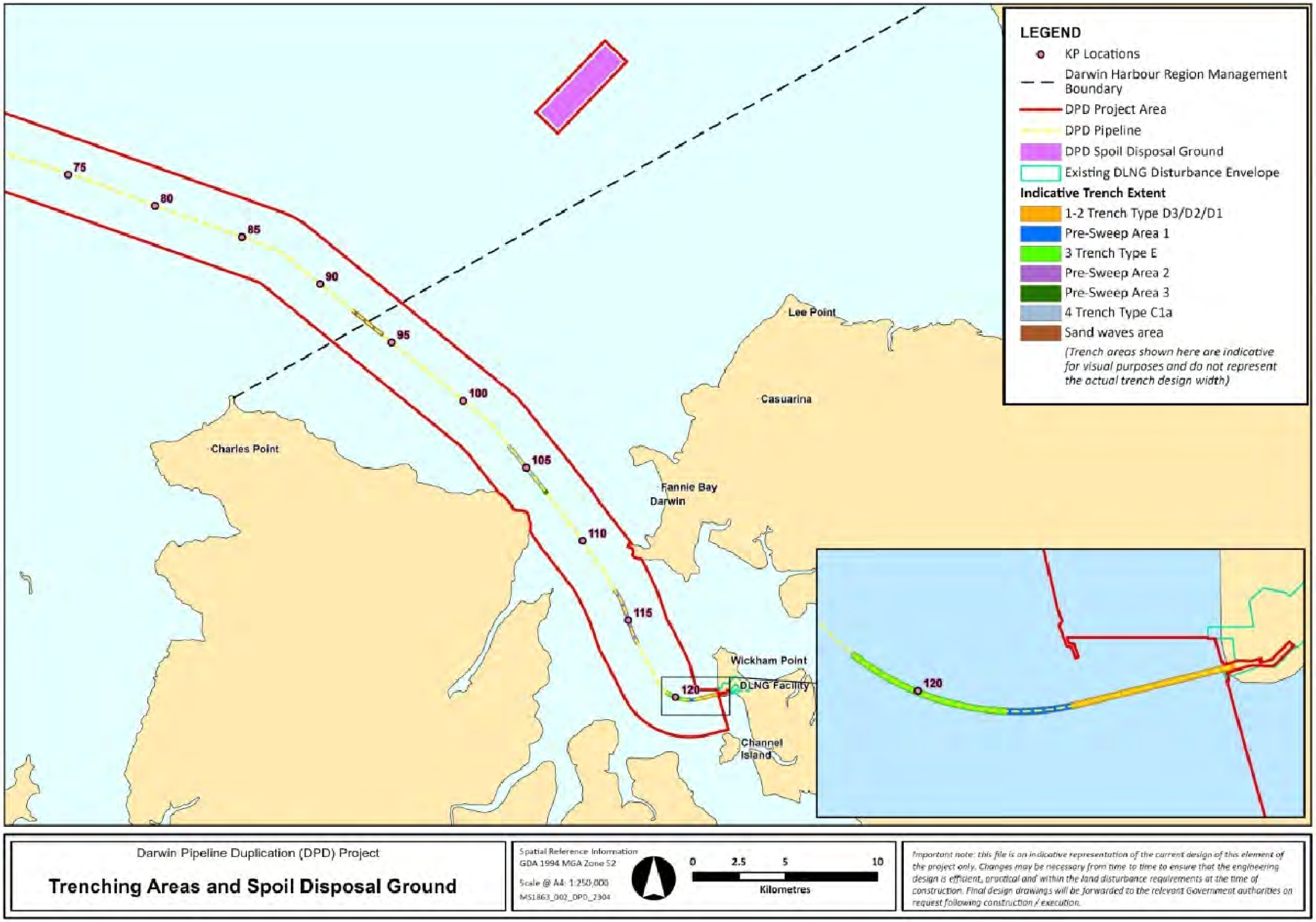

Figure 8-3 Trenching areas and spoil disposal ground

8.5.1.1 Sediment Dispersion Modelling

A review of the existing hydrodynamic and wave model frameworks for Darwin Harbour identified that refinements were required, and the models were reconfigured to increase resolution and updated with the latest bathymetric data. The reconfigured model was then re-validated against available measurements of water levels, currents, and waves (refer **Appendix 3**).

Two years (2019-2020) of hydrodynamic and wave simulation data were produced for use as input to the sediment dispersion model. The comparison of measured and modelled data showed excellent agreement between currents and water levels and the wave heights and directions were well reproduced by the wave model (**Appendix 3**).

Estimates for the three-dimensional distribution of sediments suspended by trenching and disposal activities were derived for the duration of the pipeline trenching and disposal program using numerical modelling. The modelling is in line with best practice for sediment dispersion modelling as outlined by Western Australian Marine Science Institution (WAMSI) Dredging Science Node Guidance (Sun et al., 2016).

The modelling used the sediment particle size distribution (PSD) specification to predict sediment dispersion of discharges over time for each of the expected sources of sediment from current and tidal movements at the location. The model allowed for the subsequent resuspension of settling sediments due to the erosive effects of currents and waves, the fate of sediments was assessed beyond initial settling. Refer **Appendix 3** for further details on the model methods, assumptions and limitations.

8.5.1.2 Methods and equipment

The material to be trenched from the pipeline route will consist mainly of marine sediments (modelled as approximately 200,000 m^3) and rock material (modelled as approximately 110,000 m^3). The critical geotechnical information required as input to the modelling were: (i) PSD data for the sediments to be trenched along the pipeline route; and (ii) in situ dry bulk density for the materials to be trenched along the pipeline route. The PSD data used in the modelling were based on field data collected for the Project during October 2021 and January 2022 along the proposed pipeline corridor and at the proposed offshore spoil ground (**Appendix 6**)(RPS, 2022a). The PSD for each zone was determined based on an average of the PSD results of all samples taken within each zone during site investigations.

The trenching operations for the pipeline route have been divided into eleven sections: seven trenching areas, three pre-sweep areas and the sand wave area as shown in **Figure 8-3**. The three pre-sweep areas and the sand wave area only require sediments to be removed while the other seven trenching sections requiring removal of both sediment and rock material.

The trenching in each of the seven trenching sections was assumed to be completed with either: a backhoe dredge (BHD; Trench Zones 1 and 2); or a TSHD conducting a pre-sweep to remove surface sediments, followed by a CSD crushing harder material, and a post-sweep with the TSHD to remove the CSD-crushed material. Trenching of the pre-sweep and sand wave sections is assumed to only require the TSHD.

A TSHD uses a head suction pipe with nozzles connected to a high-pressure water installation to loosen the material on the seabed. The resulting lower pressure in the pipe lifts the material discharging it into a hopper. A CSD is a vessel that includes a cutter head used to loosen the material and a suction mouth, inlet and pump used to mobilise the material from the seabed through piping into a hopper. A BHD will be used for digging and rock breaking.

Typically, a TSHD will remove the sediments or material that has been previously crushed by a CSD, and the quantities of each material type assumed in this case are detailed in **Section 2.3.1**. At the time of modelling the assumed BHD has a bucket size up to 16 m^3 and total installed power of 2416 kW, while the TSHD hopper size was assumed to be 15,000 m^3 and the CSD was assumed to have a total installed power of 28,200 kW. It has been specified that overflow of fines from the TSHD hopper will occur, with a 'green valve' incorporated into the overflow system, and that dewatering of the split hopper barges (SHBs) that accompany the BHD will also occur.

Inputs for the trenching program included accounting for all potential concurrent sources of sediment characterised by location, intensity, particle size distribution, vertical distribution in the water column, and levels of cohesivity. Also included is the potential for sediment mobilisation by TSHD propeller-wash effects which was done using data on vessel characteristics, and local depth and seabed composition.

To model the pipeline route trenching and spoil disposal operations, a range of conditions were defined for the proposed operations, including trenching and disposal methods, production rates, and sediment/rock types and quantities. Six different sources of suspended sediment plumes during trenching and disposal operations were identified and broadly defined as:

+ Direct suspension of material from the BHD bucket, from grabbing and lifting sediments and rock through the water column, and accounting for periods of no-dewatering and dewatering from the SHBs;
+ Disposal of sediment and rock excavated by the BHD from the SHBs to the spoil ground;
+ Direct suspension of material by the TSHD during trenching of sediments, and CSD-crushed material, accounting for no-overflow and overflow periods;
+ Disposal of sediment and CSD-crushed material removed by the TSHD to the spoil ground;
+ Direct suspension of material by the CSD during trenching of rock and casting material behind the dredge at low velocity, just above the seabed; and
+ Indirect suspension of material due to the propeller-wash of the SHB and TSHD while trenching.

Each of these sources of suspended sediment plumes will vary in strength and persistence depending on the nature of the operations. For the model, each source was defined by specifying the time-varying flux rate, PSD and vertical profile in the water column.

Refer **Appendix 3** for how the information has been used in the model and assumptions that have been made to supplement that information.

8.5.1.3 Modelled scenarios

Two seasonal trenching and disposal scenarios were simulated:

+ Trenching and disposal in April/May; and
+ Trenching and disposal in October/November.

The two scenarios simulated the ongoing sequence of all sediment-disturbing operations, along with simulation of a suitable post-trenching period to account for the fate of loosely consolidated material disturbed by the trenching and sediment placement. The proposed backfill and stabilisation of the pipeline using quarry rock material was not modelled because the proposed methods do not represent a significant source of suspended sediment.

Simulation outputs from each separate trenching and disposal activity were post-processed, combined and analysed to determine outcomes including zones of influence and impact for each scenario based on specified threshold criteria.

The modelled sequence of trenching has been specified to represent a worst-case scenario where the TSHD, CSD and BHD operate concurrently. The TSHD modelled sequence is assumed to start in Pre-Sweep Area 1, moving offshore along the pipeline route to the Sand Waves Area. Once the TSHD has completed its first pass over each of the trenching sections it will begin removing the material that has been crushed by the CSD, moving offshore along the pipeline route.

The BHD modelled sequence starts in Trench Zone 1 then moves to Trench Zone 2, with the BHD assumed to commence work at the same time as the TSHD on day one of the trenching program.

The CSD cannot start until the TSHD has pre-swept some of the zones, and the schedule minimises the amount of time that two pieces of equipment are in the same zone at the same time. To meet this condition the CSD will start in week two of the program in Trench Zone 3 then move sequentially offshore.

Details of estimated cycle times for trenching within each section are provided in **Appendix 3**.

8.5.1.4 Tolerance limits and management zones

Predictions of the SSC and sedimentation for each scenario were assessed against a series of water quality and sedimentation thresholds to categorise the modelled outcomes into management zones of influence and impact, defined with regard to environmental sensitivities in the study region. The thresholds and the approach to be applied to this Project are based on the extensive environmental monitoring and threshold work that INPEX completed for the Ichthys project, including during its capital and maintenance dredge campaigns in Darwin Harbour (INPEX 2010; 2011; 2013; 2018).

Following INPEX monitoring, areas of potential impact from trenching-induced excess SSC and sedimentation have been identified using seasonal tolerance limits/thresholds for sensitive receptors including mangrove, seagrass and hard coral habitats. The limits for SSC were derived from comprehensive site-specific water quality monitoring data (covering multiple years and locations), and the tolerance limits for sedimentation were derived from habitat-specific dose-response experiments and field observations reported in the scientific literature (INPEX, 2018). The defined tolerance limits also account for spatial variation with different limits applied to four trenching impact reporting zones, which were defined based on available water quality monitoring data (INPEX, 2018). The trenching impact reporting zones and the corresponding tolerance limits for different habitats that have been applied to the modelling are presented in **Table 8-2** and **Figure 8-4**.

Table 8-2 Tolerance limits for excess SSC and sedimentation (following INPEX, 2018)

Habitat	Trenching Impact Reporting Zone	Season	SSC (mg/L)	Sedimentation (mm)
Mangrove	Anywhere	All	N/A	50
Hard Coral	East Arm	Dry	11.9	15
		Wet	23.8	
	Middle Arm	Dry	12.4	15
		Wet	27.0	
	Mid Harbour	Dry	10.7	15
		Wet	28.4	
	Offshore	Dry	17.9	15
		Wet	64.2	
Seagrass	Anywhere	Dry	13.3	40
		Wet	60.6	

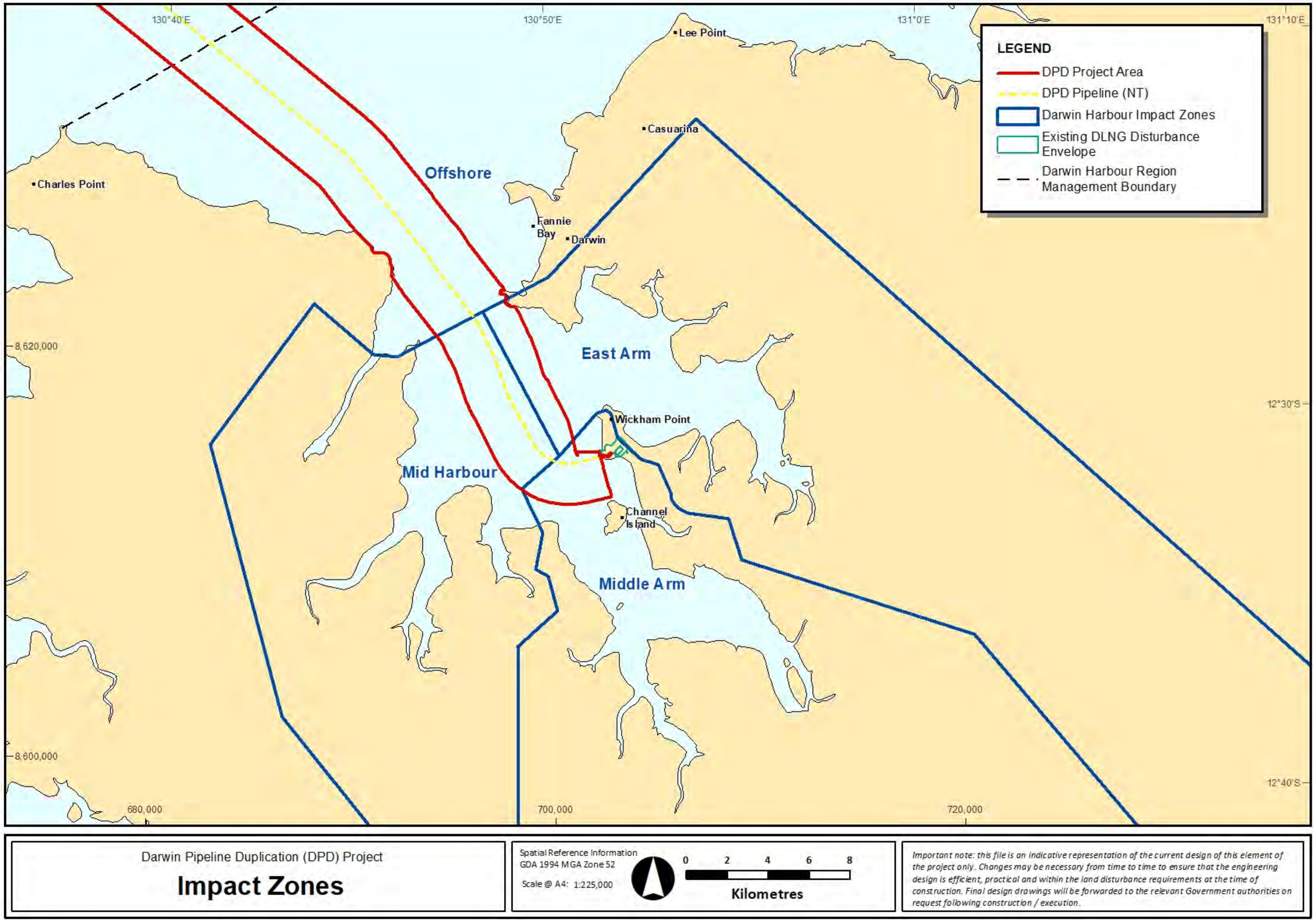

Figure 8-4 Proposed trenching impact reporting zones, based on INPEX (2010)

Following the approach applied by INPEX (2010; 2011; 2013; 2018) a Zone of High Impact, a Zone of Moderate Impact, and a Zone of Influence have been adopted.

Zone of High impact (ZoHI) is where direct impact from trenching and disposal will occur, such as removal of substrate or smothering of substrate (INPEX, 2018). Predicted impacts within this zone are expected to be severe and often irreversible. This zone includes the trench footprint and disposal area with a 20 m buffer extending outwards from these areas.

Zone of Moderate Impact (ZoMI) is defined as the area where sensitive receptor communities are predicted to be indirectly impacted by elevated SSC and sedimentation due to trenching and disposal activities (INPEX, 2018). Damage/mortality of sensitive receptor communities may occur, but the disturbed areas are considered to have good potential for recovery.

Sensitive receptors are within the ZoMI if their respective ecological tolerance limits for SSC are exceeded for 10% of the time or where the simulated sedimentation thickness exceeds their respective sedimentation tolerance limits at the end of the simulation (INPEX, 2018). For this project the maximum sedimentation thickness predicted at any time throughout the trenching operations was conservatively used for comparison against the sedimentation tolerance limits. Due to the variable nature of the sedimentation with tidal cycles and the strong currents in Darwin Harbour, larger amounts of sedimentation may occur earlier in the trenching program. As is expected, the predicted plume drift trajectories during the spring tide periods are much longer than during neap tide periods, with the suspended material being more widely dispersed and SSC becoming patchy.

The predicted ZoMI based on exceedances of the thresholds for SSC was evaluated over the duration of each trenching scenario by:

+ Creating a three-dimensional time series (hourly) of trenching-excess SSC values in each model grid cell for the entire trenching program;
+ Calculating the 90th percentile SSC value of each cell (i.e. the value that is exceeded 10% of the time); and
+ Assessing the 90th percentile data against the seasonal threshold SSC values for each sensitive receptor habitat type and trenching impact reporting zone.

The predicted ZoMI based on exceedances of the thresholds for sedimentation was evaluated over the duration of each trenching scenario by:

+ Calculating the maximum trenching-excess sedimentation thickness values in each model grid cell for the entire trenching program. A density of 700 kg/m2 was assumed for newly deposited sediments in the modelling based on field observations of the in situ density of surface material present over the mangrove areas of Darwin Harbour (INPEX, 2009); and
+ Assessing the maximum trenching-excess sedimentation thickness data against the seasonal threshold sedimentation thickness values for each sensitive receptor habitat type and trenching impact reporting zone.

The overall predicted ZoMI for each scenario was then calculated by combining both of the predicted ZoMIs from exceedance of thresholds for SSC and sedimentation thickness.

Zone of Influence (ZoI) is defined as the area where sensitive receptor communities are predicted to be indirectly influenced by elevated SSC and sedimentation (INPEX, 2018). Sensitive receptor communities may, at some time experience detectable elevations in SSC and sedimentation (beyond expected background levels). However, no sublethal stress or mortality of benthic communities is expected to occur (INPEX, 2018).

Sensitive receptor communities are predicted to be indirectly influenced where their respective ecological tolerance limits for SSC are exceeded for 5% of the time or where the simulated sedimentation thickness exceeds 3 mm at the end of the simulation (INPEX, 2018). These tolerance limits were derived from comprehensive site-specific water quality monitoring data, habitat specific dose-response experiments and field observations reported in scientific literature (INPEX, 2018). For this project the maximum sedimentation thickness predicted at any time throughout the trenching operations was used for comparison against the 3 mm sedimentation tolerance limit.

The predicted ZoI based on exceedances of the thresholds for SSC was evaluated over the duration of each trenching scenario by:

+ Creating a three-dimensional time series (hourly) of trenching-excess SSC values in each model grid cell for the entire trenching program;
+ Calculating the 95th percentile SSC value of each cell (i.e. the value that is exceeded 5% of the time); and
+ Assessing the 95th percentile data against the seasonal threshold SSC values for each sensitive receptor habitat type and trenching impact reporting zone.

The SSC results used to evaluate potential impacts were the depth-averaged results which are considered more appropriate for assessing potential impacts from SSC given it is the decrease in light through the water column that can impact sensitive benthic habitats.

The predicted ZoI based on exceedances of the thresholds for sedimentation was evaluated over the duration of each trenching scenario by:

+ Calculating the maximum trenching-excess sedimentation thickness values in each model grid cell for the entire trenching program. A density of 700 kg/m2 was assumed for newly deposited sediments in the modelling based on field observations of the in situ density of surface material present over the mangrove areas of Darwin Harbour (INPEX, 2009); and
+ Assessing the maximum dredge excess sedimentation thickness data against the 3 mm tolerance limit.

The overall predicted ZoI for each scenario was then calculated by combining both of the predicted ZoIs from exceedance of thresholds for SSC and sedimentation thickness.

8.5.1.5 Sediment dispersion modelling results

Suspended sediment concentrations

The modelling indicated that there may be significant spatial patchiness in the distribution of SSC and sedimentation at any point in time during the trenching and disposal operations because of variability in the number of sediment suspension sources, variability in the flux from each of these sources, and the varying dynamics of the transport, settlement and resuspension processes affecting the sediments.

Most material will initially be suspended low in the water column, and material suspended higher in the water column will sink as it moves away from the source. Frequent resuspension of material will also mostly affect the lower reaches. Thus, the area affected by higher concentrations is typically greater near the seabed than near the water surface. Exceptions to this include during spoil disposal activities where spoil enters the system near the surface, and in instances when there is strong resuspension of sediments that migrate to shallow water, but these will typically not be sustained for extended periods of time.

The localised movement and dispersion of the trenching-generated suspended sediment is tidally driven over short timeframes due to the very strong tidal flows in the areas where trenching is planned to occur and at the offshore disposal ground. Darwin Harbour is dominated by tidal currents year-round and is relatively sheltered from the variations in large-scale circulation observed offshore. Beyond the harbour entrance, superimposed on the tidal motion is the gradual migration of sediment due to the wind-driven residual component of the current, which drives some seasonal differences in the overall drift patterns of the suspended sediments. However, given the strength of the tidal currents even in the area offshore of the harbour, the seasonal differences were proportionally small. The sediment plume extended slightly more southwards during the winter/dry season scenario and slightly more northwards during summer/wet season scenario; refer **Figure 8-5** and **Figure 8-6.**

Given the dominance of the tidal flows in the Darwin area, the typical sediment plume movements are predicted to reflect the oscillations of the ebbing and flooding tide, both at the trenching locations and the spoil disposal site. On the ebbing tide, sediment plumes from trenching at zones within the harbour are predicted to move towards the Harbour entrance, or in a north-westerly direction parallel to the coast for the trenching zones outside the Harbour entrance. On the flooding tide the sediment plumes from trenching zones outside and near the Harbour entrance are predicted to move into the Harbour. At the proposed offshore disposal site sediment plumes from disposal operations move south-west towards Darwin Harbour on the ebbing tide and north-east towards Clarence Strait on the flooding tide. The predicted plume drift trajectories during the spring tide periods are much longer than during neap tide periods, with the suspended material being more widely dispersed and SSC becoming patchy. The sporadic nature of the disposal sources will also result in variability of SSC concentrations in space and time.

Further analysis was completed to evaluate the potential for interaction of plumes from consecutive disposals. During spring tide periods, the interaction between suspended sediment plumes from consecutive disposals is minimal, due to the rapid movement and dispersion of the plumes. The exception to this is when the timings and locations of disposals from the TSHD and BHD are close together. However, it should be noted that the SSC generated from BHD disposals is predicted to be significantly lower than for TSHD disposals, due to the lower volume of material in each load so the potential for additional impact from any interaction of plumes is considered low. During neap tide periods, when plume movement is slower and trajectories are shorter, there is more potential for interaction between consecutive disposals; however, the predicted depth-averaged SSC of the interacting plumes remains relatively low (refer **Appendix 3**).

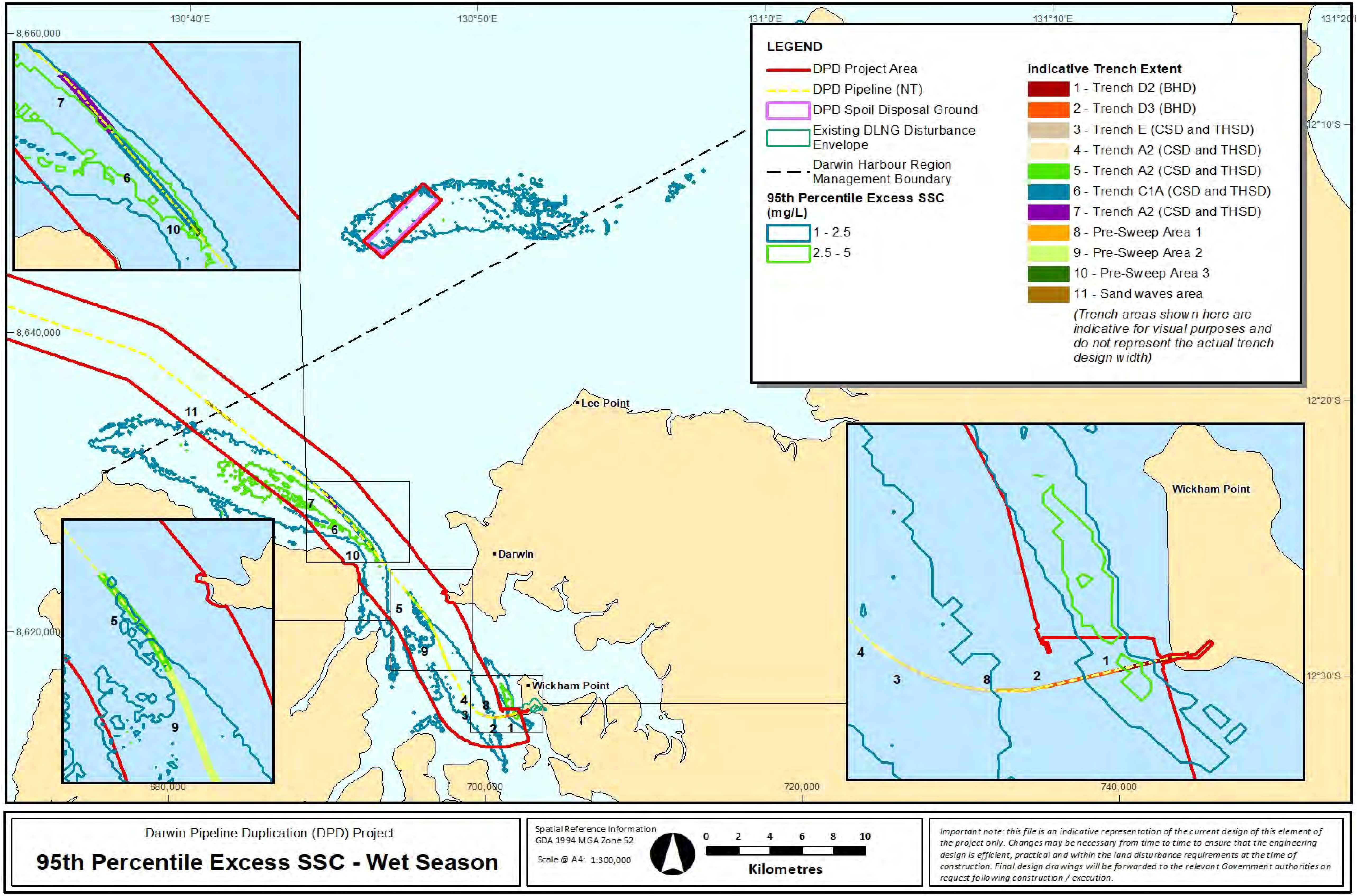

Figure 8-5 Predicted 95th percentile trenching-excess SSC for the trenching program transitioning into the summer/wet season (1st October to 9th November 2019)

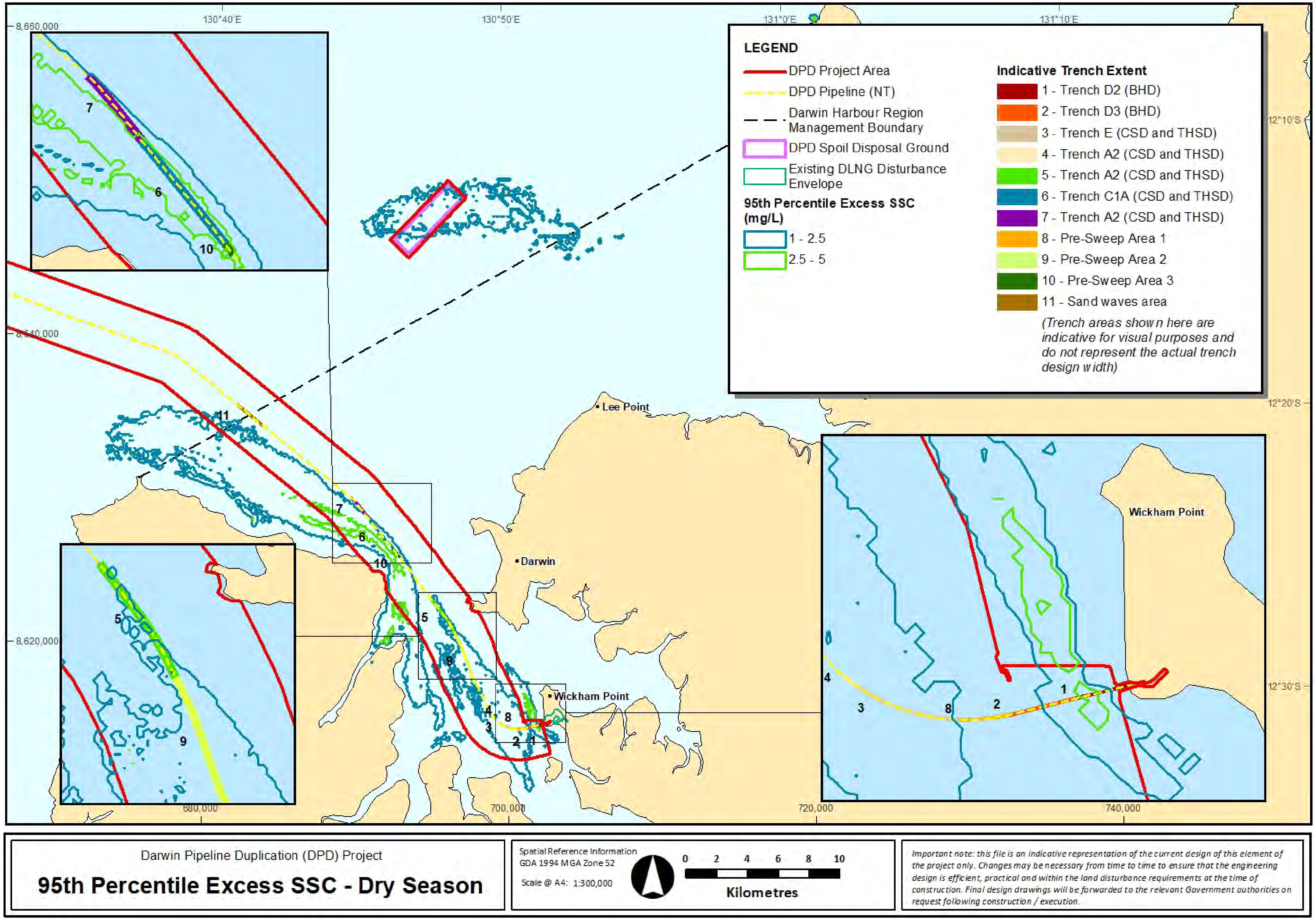

Figure 8-6 Predicted 95th percentile trenching-excess SSC for the entire trenching program transitioning into winter/dry season (1 April to 10 May 2019)

In response to expert review comments from AIMS, further analysis of the spatial and temporal distribution of SSC was completed, including comparing spatial distribution of maximum-in-water-column trenching-excess SSC and depth-averaged results.

The analysis revealed that there is significant variability in the vertical distributions of SSC in the water column and that there is a distinct increase in concentration towards the seabed. Thus, the spatial area affected above a given concentration is greater in the near-seabed layer than in the near-surface layer. Despite that, the regions predicted to have elevated levels of maximum-in-water-column trenching-excess SSC are similar to the depth-averaged results, but the spatial area above a given concentration is greater for the maximum-in-water-column SSC than depth-averaged results.

When considering the temporal variability, significant temporal variability in the distribution of SSC during the trenching and disposal operations is predicted. To explore the potential temporal exposure at sensitive receptor sites, and to respond to AIMS and DEPWS comments on the modelling a time series analysis at a set of sensitive locations was conducted. The set of analysis locations was selected from among the existing Ichthys sensitive receptor monitoring sites that the model predicted would be reached by elevated SSC levels. In addition to the sensitive receptor monitoring sites, a set of locations were defined at the proposed offshore disposal area, and at the Vernon Islands where elevated SSC levels were predicted by the model (refer to Figure 7.17 of **Appendix 3** for more detail).

The temporal variation in trenching-excess SSC at all analysis sites reflects the spatial patchiness of the plumes and the oscillations of the dominant tidal flows in the area, with rapidly changing (over hourly scales) sharp peaks and troughs. Similarly, the temporal variability in predicted SSC at the offshore disposal area sites also reflects the tidal oscillations with periods of spring and neap tides evident. However, superimposed on this signal is additional variability due to the sporadic nature of the disposal sources. Elevated SSC levels (in the order of 100-200 mg/L) occur immediately after disposal events but are rapidly dispersed and do not persist for long periods of time (scale of hours). The analysis also revealed that for sites lying outside the disposal ground, the intensity of the modelled SSC values is predicted to reduce significantly within 1-3 km of the disposal ground boundaries.

Sedimentation

Given the strong tidal flows in the Darwin area, settlement of the finer trenching-generated sediment is minimal with fine material (clay and silts) being continuously resuspended on each tide, particularly during spring tide periods where even fine sand size material is predicted to be resuspended. Coarse material (sand size) is predicted to settle rapidly near the trenching zones and at the proposed offshore disposal area, but the fine material will remain suspended, or will deposit at slack tide only to be resuspended on the following tide. This results in suspended sediment plumes having long drift trajectories, with sediments dispersed widely but at low concentrations, and with sediments deposited in thin layers.

Figure 8-7 presents the predicted maximum excess bottom thickness over the trenching and spoil disposal program, and **Figure 8-8** presents the excess bottom thickness at the end (i.e. last time step) of the trenching program for the winter/dry season scenario. A comparison of the spatial distributions in these two figures shows that sedimentation of greater than 1 mm thickness is typically limited to the vicinity of the trenching and disposal operations, with deposited sediments at greater distances being of very low concentration/thickness and most likely consisting of finer material that is resuspended and further dispersed by the end of the trenching program.

The spatial distributions of maximum bottom thickness during the trenching and spoil disposal program and bottom thickness at the end of the trenching program for transitioning into summer/wet season

(**Figure 8-9** and **Figure 8-10**) show a similar pattern of deposition, with sedimentation of greater than 1 mm thickness typically limited to the vicinity of the trenching and disposal operations, and sediments deposited at greater distances being of very low concentration/thickness and further dispersed by the end of the trenching program. A small additional patch of sedimentation with a thickness greater than 1 mm (originating from the spoil disposal ground) is predicted in the shallows at South West Vernon Island for trenching transitioning into the summer/wet season.

The disposal area sediment thickness values only represent the proportions of the material assumed to be initially suspended during placement or deposited in the surface layer available for potential resuspension. As such, actual sediment thicknesses within the disposal area may be greater than the values presented in the report figures due to direct settling of heavier particles that will not be suspended.

As was done for SSC, further analysis of the spatial and temporal distribution of sedimentation generated by trenching was completed for the same receptor locations (refer **Appendix 3** for more detail).

The time series analysis showed that the deposition rates at distance from the trenching and disposal areas are low, forming only very thin layers of material. At all sites other than those around the disposal area, the predicted thicknesses remain less than 0.2 mm. The low rates of deposition are due to the magnitude of the tidal currents in the area. Material that is suspended is dispersed rapidly and widely, with material deposited at slack tide being typically resuspended on the next tide, or the following spring tide period.

Time series plots showing predicted trenching-excess bottom thickness for each of the offshore disposal area sites reinforce the finding that deposition beyond the immediate vicinity of the disposal area is very low. The predicted bottom thickness values at sites on the edge of the disposal area never exceeded 0.5 mm and were never more than 0.2 mm at sites beyond that at all times. At the sites within the disposal area, there is variation in thickness based on relative proximity to where disposals have occurred in the modelling. Some slight reduction of the predicted bottom thickness can be seen during the run-on periods, but as the deposited material is typically the coarser sediments, the sedimentation levels are relatively stable during ambient conditions.

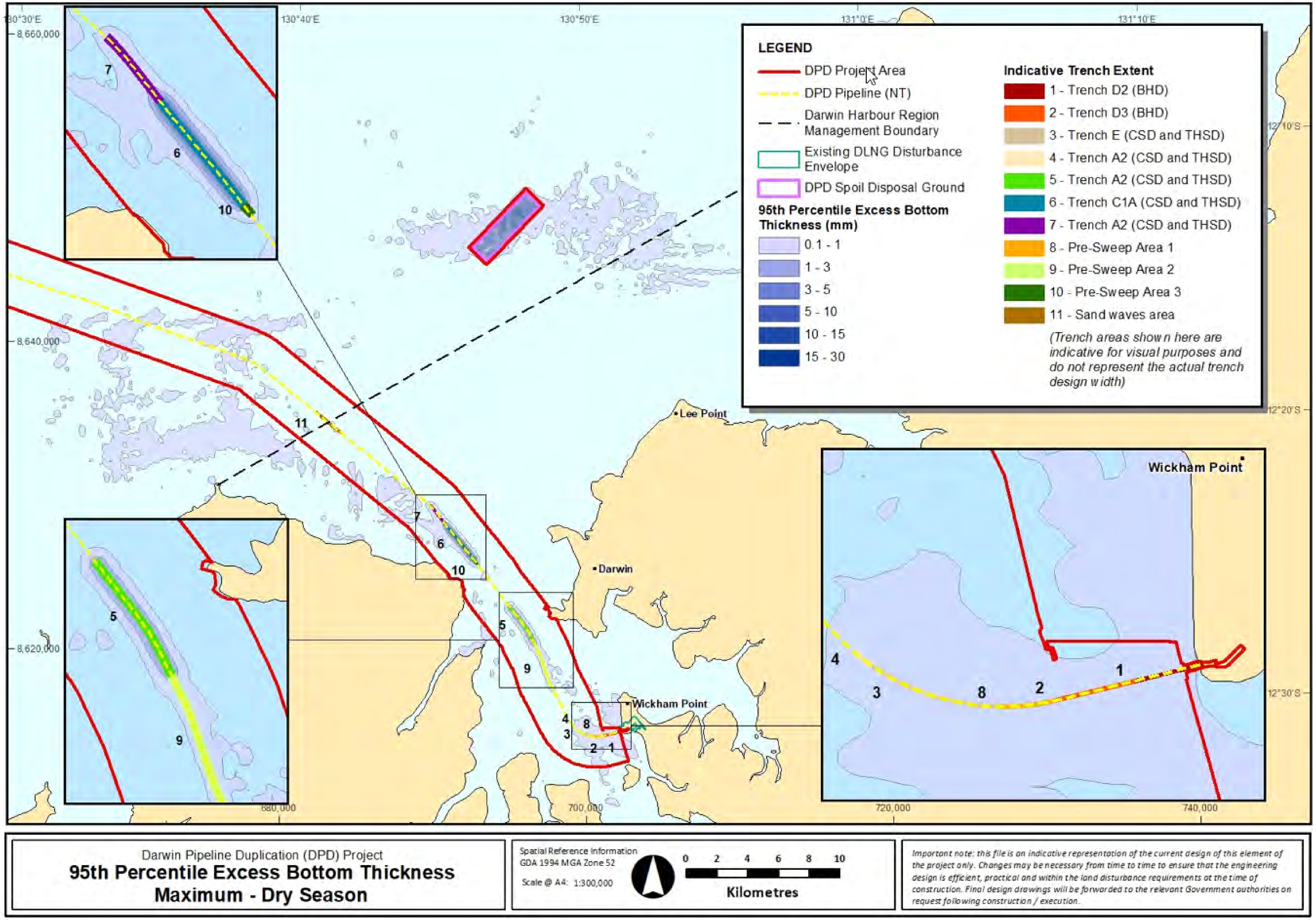

Figure 8-7 Predicted 95th percentile maximum trenching excess bottom thickness (mm) for the trenching program transitioning into winter/dry season (1st April to 10th May 2019)

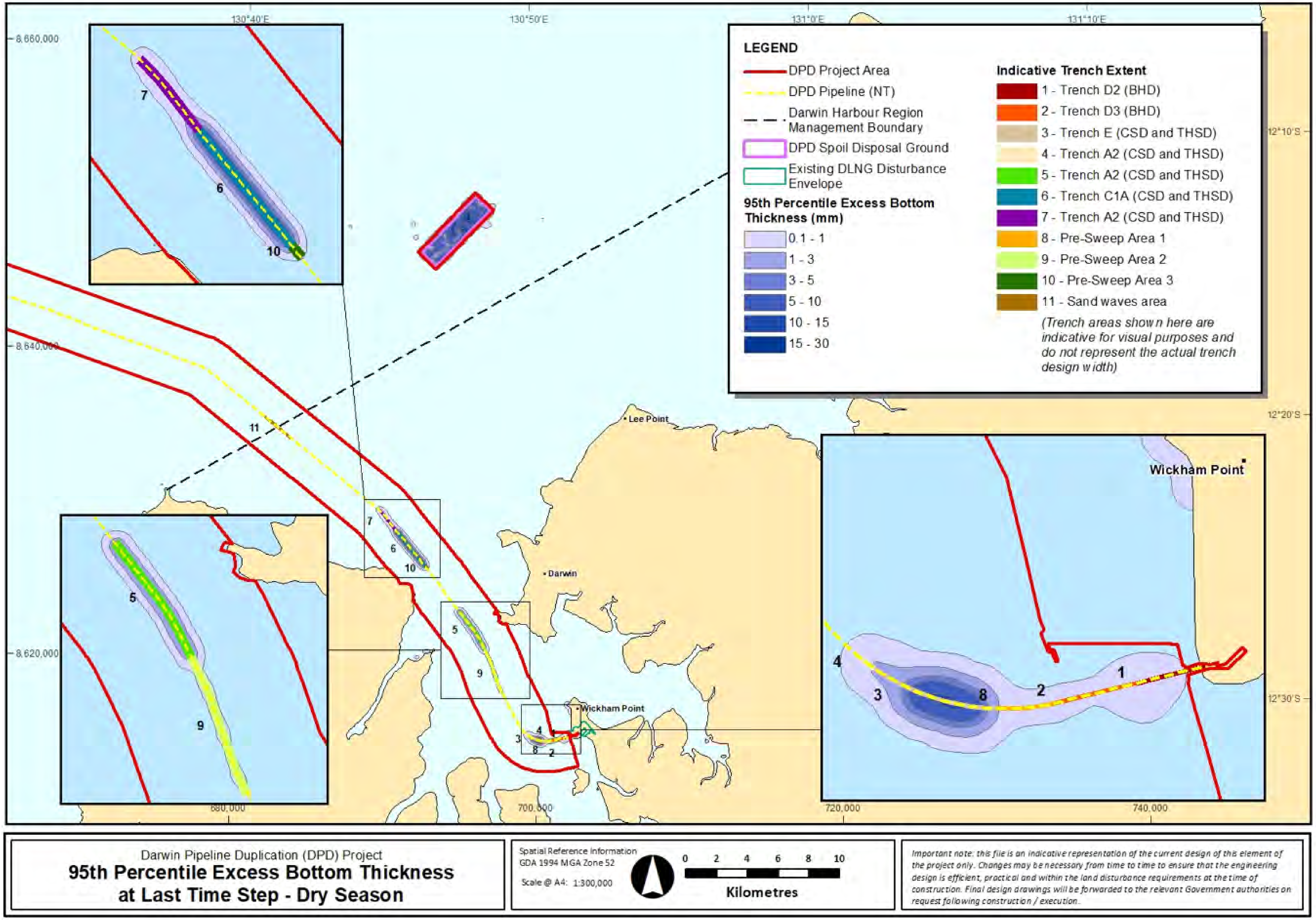

Figure 8-8 Predicted 95th percentile trenching-excess bottom thickness (mm) at the last time step of the trenching program transitioning into winter/dry season (1st April to 10th May 2019)

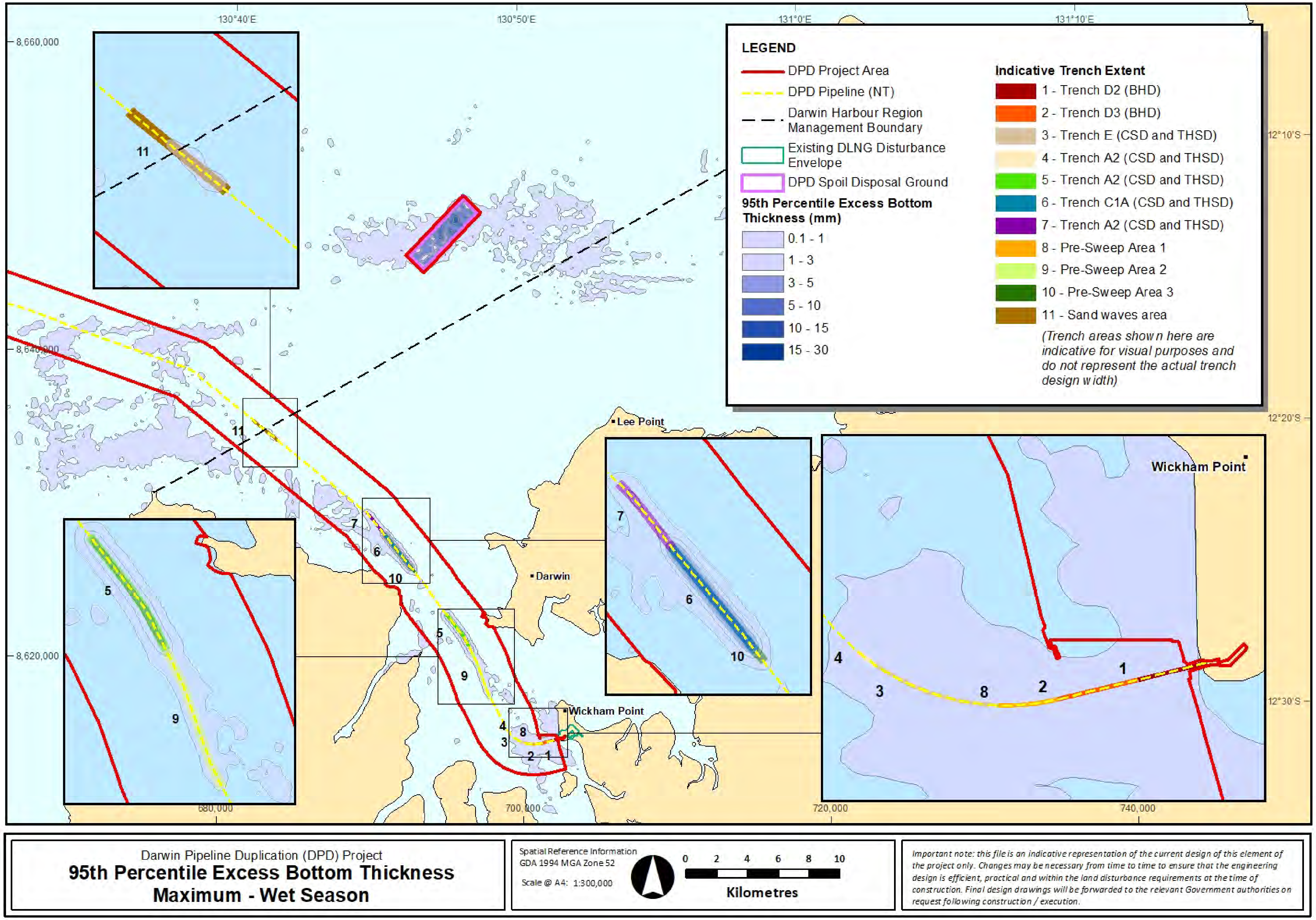

Figure 8-9 Predicted 95th percentile maximum trenching-excess bottom thickness (mm) for the trenching program transitioning into summer/wet season (1st October to 9th November 2019)

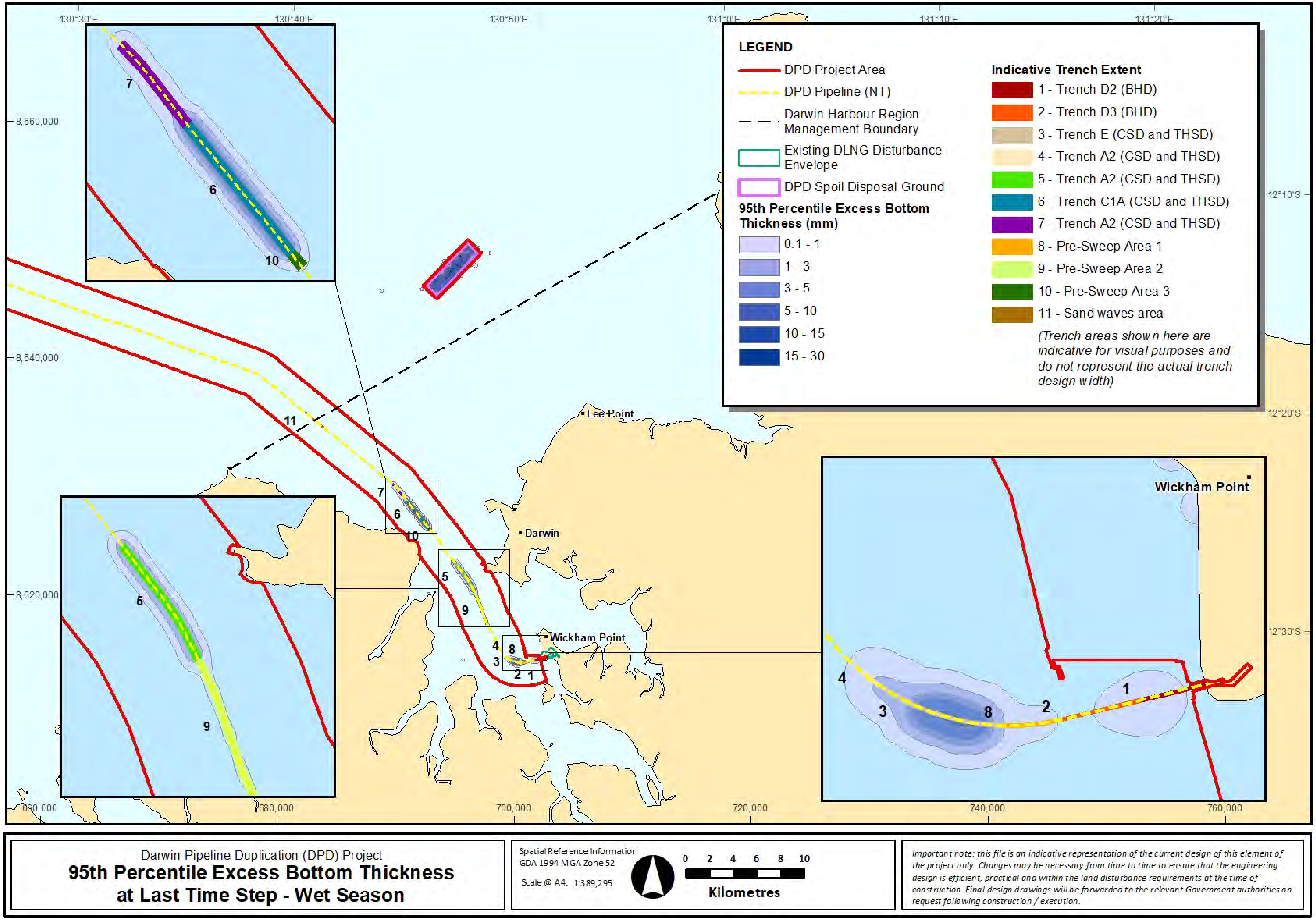

Figure 8-10 Predicted 95th percentile trenching excess bottom thickness (mm) at the last time step of the trenching program transitioning into summer/wet season (1st October to 9th November 2019)

8.5.1.6 Impact to Marine Environmental Quality

Applying the SSC thresholds for the different habitats (**Table 8-2**) to the modelling results demonstrates that no exceedance of SSC thresholds is predicted to occur for either trenching transitioning into winter/dry season or transitioning to summer/wet season. Consequently, changes to the water quality from increased SSC will not be sufficient to impact sensitive benthic habitats like hard coral and seagrass.

Sedimentation thresholds for sensitive habitats (**Table 8-2**) were also applied to the modelling results to determine the extents of the defined management zones – ZoMI and ZoI – over the entire program of trenching and disposal operations. The ZoMI and ZoI for the winter/dry season are presented in **Figure 8-11** and **Figure 8-12**, and for the summer/wet season the extents are presented in **Figure 8-13** and **Figure 8-14**. The predicted ZoMI for the trenching and disposal operations for both seasonal scenarios is restricted to within the trenching and spoil disposal footprints, which are also within the ZoHI as defined above.

The predicted ZoI for the trenching and disposal operations for both seasonal scenarios is also generally restricted to the trenching and spoil disposal footprints. The ZoI from trenching in zone 3 (~KP120, refer to **Table 2-2** and **Figure 2-4**), is predicted to extend up to 95 m beyond the trenching zone in an irregular pattern during both seasons. According to the mapping, the vast majority of the habitat under this potential footprint is bare sand, with small patches of sponges/filterers/octocorals.

Similarly, trenching in zone 5 (between KP110 -KP113.5) may result in the ZoI extending 40- 50 m beyond the trenching extent where the vast majority of the habitat is low density sponges/filterers/octocorals, with small patches of Bare Sand. Trenching in zone 6 off Mandorah (between KP103.5 – KP106.5) is predicted to have a ZoI that extend up to 85 m beyond the trenching extent. The habitats under this footprint are a mix of low-density sponges/filterers/octocorals and sponge habitat.

There is also segmentation ZoI with a very small patch of sponges/filterers/octocorals in the shallows at South West Vernon Island for trenching transitioning into summer/wet season. This isolated ZoI patch may be attributable to the combined effects of model bathymetry and hydrodynamics, representing sediments that are transported from the spoil disposal ground into the shallowest possible grid cells and then trapped upon reversal of the tide. While this demonstrates a potential for sediments released at the offshore disposal ground to disperse there, the persistence of material remaining at the water-land boundary in this location may be overstated.

Based on these results, while trenching and spoil disposal activities may temporarily decrease water quality through increased turbidity from suspended sediments, the impacts to marine environment quality are not predicted to be significant. The prediction of trenching excess SSC under influence/impact thresholds and the restricted spatial extent of sedimentation above impact thresholds means that activities are not expected to influence or impact sensitive habitats such as hard coral, seagrass and mangroves as they are not present in either the ZoMI or the ZoI for the trenching in either seasonal scenarios.

Evaluation of how seabed disturbance from trenching and spoil disposal activities could directly impact benthic habitats is provided in **Section 9.5.1**.

The analysis of sediments from the Project area identified that metals and metalloid concentrations in the sediment were all below the NAGD screening levels, except for arsenic (**Section 8.4.2**), which is considered to be naturally occurring. Santos acknowledges that there is a potential risk from the mobilising of contaminants through trenching and sediment disposal activities. The disturbance of the sediment may cause a redistribution of these contaminated sediments throughout the water column. This has the potential for contaminated sediments to transfer and settle across the marine environment or become dissolved into the water column.

Due to the sediment results showing no contaminants of concern along the pipeline route, with the exception of the naturally elevated levels of arsenic, the sediments along the pipeline route are considered to be suitable for unconfined ocean disposal, as per the National Assessment Guidelines for Dredging (NADG, 2009) and Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (2013).

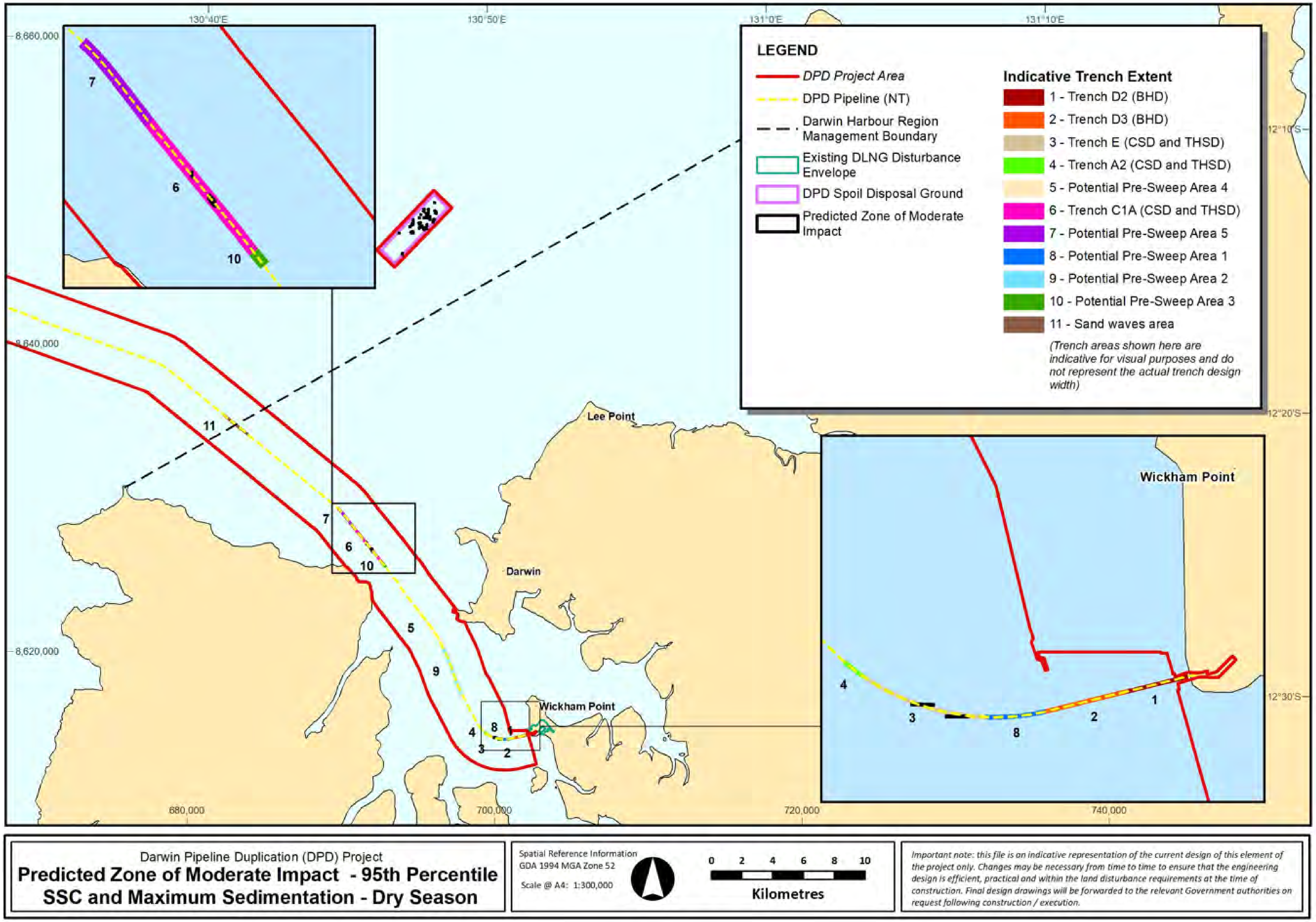

Figure 8-11 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into winter/dry season (1st April to 10th May 2019)

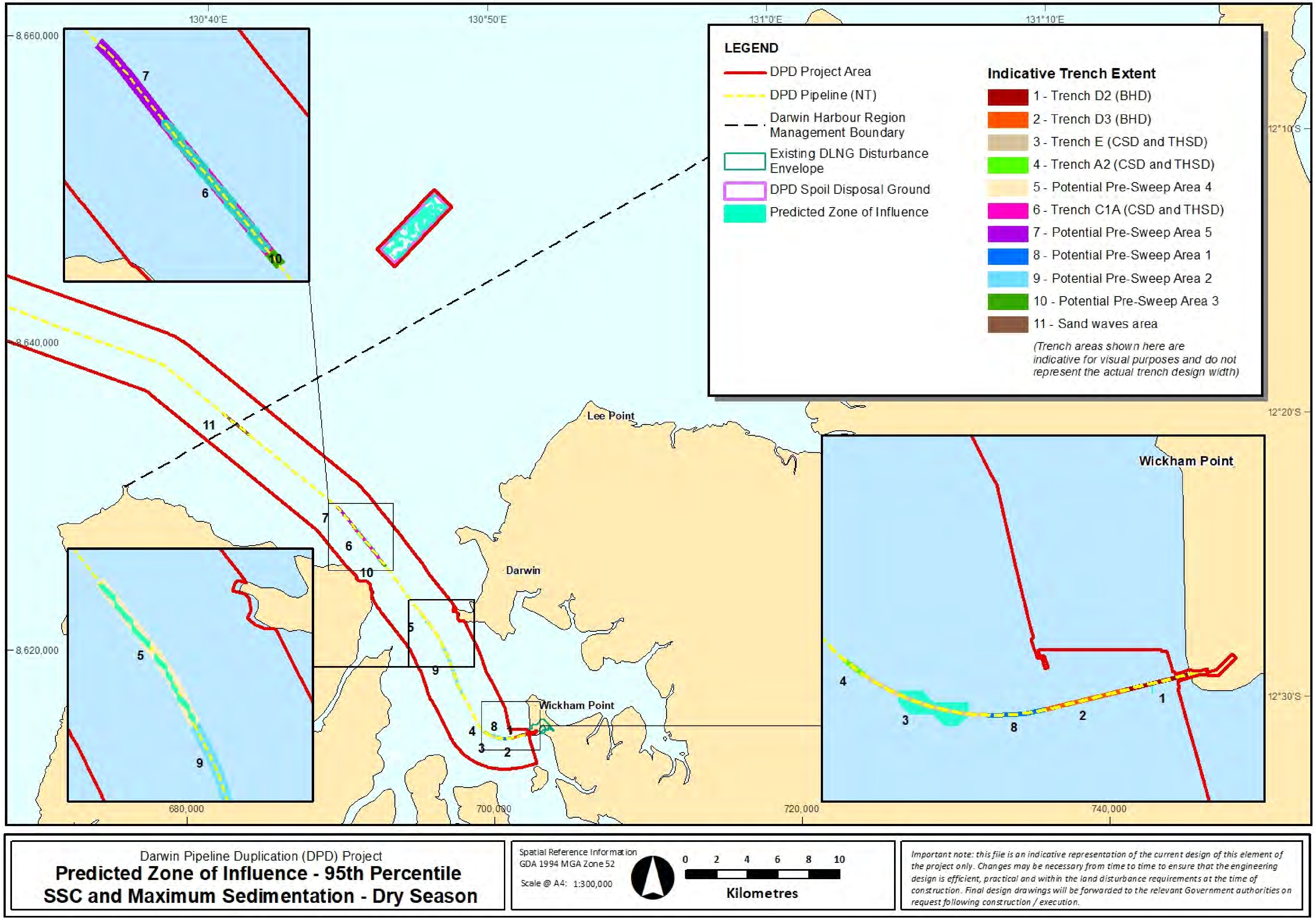

Figure 8-12 Predicted Zone of Influence following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into winter/dry season (1st April to 10th May 2019)

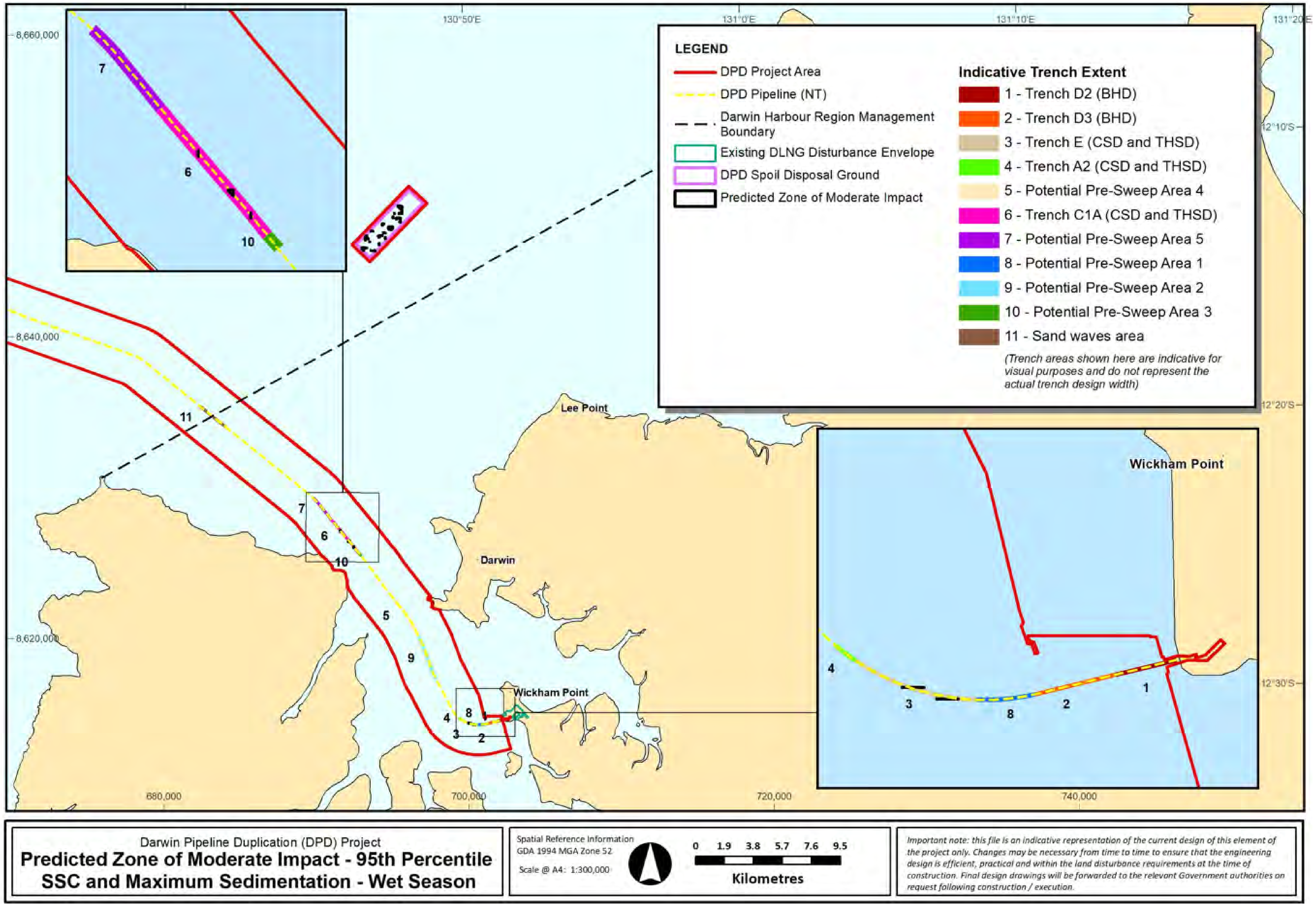

Figure 8-13 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into summer/wet season (1st October to 9th November 2019)

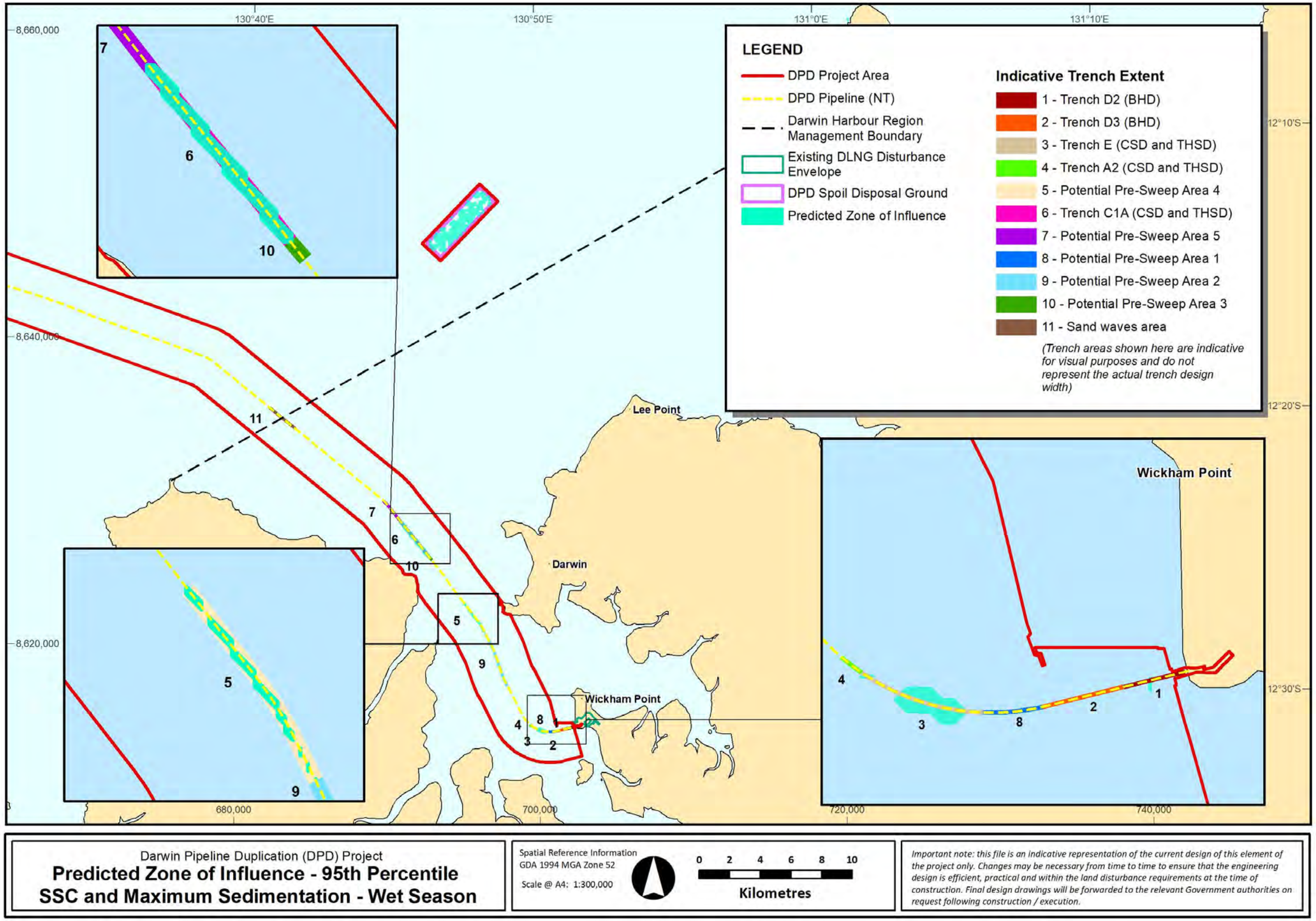

*Figure 8-14 Predicted Zone of Influence following application of the appropriate spatial thresholds (**Table** 8-2) to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into summer/wet season (1st October to 9th November 2019)*

8.5.1.7 Contingency pre-lay maintenance trenching

In the event that maintenance pre-lay trenching is required, given the considerably smaller volume of material that may need to be trenched (<80,000 m^3) and the shorter duration of the activity (refer to **Section 2.3.2**), the impacts would be less than the full trenching and spoil disposal programme presented here and thus, would not have a significant impact on Marine Environmental Quality. Furthermore, given that the system is tidally driven, the delay between the main trenching program and any maintenance trenching would not result in cumulative impacts from increased SSC or sedimentation particularly as maintenance trenching occurs for short duration events. This conclusion is supported by the temporal and spatial analysis of SSC and sedimentation generated by trenching (refer **Section 8.5.1.5**). The analysis demonstrated a low potential of interaction from plumes caused by consecutive disposals due to the rapid movement and dispersion of the plumes by tidal currents.

8.5.2 Treated seawater discharge

As presented in **Section 2.6**, discharge of treated seawater at the Commonwealth waters PLET will be required as part of the FCGT activities for the DPD pipeline. Potential impacts to NT waters were assessed and presented in **Section 8.5.2.3**.

In the unlikely event of a pipeline wet buckle (i.e. failure in the pipeline during pipe-lay) occurring, the worst case scenario is that treated seawater will need to be used (and subsequently discharged) to preserve the pipeline in the period before pipelay can continue (refer **Section 2.6.3).**

In the marine environment, due to the corrosive nature of seawater, maritime industries use and rely on a range of chemicals including corrosion inhibitors, biocides, and oxygen scavengers to protect the integrity of assets and infrastructure and prevent microbial growth.

Treated seawater is seawater that has been treated with a preservation chemical consisting of a biocidal corrosion inhibitor and oxygen scavenger to preserve the pipeline during FCGT activities. While the planned chemical for treating the seawater is expected to be either 'Hydrosure' or 'Hydro 3', there may be a requirement to use alternative similar chemical packages. All chemicals discharged to the environment will be subject to Santos' chemical selection assessment process which screens chemicals against their risk to health, safety and the environment (refer to **Section 8.5.2.1**). Both Hydrosure and Hydro 3 are inherently biodegradable with low potential for bioaccumulation and have been assessed by Santos as presenting a low risk to the environment using classification criteria developed under the Offshore Chemical Notification Scheme (OCNS). The chemical composition of Hydrosure is presented in **Table 8-3** and ecotoxicology data for Hydrosure is provided in **Table 8-4** below. A maximum concentration of 550 mg/L of Hydrosure or Hydro 3 (or equivalent chemical) would be used to preserve the pipeline in the event that this is required from a wet buckle event. Discharge modelling has been conducted for Hydrosure at this concentration and is presented in **Section 8.5.2.3.**

Table 8-3 Chemical composition of Hydrosure

Function	Chemical	Formula	CAS No.	Composition	Pipeline Concentration [mg/L] [~ppm]
Biocide	Alkyl dimethyl benzyl ammonium chloride	$C_{22}H_{40}ClN$	68424-85-1	10-30%	55-165
Oxygen Scavenger	Ammonium Bisulphite	NH_4HSO_3	10192-30-0	10-30%	55-165
Solvent	Dipropylene Glycol Methylether	$C_7H_{16}O_3$	34590-94-8 (mixture isomers)	1-10%	5.5-55
Solvent	Ethylene glycol	$C_2H_6O_2$	107-21-1	<1%	<5.5
Solvent	Water	H_2O	7732-18-5	30-50%	165-275

8.5.2.1 Chemical selection process

Santos has a chemical approval process to ensure all chemicals (hazardous and non-hazardous) that selected for use on the DPD Project are approved prior to procurement and/or mobilisation to site. Santos will preferentially select for use those chemicals which are rated as Gold/Silver through the Offshore Chemical Notification Scheme (OCNS) Chemical Hazard and Risk Management (CHARM) or OCNS group rating of D/E (if not CHARM rated). The chemical management requirements for the DPD Project will include:

+ **Chemical requests**: Chemicals planned to be discharged to the environment will require that the DPD Project contractors submit a chemical application form with the safety data sheets (SDS) to Santos for approval (unless already approved for Santos to use);
+ **Chemical environmental assessment criteria**: Santos will approve chemicals planned to be discharge to the environment if they are:
  - Rated Gold/Silver (OCNS) (CHARM);
  - Rated D/E under OCNS (if not CHARM rated); or
  - If not CHARM or OCNS rated, have an environmental risk assessment submitted by contractor and approved by Santos. The environmental risk assessment shall develop a residual risk rating based on:
  - Evaluation of the receiving marine environmental characteristics, values and sensitivities, and with regard to the nature and scale of the proposed chemical product to be discharged;
  - Review of alternative chemical products that are technically equivalent in the context of the requirements of the work;
  - Demonstration that the selected chemical represents the least hazardous option, whilst

still meeting the technical requirements;

- Evaluation of ecotoxicity thresholds and application of OCNS ratings, which may include:
  + Establishment of an alternative `pseudo' rating that can be applied to the chemical in accordance with international standard protocols or guidelines (e.g. International Organization for Standardization (ISO) test guidelines, Organisation for Economic Cooperation and Development (OECD) test guidelines, and OSPAR guidelines); or
  + Use of alternative similar toxicity data if insufficient toxicity information is available on the non-rated chemicals.

+ **Maintaining register**: The contractor will maintain (and make available to Santos) their own register of chemicals, SDS's, chemical application forms and risk assessments/risk rankings for chemicals that may be discharged to environment.

8.5.2.2 Ecotoxicity

Table 8-4 presents Whole Effluent Testing (WET) for Hydrosure conducted by Chevron (2015). Testing was undertaken according to protocols recommended by ANZECC and ARMCANZ (2000) (Chevron, 2015) and included five locally relevant species from a range of trophic levels (primary producer, herbivore and carnivore) which provide a representation of the different biota types likely to be present in the Project area. The testing results showed that NOECs ranged from 0.13 mg/L for the crustacean to 12.5 mg/L for the fish. In general, simpler life forms (algae and species in their larval stage) exhibited higher sensitivity compared to more complex life forms such as the fish (refer **Table 8-4**).

Species protection levels calculated from statistical distribution of the no observed effective concentrations (NOECs) and the dilutions to achieve the concentration based on a dosage of 550 mg/L are presented in **Table 8-5**. For long term continuous discharges (e.g. sewage outfalls), ANZECC and ARMCANZ (2000) recommend that the 99% species protection concentrations should be applied to develop environmental criterion for high conservation ecosystems. For chemicals with negligible potential for bioaccumulation the 95% level of species protection may also be applied.

While the dewatering discharge is short term (<22 hours) with negligible risk of bioaccumulation (the treatment products are not considered to bioaccumulate), a conservative criteria (99% of species protection level or PC99%) was adopted. This is in line with recent pipeline projects undertaken in Australian Waters (e.g. Wheatstone (see Chevron, 2015)). Based on this, the NOEC threshold above which impacts may occur if prolonged exposure occurs (greater than 48 hours) is 0.06 mg/L (which is a dilution of 1:9,167 based on an initial concentration of 550 mg/L).

Table 8-4 Ecotoxicological testing results for Hydrosure (from Chevron, 2015)

Species	Test	Type	NOEC ppm (or mg/L)
Nitzschia Closterium (algae)	72 hr growth inhibition	Chronic	1.30
Saccostrea echinate (mollusc)	48 hr larval abnormality	Chronic	0.250
Heliocidaris tuberculate (echinoderm)	72 hr larval development	Chronic	1.25

Species	Test	Type	NOEC ppm (or mg/L)
Melita plumulosa (crustacean)#	96 hr acute toxicity	Acute	0.13
Lates calcifer (fish) #	96 hr acute toxicity	Acute	12.5

#Toxicity test is defined as an acute test.

Table 8-5 NOEC values for varying species protection levels for Hydrosure based on WET testing (Chevron, 2015)

Species protection level	NOEC threshold concentration (mg/L)	Dilution to achieve the NOEC threshold based on an inhibitor dosing concentration of 550 mg/L (or ppm)
NOEC PC99%	0.06	1:9,167
NOEC PC95%	0.10	1:5,500
NOEC PC90%	0.15	1:3,667
NOEC PC80%	0.23	1:2,391

8.5.2.3 Contingency treated seawater discharge modelling in NT waters

If following a wet-buckle event, preservation of the pipeline is required, treated seawater will be used to fill the section of pipeline and some of the treated seawater will be discharged from the end of the pipeline as a result of over-pump to ensure the entire pipeline exposed to raw seawater is preserved. Following any repairs or remediation work, the pipeline would then need to be dewatered before pipelay activities can continue.

While this is an unlikely event, it has been known to occur, and as such, for assessment purposes discharge modelling has been undertaken to evaluate if overflow or dewatering of treated seawater could pose a significant risk to the environment. A summary of the modelling and outputs is provided below, and the full modelling report is provided in **Appendix 5**.

As a wet buckle could theoretically occur anywhere along the pipeline length, locations to model the discharge and inform the assessment of both discharge from overflow (600 m^3) and dewatering (volume dependent on the location of discharge) needed to be identified.

The locations were selected to capture a range of dewatering volumes, with consideration of the hydrodynamic conditions inside and outside Darwin Harbour, and proximity to sensitive receptors. Based on these considerations, three discharge locations were identified (**Figure 8-15**):

+ Location 1 – KP84
  - Large discharge volume and near Charles Point Wide RFPA
+ Location 2 – KP102
  - More complex hydrodynamics near mouth of Darwin Harbour and potential for sensitive receptors near Mandorah
+ Location 3 – KP114

- Representative hydrodynamics within the harbour and closest pipeline point to Weed Reef.

The physical mixing of the treated seawater at each location was assessed for both near-field and far-field zones. The near-field zone is defined by the region where the levels of mixing and dilution are purely controlled by the discharge plume's initial jet momentum and the static current. The buoyancy in this instance is negligible given that the treated seawater has the same density as the surrounding seawater. Once the near-field assessment was complete, the far-field phase examined the transport and mixing of the preservation chemical by the ambient currents.

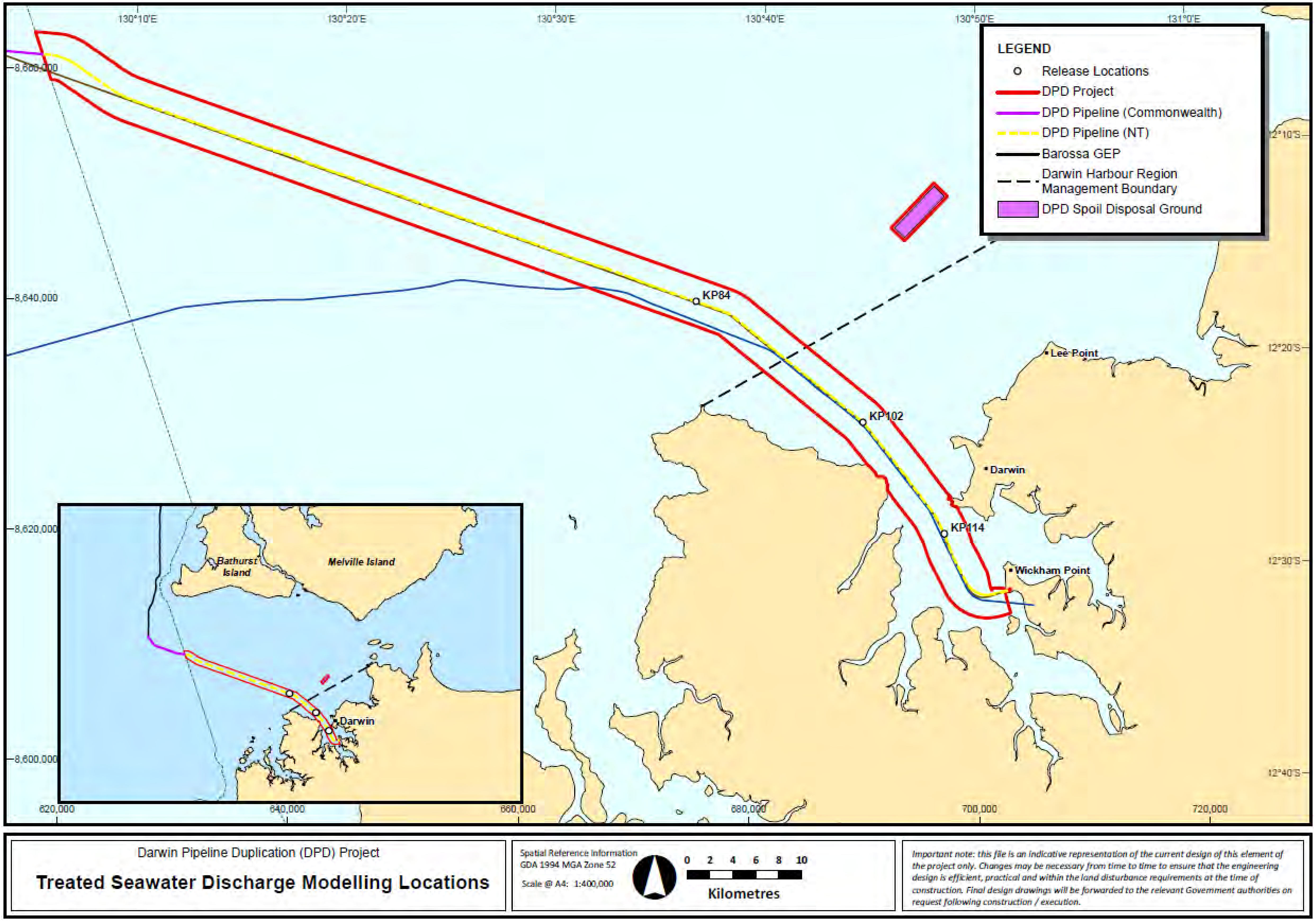

Figure 8-15 Contingency treated seawater discharge modelling locations

Table 8-6 Volumes and locations of the three scenarios for treated seawater discharges

	Location 1 – KP84		Location 2 – KP102		Location 3 – KP114	
	Latitude (S)	Longitude I	Latitude (S)	Longitude I	Latitude (S)	Longitude I
Coordinates of discharge	8,639,681.22	675,450.46	8,629,189.96	689,902.26	8,619,537.48	696,972.89
Water Depth (m)	-23.65		-23.30		-19.44	
Preservation chemical	Hydrosure					
Preservation chemical dosing concentration (ppm)	550					
Treated seawater temperature	Same as ambient					
Treated seawater salinity	Same as ambient					
Overflow						
Volume of treated seawater released as overflow (m^3)	600		600		600	
pig velocity (m/s)	0.5		0.5		0.5	
Flow rate during overflow (m^3/s)	0.26		0.26		0.26	
Release duration during overflow (hours)	0:38:34		0:38:34		0:38:34	
Description of outlet	4-inch pipe		4-inch pipe		4-inch pipe	
Discharge height (m) above the seabed	At seabed + 0.5 m		At seabed + 0.5 m		At seabed + 0.5 m	
Dewatering						
Volume of treated seawater released during dewatering (m^3)	19958		10623		4400	
pig velocity (m/s)	0.5		0.5		0.5	
Flow rate for dewatering (m^3/s)	0.26		0.26		0.26	
Release duration during dewatering (hours)	21:22:48		11:22:48		4:42:48	
Description of outlet	4-inch pipe		4-inch pipe		4-inch pipe	

	Location 1 – KP84		Location 2 – KP102		Location 3 – KP114	
	Latitude (S)	Longitude I	Latitude (S)	Longitude I	Latitude (S)	Longitude I
Discharge height (m) above the seabed	At seabed + 0.5 m		At seabed + 0.5 m		At seabed + 0.5 m	

The modelling demonstrated decreasing concentrations of the preservation chemical with increasing distance from the release location. It also highlighted that tidal movement dominates the local currents and drive the plume behaviour. Results showed that treated seawater would initially project horizontally approximately 1 – 2 m due to the orientation of the outlet and the fast exit velocities. Once the plume had lost its momentum, it mixed laterally due to the currents as it is neutrally buoyant.

Published NOEC values for Hydrosure were derived from longer term tests whereby organisms were exposed to the preservation chemical between 48 and 96 hrs (**Table 8-4**). This means that effects only occur when a species is exposed to a concentration above the NOEC threshold for longer than 48 hours. The modelling of discharge (both overflow and dewatering) did not predict any exceedance of the NOEC threshold of 0.06 mg/L (PC99%) over a 48-hour period at any of the three locations. Therefore, in the unlikely event of a wet buckle which then also requires an extended delay before continuing pipelay activities, the one-off discharge of treated seawater at each location is unlikely to have a significant impact on marine life.

Despite this conclusion, to better understand the plume behaviour over shorter timeframes and thus, lower dosage levels, the concentration in each modelled cell were also examined over 24 and 12-hour durations.

The results showed there was no exceedance of the PC99% threshold over a 24-hour period at KP84 and KP114 and only an area of 0.16 km^2 (16 Ha) was predicted to exceed the PC99% threshold over a 24-hour period from the dewatering at KP102. While this result reflected the reduced water flow and dilution in the shallower water west of KP102, the time of exposure above PC99% was lower than that at which impacts have been demonstrated in laboratory tests (i.e. 48 hours or more).

There was no predicted exposure above the PC99% threshold over a 12-hour period from the preservation chemical during overflow pumping at all three locations. Concentrations following dewatering did exceed the PC99% threshold over a 12-hour period.

The predicted plume distribution and concentrations after 12 hours from each discharge location are presented below (**Figure 8-16, Figure 8-17** and **Figure 8-18**) to show the predicted plume distribution, but given the short duration, i.e., below 48 hours, there is a low likelihood of impact in these areas.

The discharge at KP84 resulted in a preservation chemical plume that was generally continuous up to ~1.4 km from the release location, with small, isolated patches predicted up to 9.61 km. Isolated patches beyond 2 km were predicted to occur during 2 of the 25 simulations and the plume was predicted to travel a maximum distance of 9.61 km in only one simulation. The isolated patches were due to an accumulation of the treated seawater, which had occurred during a current reversal, causing it to concentrate. The potential areas of exposure based on the PC99%, PC95% and PC90% thresholds 0.40 km^2, 0.17 km^2 and 0.08 km^2, respectively.

Similarly, for KP102 there were isolated patches of the preservation chemical up to 6.78 km from the release location due to the plume drifting into the shallow intertidal areas, reducing the potential for mixing and dilution. The modelling also predicted a continuous area of exposure up to ~4 km west offset from the release location due to the plume migrating into the shallower waters, mixing less, resulting in the concentration accumulating. The area of exposure for the PC99% threshold was 4.14 km^2.

For the discharge at KP114, the maximum distance from the release location and area of exposure based on the PC99% threshold was 2.40 km and 1.45 km^2, respectively. The preservation chemical concentrations did not trigger any other threshold over a 12-hour continuous duration.

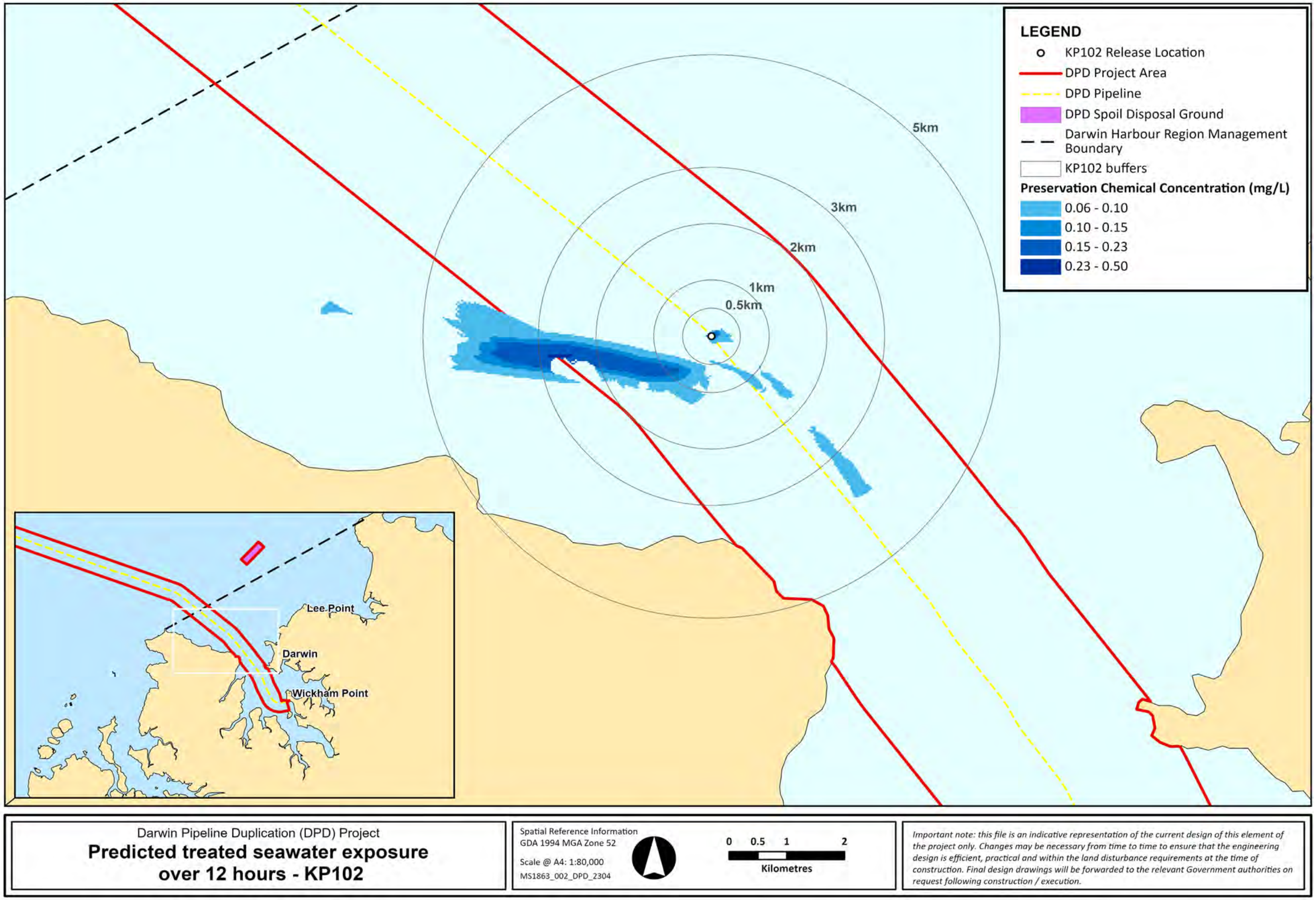

Figure 8-16 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP84 (based on 25 simulations with different metocean conditions)

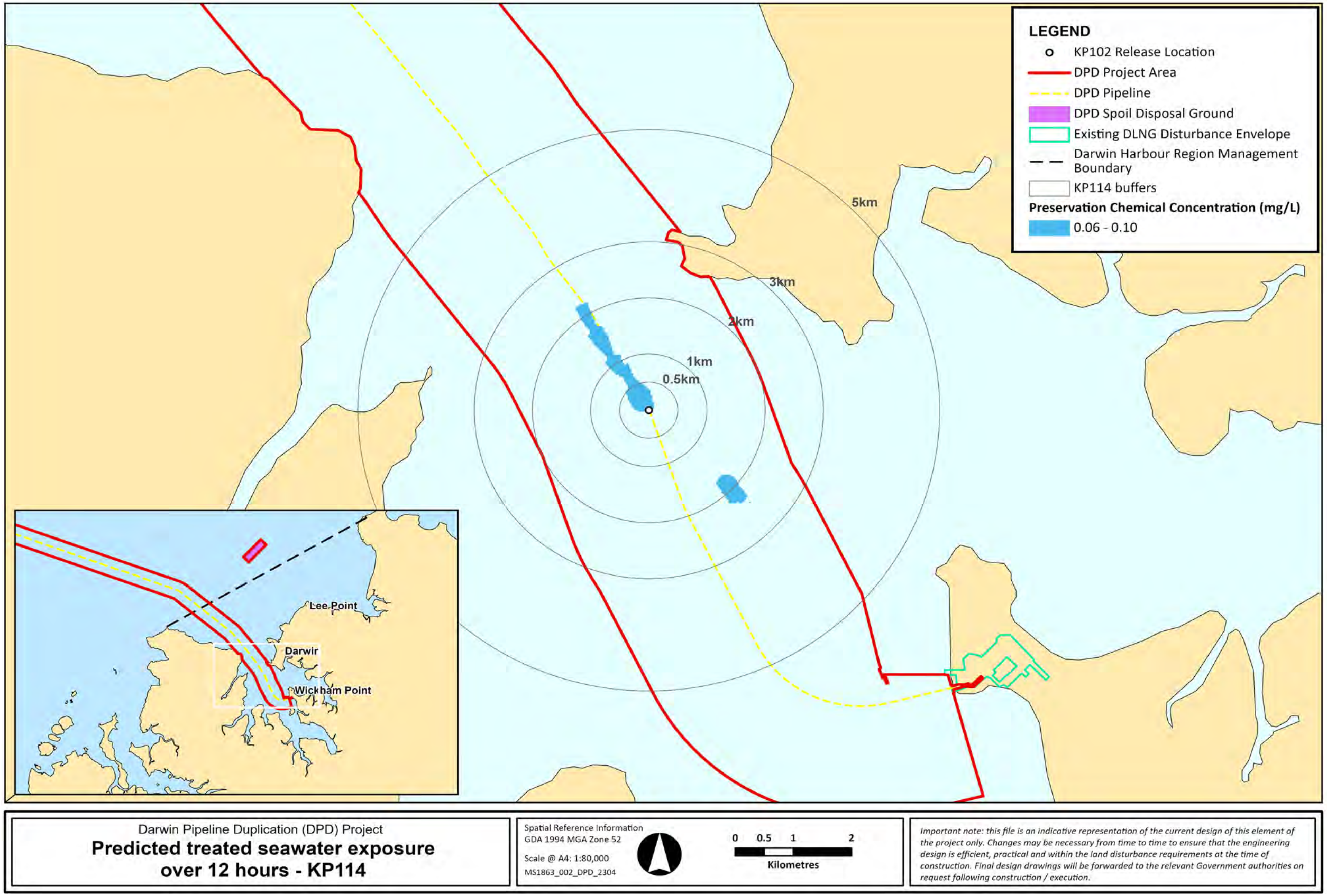

Figure 8-17 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP102 (based on 25 simulations with different metocean conditions)

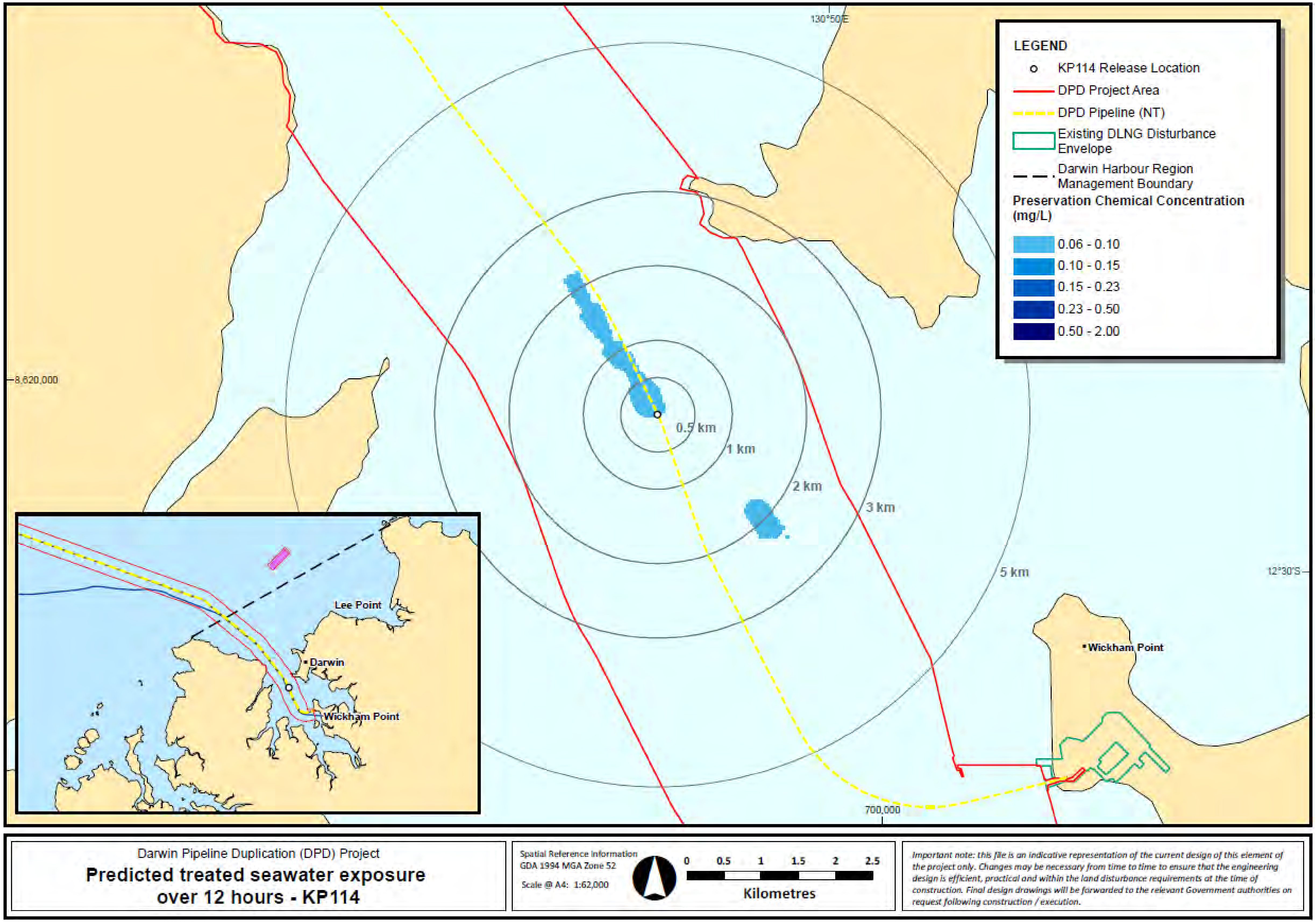

Figure 8-18 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP114 (based on 25 simulations with different metocean conditions

Based on these results, if a wet buckle event that required the use of treated seawater to preserve the pipeline occurred, the subsequent the discharge of treated seawater would result in localised and temporary reduction in water quality around the discharge location. The chemicals that will be used are inherently biodegradable with low potential for bioaccumulation and there was no predicted exceedance of the NOEC PC99% threshold over a 48-hour period at any of the three modelled locations.

For the above reasons, no substantial change in water quality is expected from dewatering after a wet buckle event and consequently, discharging treated seawater will not significantly impact Marine Environmental Quality.

8.5.2.4 Treated seawater discharge in Commonwealth waters

In Commonwealth waters, there will be planned discharge of treated seawater at the PLET as part of FCGT activities (**Section 2.6.1**) and a potentially contingency discharge associated with repairing a pipeline wet buckle. As presented in **Section 2.6.1**, at the completion of FCGT activities, the flooded pipeline will be dewatered and conditioned with mono-ethylene glycol (MEG). The dewatering activities will result in approximately 56,000 m^3 of treated seawater and approximately 1,000 m^3 of MEG separately discharged at the Commonwealth waters PLET. The contingency discharge of treated seawater in Commonwealth waters relates to an unlikely wet buckle event as described in **Section 2.6.3**.

To determine the potential area that may be exposed to the chemicals used to treat the seawater, discharge dispersion modelling from the Commonwealth PLET has been undertaken to support the Commonwealth approvals process (RPS, 2021). The physical mixing of the treated seawater from the discharge point was assessed for both near-field and far-field zones with 25 simulations run to represent a range of current and metocean conditions. **Table 8-7** presents the modelling parameters applied at the PLET subsea discharge of the treated seawater volume. A conservative discharge volume of 55,614 m^3 was modelled over a 35 hour release period.

Table 8-7 Summary of model parameters used to model discharges from the Commonwealth PLET

Parameter	Value/design
Maximum discharge volume	55,614 m^3
Discharge duration	35 hours
Model run duration	3 days
Discharge depth (m)	3.5 m above the seafloor
Diffuser configuration	Three 4” ports spaced 4” apart and oriented 45° vertically upwards
Exit diffuser velocity (m/s)	21.3
Hydrotest water temperature (°C)	28.2 - same as ambient
Hydrotest water salinity (psu)	34.6 - same as ambient
Initial chemical treatment concentrations	550 mg/L

The near-field results showed that the initial mixing that takes place is due to the high exit velocities and once the plume has lost its momentum, the neutrally buoyant plume was predicted to travel laterally and mix/disperse with the currents. Concentrations of the chemical inhibitor rapidly reduced upon discharge with concentrations of 21.3, 7.3 and 7.7 mg/L predicted within 30 m of this discharge point under weak, moderate and strong currents respectively.

The far-field modelling demonstrated that plume movement and chemical concentrations were dominated by tidal movements with decreasing concentration away from the discharge site. The maximum distance from the release location to where the NOEC threshold of 0.06 mg/L (PC99%) was exceeded for a 12-hour period was 7.23 km to the south of the discharge point (NT waters are approximately 16.2 km to the east) (**Figure 8-19**). The discharge modelling did not predict any exceedance of the PC99% NOEC threshold over a 48-hour period (i.e. the period over which ecotoxicity tests demonstrated an observable effect). Furthermore, the modelled results are considered conservative given the modelling did not take into consideration that the corrosion inhibitor will biodegrade over time during the hydrotest and thus reduce in concentration within the pipeline before being discharged. Therefore, Santos anticipates that discharge concentrations will be less than that modelled and mixing and dilution to NOEC PC99% will occur closer to the discharge point than indicated by the modelling outputs.

Based on the modelling results, discharge from the Commonwealth PLET will not enter NT waters above the NOEC threshold of 0.06 mg/L (PC99%) for any period of time. The modelling supports the conclusion that discharge of treated seawater from the Commonwealth PLET will not impact Marine Environmental Quality, nor Marine Ecosystems in either Commonwealth or NT waters.

With respect to the planned 1,000 m^3 MEG conditioning discharge at the Commonwealth PLET, MEG is soluble in water, does not volatilise or undergo photodegradation, and is not adsorbed on to soil particles (Hook and Revill, 2016). Ethylene glycols biodegrade readily when released to the environment, and several strains of micro-organisms can use them as an energy source. The ANZG for Fresh and Marine Water Quality specify a marine low reliability trigger value of 50,000 µg/L (50 mg/L) for MEG in seawater. The World Health Organization (WHO) has reported a NOEC of 24,000 ppm for MEG. In accordance with the Organisation for Economic Co-operation and Development because three NOECs are described for three separate taxonomic groups, a safety factor of 10 was adopted for the protection of marine fauna and benthic habitats. Based on the NOEC provided by WHO a protected no effect concentration (PNEC) of 2,400 ppm (or 2,400 mg/L) was used to inform the concentration level above which there is potential to result in an environmental impact (Chevron, 2020).

Based on the dilution rates predicted by the discharge modelling, chemicals will be diluted between 3,500 to 10,000 times within 7.5 km of the discharge point. This dilution rate will result in MEG concentrations well below the PNEC toxicity value of 2400 mg/L. Given there will also be rapid biodegradation of MEG during FCGT activities and upon discharge, the discharge of MEG from the Commonwealth PLET will not impact Marine Environmental Quality, nor Marine Ecosystems in either Commonwealth or NT waters.

While activities in Commonwealth waters are outside the scope of this report, the discharge plume from the contingency discharge of treated seawater arising from a wet buckle event in Commonwealth waters has the potential to cross into NT waters. Consequently, the potential for impact to NT Marine Environmental Quality was assessed using modelling results from the planned discharge modelling at the Commonwealth PLET. The contingency discharge modelling for KP84 was also referred to, but as it likely represents a lower volume of discharge to that that may be required in Commonwealth waters, it was not used for the basis of the assessment.

The bathymetry, seabed and metocean conditions at the Commonwealth PLET are considered comparable to those found anywhere along the section of the DPD pipeline in Commonwealth waters and consequently discharges anywhere along this 23 km section of pipeline are expected to behave in a similar manner with similar dispersion and dilution rates.

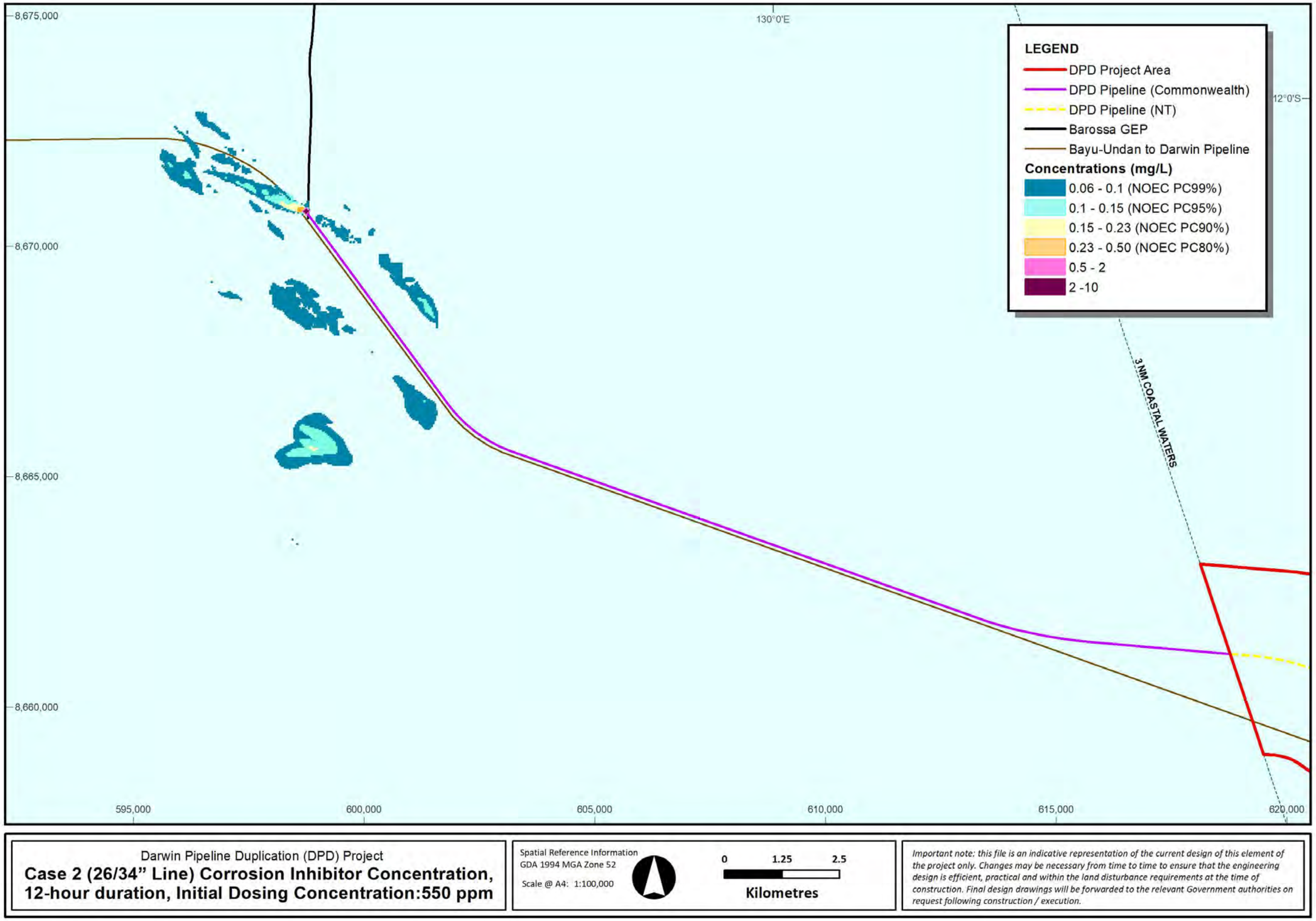

Figure 8-19 Predicted corrosion inhibitor concentrations assessed over a 12-hour continuous exposure period (calculated from 25 simulations)

Given that the volume of contingency treated seawater that would be discharged from a wet buckle event at the Commonwealth/ NT waters boundary would be much less than that to be discharged at the Commonwealth PLET, using the dispersion extents from that modelling is considered conservative and appropriate for the impact assessment.

As presented above, modelling predicted the maximum distance from the release location to where the NOEC threshold of 0.06 mg/L (PC99%) was exceeded for a 12-hour period was 7.23 km to the south of the discharge point (**Figure 8-19**). Given that, a discharge following a wet buckle event would need to be very close to the Commonwealth/ NT boundary for the plume to enter NT waters and even if it were to occur, the discharge modelling did not predict any exceedance of the PC99% NOEC threshold over a 48-hour period and thus no impact to Marine Environmental Quality, or Marine Ecosystems is expected.

In conclusion, while the discharge of treated seawater after an unlikely wet buckle event in Commonwealth waters will result in localised and temporary reduction in water quality around the discharge location, the chemicals that will be used are inherently biodegradable with low potential for bioaccumulation and as there was no predicted exceedance of the NOEC PC99% threshold over a 48-hour period, discharging treated seawater in Commonwealth waters does not have the potential to significantly impact Marine Environmental Quality in NT waters.

8.5.3 Discharge of water from backflushing activities during FCGT

As described in **Section 2.6.2** water will be taken from Darwin Harbour to provide water for FCGT activities. As filtering is required to remove the solids, the water will be filtered and regular cleaning of the filters via backflushing will be required. It is expected that approximately 300 m^3 of filter backflush water will be discharged over a period of approximately three days.

The discharged water from backflush activities will have a higher suspended solids loading compared to water extracted (i.e., higher than ambient Darwin Harbour water suspended solid concentration). The concentration of total suspended solids (TSS) from backflush water will be dictated by the ambient concentration of TSS from within Darwin Harbour. This will be variable due to tidal state and season, with water during spring tides and over the wet season water expected to be more turbid (i.e., higher TSS concentration of approximately 1,500 mg/L) than water during neap tides and over the dry season (i.e., lower TSS concentrations of approximately 680 mg/L). The size range of the TSS will vary between 50 – 150 µm.

Backflush water will be discharged onto the existing disturbed shore crossing construction site, and where possible, and dependent on the progress of shore crossing rock installation at time of FCGT activities, backflush water will be discharged onto installed rock, to baffle the flow of the discharged backflush and reduce sediment load returning to Darwin Harbour. Any increased sediment load is expected to rapidly dilute and disperse with the tidal movement. Given it will occur at the existing disturbance site, and due to the lack of benthic primary producer habitat in that location, no significant impact from discharging backflushed water is expected.

8.5.4 Invasive marine species

Vessels are the most common vector for the translocation of Invasive Marine Species (IMS) in the marine environment. IMS can be introduced or spread when vessels are mobilised to the operational area, particularly if the vessels originate from international waters with similar water temperatures (e.g. south-east Asia). IMS may be present as biofouling (e.g. adult sessile organisms) on vessel hulls and submersible equipment, and in the ballast water (e.g. as larvae). IMS require suitable habitat to become established in an area; many potential IMS are sessile benthic organisms (e.g. mussels).

The introduction of IMS may result in considerable modification of the environment through out-competing native species and modifying existing habitats. Such modifications may result in significant environmental impact, including decrease in biodiversity (from the reduction or loss of native marine species) and loss of fishing resources. Once established, IMS may be very difficult or impossible to eradicate from an area. The greatest risk of IMS colonising areas is considered to be in Darwin Harbour in the shallower water where there is suitable light and habitat available.

Darwin Harbour is a commercial port where large commercial vessels, such as cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels enter, exit and move around the harbour on a regular basis. Risks of IMS are monitored and managed by the Aquatic Biosecurity Unit of NT Fisheries. This includes monitoring for early detection, inspections and treatment of high-risk vessels entering Darwin and responding to reported sightings of IMS. Its current monitoring focuses on locations where IMS are most likely to occur, such as marinas, wharves and ports (NT Government, 2022).

The Project activities are not considered to have any significantly higher risk of introducing IMS into the area than regular activities within the harbour and the proposed controls are considered effective and appropriate to reduce the risk of introducing IMS and impacting Marine Environmental Quality to a low level.

8.5.5 Hydrocarbon spill – marine diesel oil

The release of marine diesel oil (MDO) fuel from a Project vessel is considered an unlikely event as it is for other commercial vessels that move in, out and within Darwin Harbour on a daily basis. Historical records show that vessel collisions are infrequent events and collisions resulting in rupture and release of fuels even more infrequent. With controls in place as per **Section 12**, including those dictating Darwin Port operations, vessel collisions will be prevented. MDO will be used on Project vessels rather than the more persistent intermediate or heavier fuel oils. Following best practice, conservative worst case spill volumes and exposure thresholds have been adopted for hydrocarbon spill modelling to inform risk assessment. The fuel tank volumes on Project vessels are within the range of fuel and hydrocarbon storage tank volumes present on the large commercial vessels that regularly use Darwin Harbour (Darwin Port, 2020).

8.5.5.1 Spill scenario selection

Refuelling incident

During pipelay activities, vessel to vessel refuelling may be required (**Section 2.8**). A minor spill (of up to approximately 10 m^3) of MDO could occur during vessel refuelling resulting in a loss of hydrocarbons to the marine environment at sea surface. Spills during refuelling can occur through several pathways, including fuel hose breaks, coupling failure or tank overfilling.

Spills resulting from overfilling will be contained within the vessel drains and slops tank system. In the event that the refuelling hose is ruptured, the fuel bunkering activity will cease by turning off the pump; the fuel remaining in the transfer line will escape to the environment as well as fuel released prior to the transfer operation being stopped. A worst-case spill volume was determined from transfer hose inventory and spill prevention measures including 'dry break' or 'break away' couplings, rapid shutdown of fuel pumps and spill response preparedness, with 10 m^3 considered to be the maximum volume that could escape from the hose prior to shut down.

A spill of MDO during refuelling was modelled within Darwin Harbour at KP114.

Vessel collision

While unlikely, it is considered credible that a release of MDO to the marine environment could occur from a collision between DPD Project vessels and another vessel. Such events could have sufficient impact to result in the rupture of a MDO tank. A number of prerequisite conditions must exist for a vessel collision to result in the loss of fuel to the environment:

+ The vessel must be involved in a collision:
  - Collisions involving offshore support vessels, comparable to those that will undertake DPD Project activities, are very uncommon. Statistics compiled by the Australian Transport Safety Bureau indicated that offshore support vessels were involved in only one collision-related incident between 2011 and 2020, and no pollution-related incidents from offshore support vessels were recorded in the same time period;
+ The collision must occur with sufficient force to rupture a fuel tank:
  - Fuel tanks are typically located at various positions around a vessel within the hull; and
+ The rupture must be of such a nature that the fuel can be released into the environment:
  - A tank rupture must be above or near the fuel level within the tank to result in a loss of containment from the tank. Once lost from the tank, fuel may leak to the environment or drain into the vessel hull. Fuel from ruptured tanks may be transferred to other tanks onboard, reducing the volume in the ruptured tank. Emergency fuel transfer measures are typically detailed in vessel Shipboard Oil Pollution Emergency Plans (SOPEPs).

Guidance from Australian Maritime Safety Authority (AMSA) on spill contingency planning for vessel-based activities (AMSA 2015) suggests 50% of the volume of the single largest tank on a vessel is appropriate to inform the risk assessment of an MDO release from a vessel collision. This is based on the scenario of a non-major collision of an oil tanker with tanks protected by a double hull. Both the shallow water and deep water pipelay vessels have all fuel tanks internally located and protected by water ballast compartments or double hull. Furthermore, with management actions in place, including safety exclusion zones around pipelay vessels, and surveillance of exclusion zones, only non-major collisions are considered credible. Santos has considered vessel specifications for all vessels that could be contracted and has determined that a worst-case spill (largest spill volume) in Offshore NT waters would be from the deep water pipelay vessel. No fuel tank onboard the deep water pipelay vessels considered exceeded 1,400 m^3, hence a 700 m^3 volume is considered suitable to inform the risk assessment for the deep water pipelay vessel. In Darwin Harbour, the worst-case spill (largest MDO tank) was considered to be from the shallow water pipelay barge. No fuel tank onboard the shallow water pipelay barges will exceed 600 m^3, hence 300 m^3 was used to inform spill modelling. In addition to the 300 m^3 spill scenario a smaller spill scenario of 87.5 m^3 was also modelled in Darwin Harbour, to be more representative of smaller Project vessels fuel tank sizes.

An MDO release of 700 m^3 from the deep water pipelay vessel was modelled at KP91.5 (offshore, outside of Darwin Harbour) and an MDO release of 300 m^3 from the shallow water pipelay barge and a smaller 87.5 m^3 release from a Project vessel was modelled at KP114 (within Darwin Harbour).

8.5.5.2 MDO characteristics

International Tanker Owners Pollution Federation (2011) and the Australian Marine Oil Spill Centre (AMOSC, 2011) categorise MDO as a light 'group II' hydrocarbon. In the marine environment, a 5% residual of the total quantity of diesel spilt will remain after the volatilisation and solubilisation processes associated with weathering.

A summary of the representative characteristics of MDO, is provided in **Table 8-8**.

Table 8-8 Summary of MDO characteristics

Parameter	Diesel
API Gravity	36.4
Specific Gravity	0.843
Wax Content (%)	0.05
Pour Point (°C)	Less than -36
Asphaltene (%)	Less than 0.05
Viscosity (cSt)	3.9 (@ 20°C)

Marine diesel oil is moderately persistent in the marine environment but has a low residual component (5%) following initial weathering. Under constant low winds (2.6 m/s), 41% of the surface slick is predicted to evaporate in the first 24 hours, and approximately 20% would remain on the sea surface after five days (RPS, 2022c). Under variable wind conditions, where the winds are of greater strength, entrainment into the upper water column is indicated to be significant. Approximately 72% is expected to entrain after 24 hours and further 24% is forecast to evaporate, leaving less than 1% floating on the sea surface. The low viscosity of MDO indicates that it will spread quickly when released and will form a thin to low thickness film on the sea surface, increasing the rate of evaporation. Marine diesel has a very low tendency for emulsion formation (Galieriková et al., 2021).

8.5.5.3 Hydrocarbon exposure values (Thresholds)

To inform impact assessment, exposure values that may be representative of biological impact have been identified. These are called 'moderate exposure value' and 'high exposure value'. Moderate and high exposure values are applied to the spill trajectory modelling to identify what hydrocarbon contact is predicted for surface (floating oil), subsurface (entrained oil and dissolved aromatic hydrocarbons), and shoreline accumulation of hydrocarbon. Low exposure values were also modelled. Low exposure values are not considered to be representative of a biological impact, but they are adequate for identifying the full range of environmental receptors that might be contacted by surface and/or subsurface hydrocarbons (NOPSEMA, 2019) and a visible sheen.

Determining exposure values that may be representative of biological impact is complex since the degree of impact will depend on the sensitivity of the receptors contacted, the duration of the exposure and the toxicity of the hydrocarbon type making the contact. The toxicity of a hydrocarbon will also change over time, due to weathering processes altering the composition of the hydrocarbon. To identify appropriate exposure values Santos has considered the advice provided by the National Offshore Petroleum, Safety and Environmental Management Authority (NOPSEMA) Bulletin #1 Oil Spill Modelling (NOPSEMA, 2019) and scientific literature. The hydrocarbon exposure values applied to the oil spill modelling are discussed in **Table 8-9** to **Table 8-12**. These tables explain how the exposure value is relevant to the risk evaluation.

Table 8-9 Floating hydrocarbon exposure values

Surface Oil Concentration (g/m^2)	Exposure value	Description
1	Low	Risk Evaluation It is recognised that a lower floating oil concentration of 1 g/m^2 (equivalent to a thickness of 0.001 mm or 1 ml of oil per m^2) is visible as a rainbow sheen on the sea surface. Although this is lower than the exposure value for ecological impacts, it may be relevant to socio-economic receptors.
10	Moderate	Risk Evaluation There is a paucity of data on floating oil concentrations with respect to impacts to marine organisms. Hydrocarbon concentrations for registering biological impacts resulting from contact of surface slicks have been estimated by different researchers at about 10 to 25 g/m^2 (French et al., 1999; Koops et al., 2004). The impact of floating oil on birds is better understood than on other receptors. A conservative exposure value of 10 g/m^2 has been applied to impacts from surface hydrocarbons (floating oil). Although based on birds, this hydrocarbon exposure value is also considered appropriate for turtles, sea snakes and marine mammals
50	High	Risk Evaluation At greater thicknesses the potential for impact of surface oil to wildlife increases. All other things being equal, contact to wildlife by surface oil at 50 g/m^2 is expected to result in a greater impact.

Table 8-10 Shoreline hydrocarbon accumulation exposure values

Shoreline Oil Concentration (g/m^2)	Exposure value	Description
10	Low	Risk Evaluation An accumulated concentration of oil above 10 g/m^2 on shorelines is considered to represent a level of socio-economic effect (NOPSEMA, 2019). For example, reduction in visual amenity of shorelines. This value has been used in previous studies to represent a low contact value for interpreting shoreline accumulation modelling results (French-McCay, 2005a, 2005b).
100	Moderate	Risk Evaluation The impact exposure value for exposure to hydrocarbons stranded on shorelines is derived from levels likely to cause adverse impacts to marine or coastal fauna and habitats. These habitats and marine fauna known to use shorelines are most at risk of exposure to shoreline accumulations of oil, due to smothering of intertidal habitats (such as mangroves and emergent coral reefs) and coating of marine fauna. Environmental risk assessment studies (French-McCay, 2009) report that an oil thickness of 0.1 mm (100 g/m^2) on shorelines is assumed as the lethal exposure value for invertebrates on hard substrates (rocky, artificial or man-made) and sediments (mud, silt, sand or gravel) in intertidal habitats. Therefore, a conservative exposure value for impacts of 100 g/m^2 has been applied to impacts from shoreline accumulation of hydrocarbons.
1,000	High	Risk Evaluation At greater thicknesses, the potential for impact of accumulated oil to shoreline receptors increases. Accumulation of oil above 1000 g/m^2 is expected to result in a greater impact.

Table 8-11 Dissolved aromatic hydrocarbon exposure values

Water Column Oil Concentration (ppb)	Exposure value	Description
10	Low	Risk Evaluation Dissolved Aromatic Hydrocarbons (DAH) include the monoaromatic hydrocarbons (compounds with a single benzene ring such as benzene, toluene, ethyl benzene, and xylenes) and polycyclic aromatic hydrocarbons (PAHs – compounds with multiple benzene rings such as naphthalene and phenanthrene). These compounds have a greater bioavailability that other components of oil and are considered to be main contributors to oil toxicity. The toxicity of DAHs is a function of the concentration and the duration of exposure by sensitive receptors with greater concentration and exposure time causing more severe impacts. Typically tests of toxicity done under laboratory conditions measure toxicity as a proportion of test organisms affected (for example, 50% mortality or LC50) at the end of a set time period, often 48 or 96 hours. French-McCay (2002) in a review of literature, reported LC50 for dissolved PAHs with 96 hour exposure, range between 30 ppb for sensitive species (2.5th-percentile species) and 2,260 ppb for insensitive species (97.5th-percentile species), with an average of about 250 ppb. The range of LC50s for PAHs obtained under turbulent conditions (this includes fine oil droplets) was 6 ppb to 410 ppb with an average of 50 ppb (French McCay, 2002). More recently, French-McKay (2018) described in-water thresholds as 10 – 100 µg / L (equivalent to ppb). Regarding the effect of UV on PAH toxicity, French-McKay et al (2018) uses the findings of DWH NRDA Trustees (2016) to adjust for this affect by reducing the water column exposure thresholds by 10 x in the top 20 m of the water column.
50	Moderate	Risk Evaluation Approximates potential toxic effects, particularly sublethal effects to sensitive species (refer to above text). Consistent with NOPSEMA (2019).
400	High	Risk Evaluation Approximates toxic effects including lethal effects to sensitive species (NOPSEMA, 2019).

Table 8-12 Entrained hydrocarbon exposure values

Water Column Oil Concentration (ppb)	Exposure value	Description
10	Low	Risk Evaluation Entrained hydrocarbons (also referred to as total WAF), as opposed to dissolved, are oil droplets suspended in the water column and insoluble. Entrained hydrocarbons are not as bioavailable to marine organisms compared to DAHs and on that basis are considered to be a less toxic, especially over shorter exposure time frames. Entrained hydrocarbons still have potential effects on marine organisms through direct contact with exposed tissues and ingestion (NRC, 2005) however the level of exposure causing effects is considered to be considerably higher than for dissolved hydrocarbons. Much of the published scientific literature does not provide sufficient information to determine if toxicity is caused by entrained hydrocarbons, but rather the toxicity of total oils which includes both dissolved and entrained components. Variations in the methodology of the total water accommodated fraction (TWAF (entrained and dissolved)) may account for much of the observed wide variation in reported exposure values, which also depend on the test organism types, duration of exposure, oil type and the initial oil concentration. Total oil toxicity acute effects of total oil as LC50 for molluscs range from 500 to 2,000 ppb (Clark et al., 2001; Long and Holdway, 2002). A wider range of LC50 values have been reported for species of crustacea and fish from 100 to 258,000,000 ppb (Gulec et al., 1997; Gulec and Holdway, 2000; Clark et al., 2001) and 45 to 465,000,000 ppb (Gulec and Holdway, 2000; Barron et al., 2004), respectively. The 10 ppb exposure value represents the very lowest concentration and corresponds generally with the lowest trigger levels for chronic exposure for entrained hydrocarbons in the ANZECC (2018) water quality guidelines. This is consistent with NOPSEMA (2019) guidance.
100	Moderate	Risk Evaluation The 100 ppb exposure value is considered to be representative of sub-lethal impacts to most species and lethal impacts to sensitive species based on toxicity testing as described above. This is considered conservative as toxicity to marine organisms from oil is likely to be driven by the more bioavailable dissolved aromatic fraction, which is typically not differentiated from entrained hydrocarbon in toxicity tests

Water Column Oil Concentration (ppb)	Exposure value	Description
		using water accommodated fractions (WAFs). Given entrained hydrocarbon is expected to have lower toxicity than dissolved aromatics, especially over time periods where these soluble fractions have dissoluted from entrained hydrocarbon, the moderate exposure value is considered appropriate for risk evaluation.

8.5.5.4 Hydrocarbon spill modelling

To determine the spatial extent of impacts from potential MDO spills, modelling was completed for the vessel collision and refuelling incident scenarios (**Appendix 15**).

In this study, oil spill modelling was undertaken using a three-dimensional oil spill trajectory and weathering model, SIMAP (Spill Impact Mapping and Analysis Program), which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces. A total of 100 individual 'realisations' made up the full stochastic simulation set for each of the spill scenarios.

For each set of 100 stochastic realisations, SIMAP spatially tracked the surface oil, entrained oil in the water column, dissolved oil and oil on shorelines.

The outputs of this modelling showed a number of different possible outcomes of a spill, which were then analysed to determine the concentrations of hydrocarbon at each grid cell of the model, providing information about the probability of contact and concentration at contact of hydrocarbons at receptor locations.

The model settings applied to the assessment are summarised in **Table 8-13**.

Table 8-13 Summary of oil spill model settings for four modelled diesel release scenarios

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Description	Vessel fuel tank rupture	Vessel fuel tank rupture	Vessel to vessel refuelling	Vessel fuel tank rupture
Vessel Class	DWPLV	PSV/CSV	Any	SWPLB
Location Name	KP91.5	KP114	KP114	KP114
Spill Volume (m^3)	700	87.5	10	300
Release Duration (Hours)	6	6	Instantaneous	6
Simulation Length (Days)	50	20	10	20

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Number of randomly selected spill start times per season	100			
Model Period	Wet season (November to April) and dry season (May to October)			
Oil type	MDO			
Release type	Surface			
Floating oil exposure thresholds (g/m^2)	1 (low exposure) 10 (moderate exposure) 50 (high exposure)			
Shoreline accumulation thresholds (g/m^2)	10 (low potential exposure) 100 (moderate potential exposure) 1,000 (high potential exposure)			
Dissolved hydrocarbon exposure thresholds (ppb)	10 (10 ppb x 1 hr, potential low exposure) 50 (50 ppb x 1 hr, potential moderate exposure) 400 (400 ppb x 1 hr, potential high exposure)			
Entrained hydrocarbon exposure thresholds (ppb)	10 (10 ppb x 1 hr, potential low exposure) 100 (100 ppb x 1 hr, potential high exposure)			

8.5.5.5 Summary of modelling results – Scenario 1 – 700 m^3 release of MDO at KP91.5

Scenario 1 modelling in **Figure 8-20** and **Figure 8-21**, demonstrates the moderate and above impact threshold contours, and moderate and above shoreline loading impact threshold in a stochastic representation of 100 simulations, in both dry and wet seasons. Therefore, these figures represent and area in which the threshold may be reached however, and importantly does not represent an area of a single spill.

The Scenario 1 stochastic modelling results showed that due to the location, the predominant movement of the MDO would be in a northwest and south easterly direction. This was largely due to the sweep of the ebb and flood tide.

The maximum distances of floating MDO exposure zones to the release location at the low (≥1 g/m^2), moderate (≥10 g/m^2) and high (≥ 50 g/m^2) thresholds were 26.4 km (southeast), 19.9 km (southeast) and 14 km (west northwest), respectively.

The probability of MDO accumulating on any shoreline on shorelines at, or above, the low threshold (≥10 g/m^2) was highest for spills commencing during the wet season conditions (50%) and lower during the dry season months (25%) conditions. At the moderate threshold (100 g/m^2), these probabilities were reduced to 12% and 3%, respectively. The quickest time for MDO to accumulate on shorelines at, or above, the moderate threshold was 1.29 days during the wet season. The greatest volume of MDO ashore from a single spill during dry and wet conditions was 28.1 m^3 and 59.7 m^3, respectively. The wet season simulation resulting in the highest volume ashore took 2 days to initially reach the shorelines. The maximum length of shoreline contacted at the moderate threshold was 12 km (dry season).

The greatest probabilities of MDO accumulation at, or above, the moderate threshold were predicted for the East Arm (9% wet and 0% dry seasons), Outer Harbour East (6% wet and 0% dry seasons) and Outer Harbour West (3% wet and 2% dry seasons). The greatest volume (peak) of MDO accumulation during the dry and wet seasons was predicted to occur along Outer Harbour West (22.2 m^3) and Outer Harbour East shorelines (43.8 m^3), respectively. The minimum time for an oil spill simulation to reach a shoreline (at the moderate threshold) was 1.96 days and 1.29 days at Outer Harbour West during the dry season and wet season, respectively.

Dissolved hydrocarbon exposure at, or above, the low (10 ppb) and moderate (≥ 50 ppb) thresholds were 16.9 km (west) and 13.7 km (southeast), respectively, from the release location during both seasons. No exposure was predicted for either season at the high threshold (≥ 400 ppb).

For entrained hydrocarbon exposure, the maximum distances from the release location within the 0 – 10 m depth layer to the low (at the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds), ranged between 182.3 km northeast (wet conditions) and 51.3 km east northeast (wet conditions) from the release location, respectively.

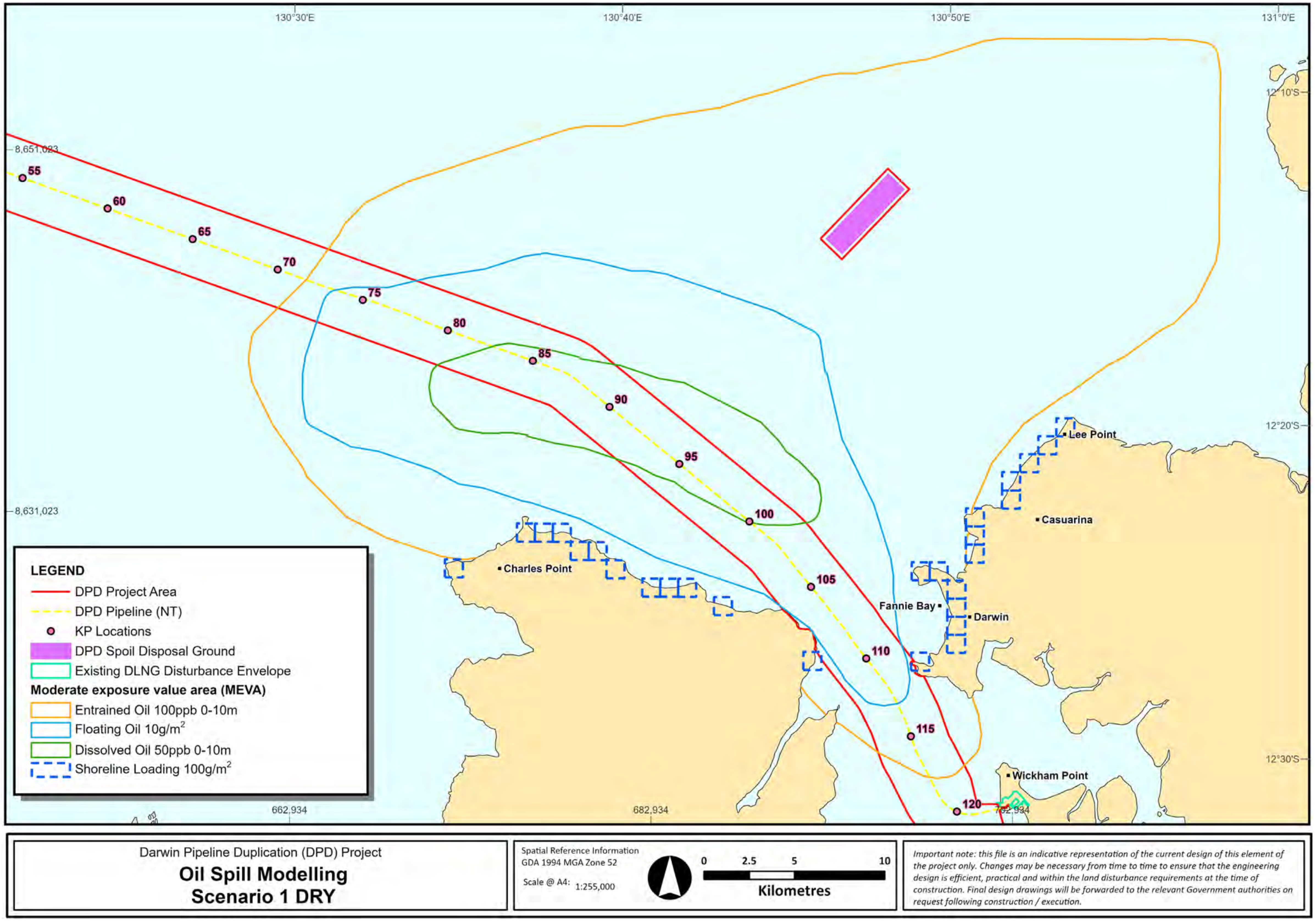

Figure 8-20 Stochastic MDO spill modelling (100 simulations) – Scenario 1 – dry season

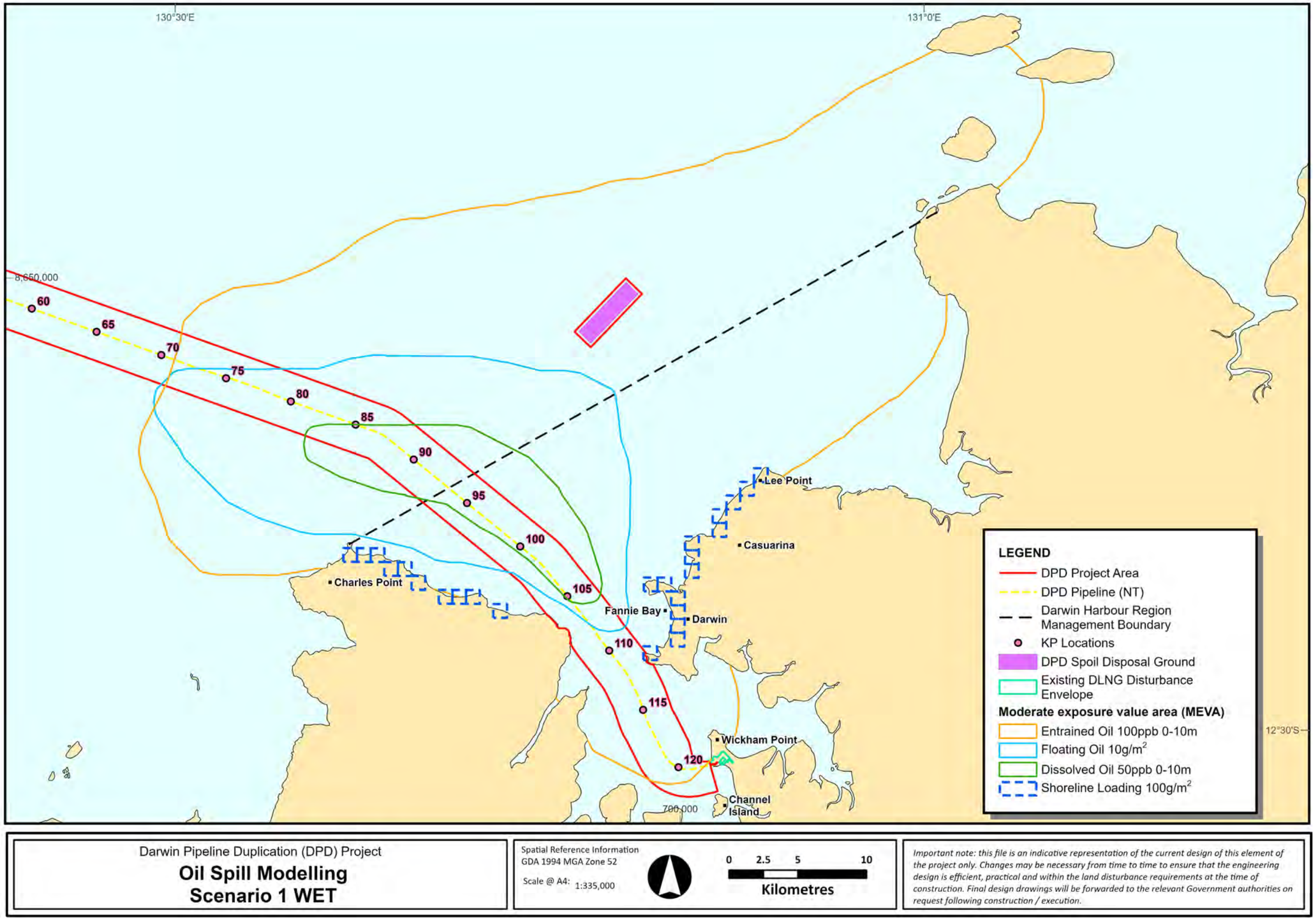

Figure 8-21 Stochastic MDO spill modelling (100 simulations)– Scenario 1 – wet season

8.5.5.6 Summary of modelling results – Scenario 2 – 87.5 m^3 of MDO at KP114

Scenario 2 modelling in **Figure 8-22** and **Figure 8-23**, demonstrates the moderate and above impact threshold contours, and moderate and above shoreline loading impact threshold in a stochastic representation of 100 simulations, in both dry and wet seasons. Therefore, these figures represent and area in which the threshold may be reached, importantly however, does not represent an area of a single spill.

The Scenario 2 modelling results indicated that the predominant movement for the spilt MDO was in a north and south easterly direction, in line with the major tidal axis. Due to the high energy environment, the release was predicted to spread rapidly across the water surface within various reaches of the harbour.

The maximum distances to the low, moderate and high floating oil exposure zones were 29.3 km (west northwest), 14.9 km (southeast) and 0.1 km (west northwest), respectively.

The probability of oil accumulation at, or above, the low threshold was 94% (dry season) and 83% (wet season). At the moderate threshold (100 g/m^2) these probabilities were reduced to 45% and 52%, respectively. The quickest time for a spill to reach a shoreline and for oil accumulation to occur at, or above, the moderate threshold ranged between 0.38 days (dry season) and 0.21 days (wet season). The maximum volume ashore for a single spill ranged between 24.8 m^3 (dry season) and 24.7 m^3 (wet season). The maximum length of shoreline contacted at the moderate threshold was 6.5 km (dry season).

The highest probability of oil accumulation at the moderate threshold was predicted along West Arm (38% dry and 31% wet conditions), East Arm (8% dry, 16% wet) and Wickham Point (1% dry, 7% wet) shorelines. The highest volume of oil accumulation during the dry and wet seasons occurred along the West Arm shoreline (24.2 m^3 (dry season) and 24.6 m^3 (wet season)). The minimum time for oil accumulation at the moderate threshold was 0.38 days (West Arm) for the dry season and 0.21 days (East Arm) during the wet season conditions.

There was no exposure predicted for the moderate and high dissolved hydrocarbon thresholds. The maximum distances to the low threshold exposure zones during the dry and wet seasons were 3.9 km and 12.2 km north northwest, respectively. Exposure was limited to the 0 – 10 m depth layer.

The maximum distances travelled by entrained hydrocarbons within the 0 – 10 m depth layers at the low and moderate thresholds ranged between 36.1 km and 23.9 km northwest from the release location.

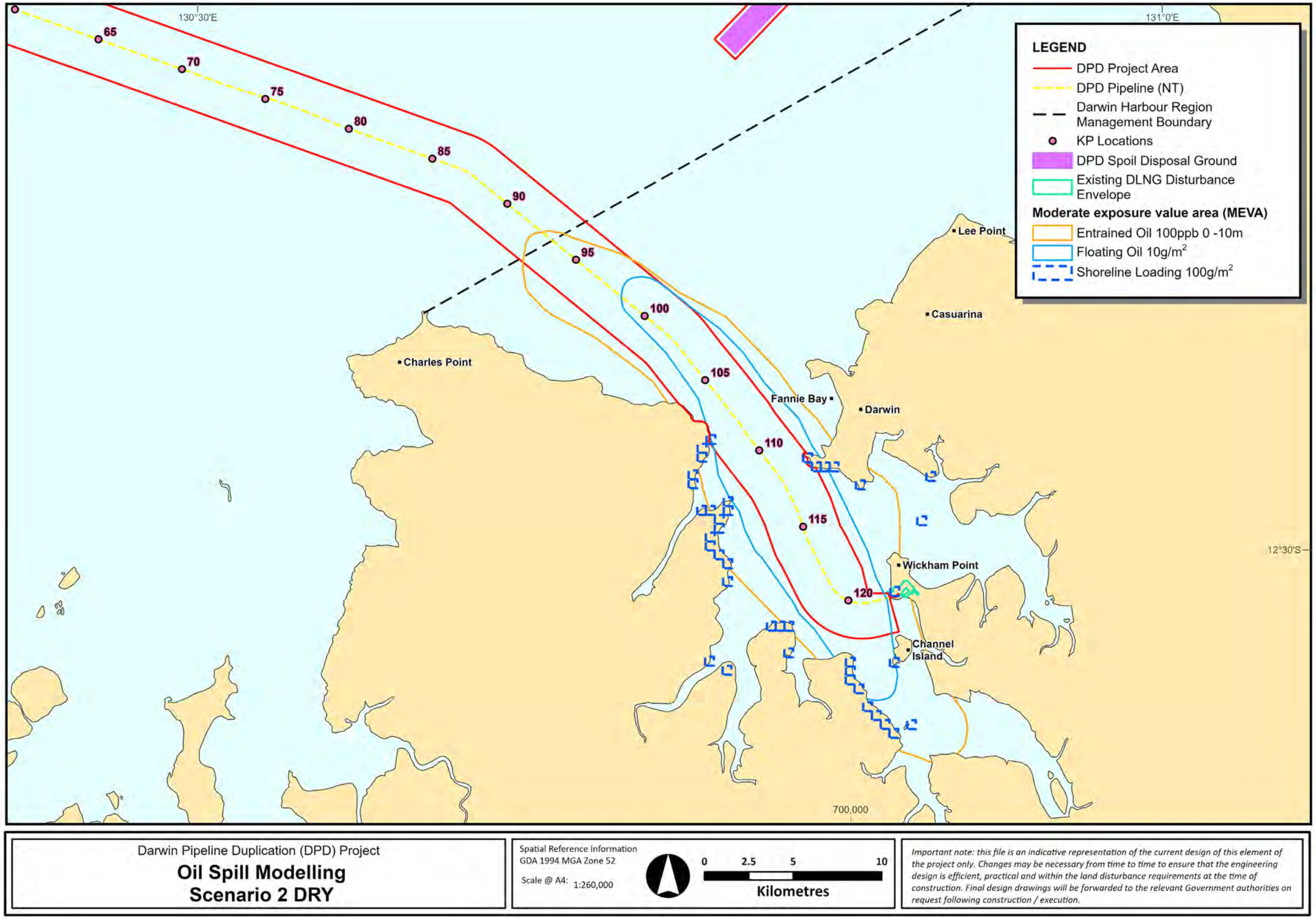

Figure 8-22 Stochastic MDO spill modelling (100 simulations)– Scenario 2 – dry season (Note: no dissolved oil exposure at MEVA [50ppb])

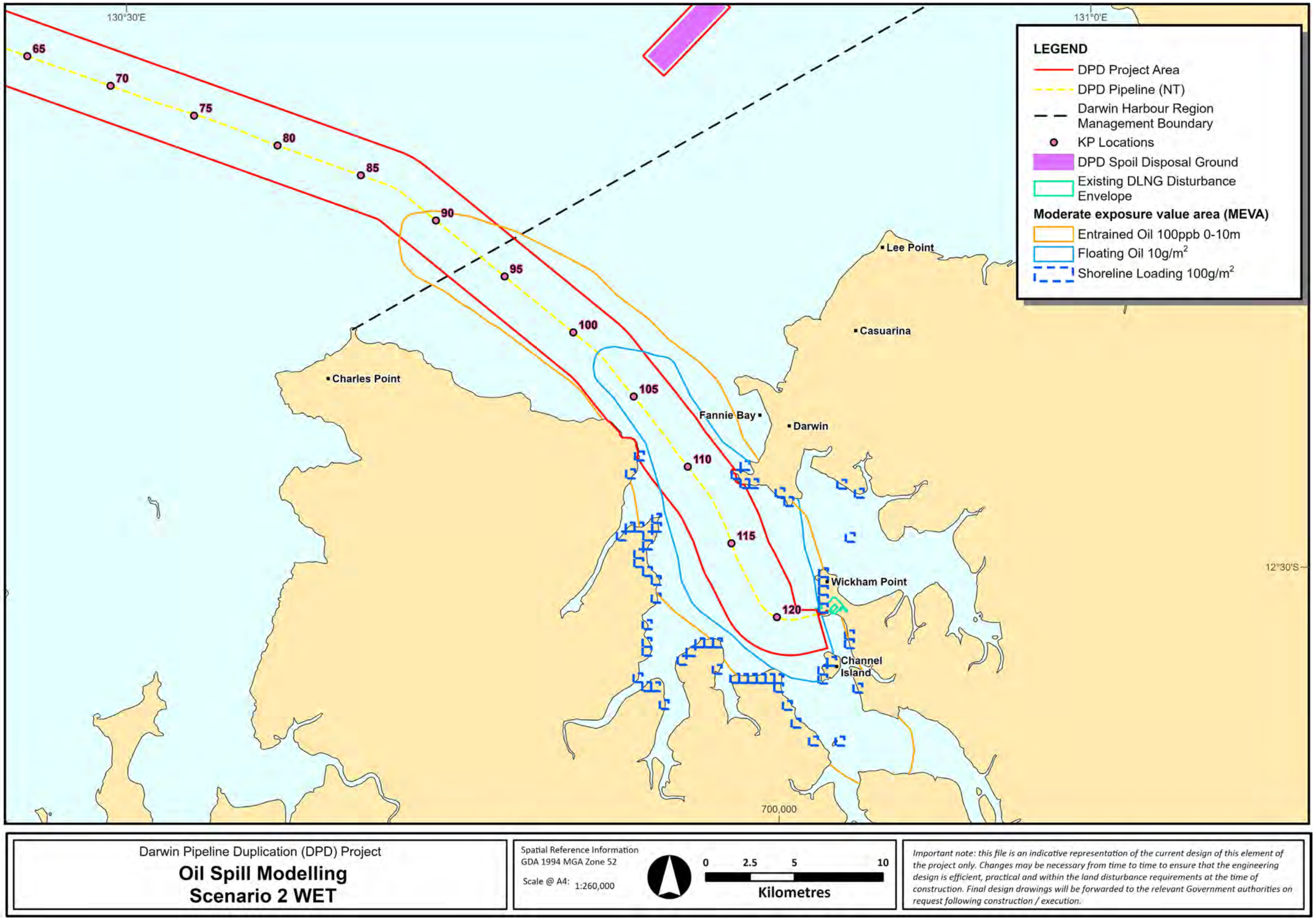

Figure 8-23 Stochastic MDO spill modelling (100 simulations)– Scenario 2 – wet season (Note: no dissolved oil exposure at MEVA [50ppb])

8.5.5.7 Summary of modelling results – Scenario 3 10 m^3 of MDO at KP114

Scenario 3 modelling in **Figure 8-24** and **Figure 8-25**, demonstrates the moderate and above impact threshold contours, and moderate and above shoreline loading impact threshold in a stochastic representation of 100 simulations, in both dry and wet seasons. Therefore, these figures represent and area in which the threshold may be reached, importantly however, does not represent an area of a single spill.

In Scenario 3, floating oil exposure zones to the low and moderate thresholds were limited to 22.9 km (northwest) and 12.5 km (northwest), respectively during dry season conditions. There was no exposure predicted for the high threshold. Only the Outer Harbour waters were predicted to be contacted by floating oil at or above the moderate threshold, with a very low probability (2%) during the dry season and no exposure during the wet season.

During the dry and wet seasons, the probability of oil accumulation at the low threshold and moderate threshold was 58% and 14% respectively, and the minimum time was 0.25 days and 0.29 days, respectively. The maximum volume ashore for a single spill ranged between 3.9 m^3 (dry season) and 4.3 m^3 (wet season). The maximum length of shoreline contacted at the moderate threshold was 2 km for the two seasons.

The West Arm (6% dry and 8% wet seasons) and East Arm (4% dry and 6% wet seasons) shorelines recorded the highest probability of oil accumulation at the moderate threshold. The minimum time before the accumulation was 0.38 days (West Arm) during the dry season and 0.29 days (East Arm and West Arm) during the wet season conditions.

There was no dissolved hydrocarbon exposure predicted for any spills during this scenario at or above the low threshold (≥ 10 ppb).

Entrained hydrocarbons within the 0 – 10 m depth layers for the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds, were predicted to range between 32 km and 19.6 km northwest.

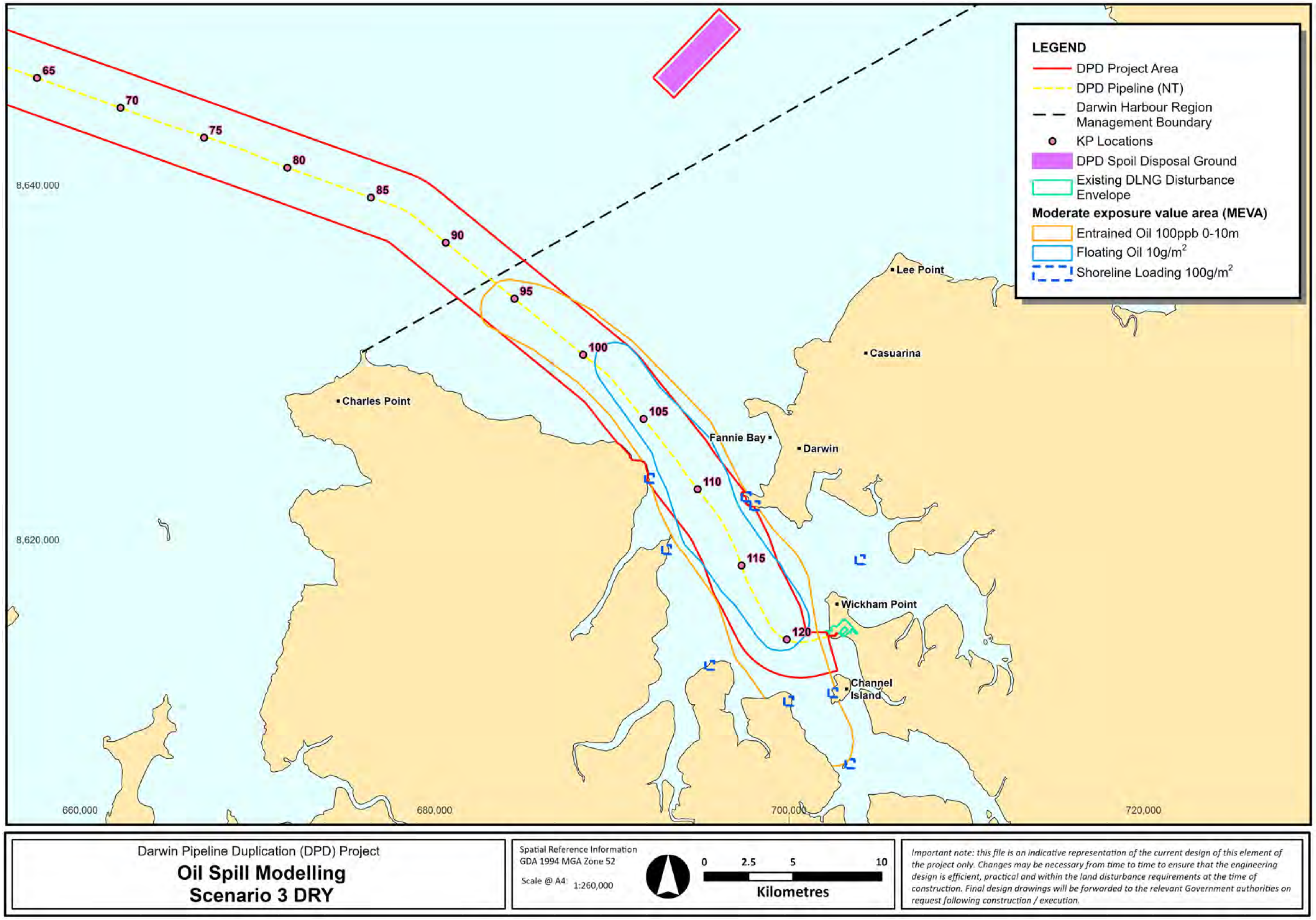

Figure 8-24 Stochastic MDO spill modelling (100 simulations)– Scenario 3 – dry season (Note: no dissolved oil exposure at MEVA [50ppb])

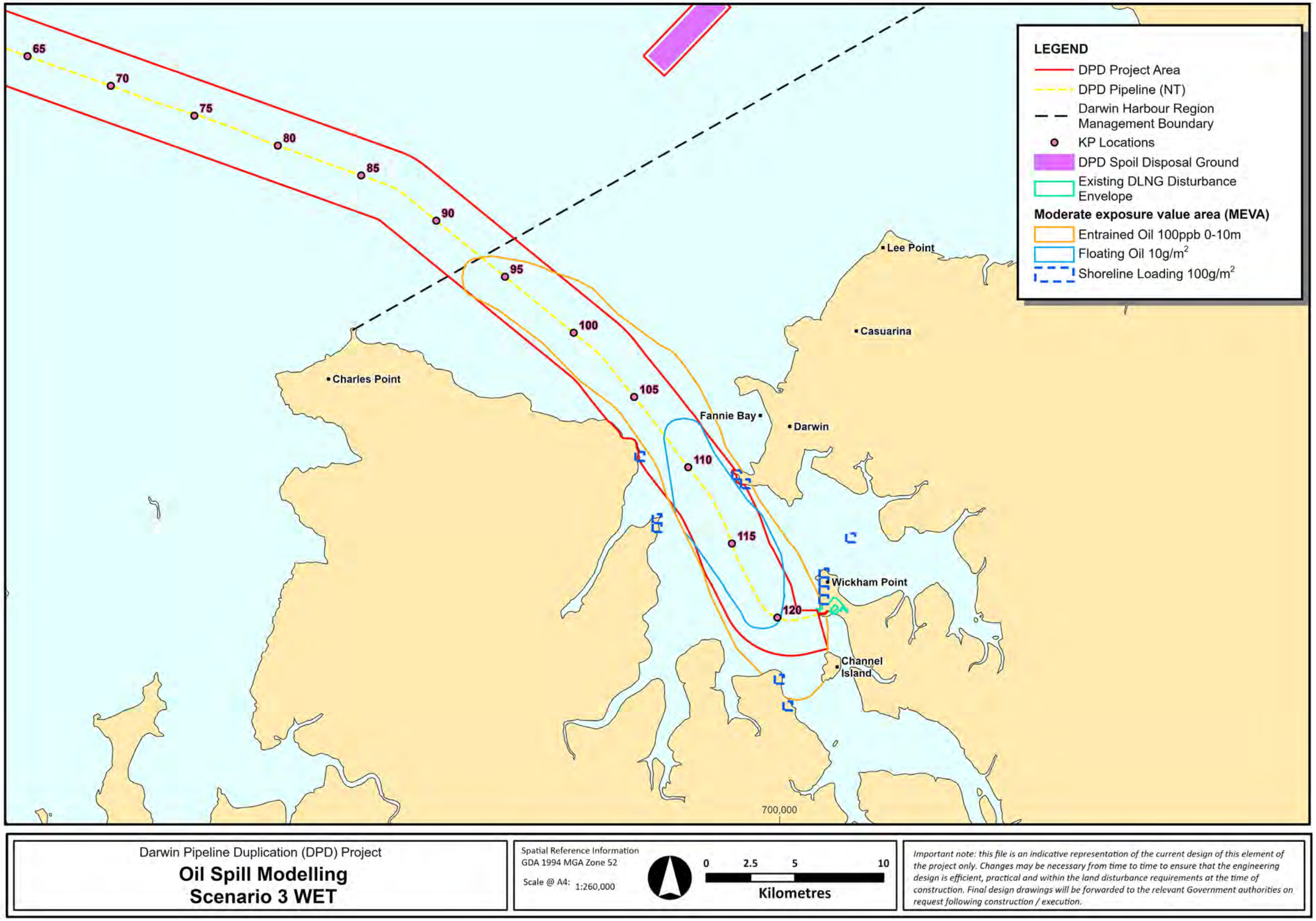

Figure 8-25 Stochastic MDO spill modelling (100 simulations)– Scenario 3 – wet season (Note: no dissolved oil exposure at MEVA [50ppb])

8.5.5.8 Summary of modelling results – Scenario 4 300 m^3 of MDO at KP114

Scenario 4 modelling in **Figure 8-26** and **Figure 8-27**, demonstrates the moderate and above impact threshold contours, and moderate and above shoreline loading impact threshold in a stochastic representation of 100 simulations, in both dry and wet seasons. Therefore, these figures represent and area in which the threshold may be reached however, does not represent an area of a single spill.

The Scenario 4 modelling results demonstrated that floating MDO exposure zones to the low, moderate and high thresholds were limited to 33.4 km (northwest; wet season), 19.6 km (northwest; dry season) and 10.2 km (north-northwest; dry season), respectively.

The probability of shoreline accumulation at, or above, the low threshold (10 g/m^2) was 100% (dry season) and 91% (wet season). The minimum time before MDO accumulation at, or above, the low threshold was 0.21 days during dry and wet seasons. The maximum volume ashore for a single spill during the dry and wet season was 114.8 m^3 and 115.5 m^3, respectively, and the maximum length of shoreline contacted at the low threshold was 57.7 km (dry season) and 54.2 km (wet season).

The highest probability of MDO accumulation at the low threshold was predicted along the West Arm (88% dry and 49% wet seasons) and East Arm (44% dry and 60% wet season) shorelines. The highest volume of oil accumulation during the dry and wet seasons occurred along the West Arm shoreline (103.5 m^3 (dry season) and 111.7 m^3 (wet season)).

The maximum distances travelled by dissolved hydrocarbons from the release location to the low (≥ 10 ppb) exposure zone was 12.8 km (dry season) and 20.0 km (wet season), whilst distances were reduced to 0.6 km (dry season) and 7.3 km (wet season) for the moderate (≥ 50 ppb) exposure threshold. Exposure was limited to the 0 – 10 m depth layer. No exposure was predicted for the high (≥ 400 ppb) threshold.

Dissolved hydrocarbon exposure at the low threshold was also predicted at shipwreck receptors during the dry (3) and wet seasons (5) with dry season probabilities ranging from 1 – 10% and wet season probabilities of exposure ranging between 2 – 17%. The greatest probability of low threshold exposure during the dry and wet season was predicted for Ham Luong and Mauna Loa USAT, respectively.

The maximum distances travelled by entrained hydrocarbons from the release location to the low (≥ 10 ppb) exposure zone was 41.7 km (dry season) and 48.3 km (wet season), whilst distances were reduced to 30.3 km (dry season) and 32.4 km (wet season) for the moderate exposure threshold.

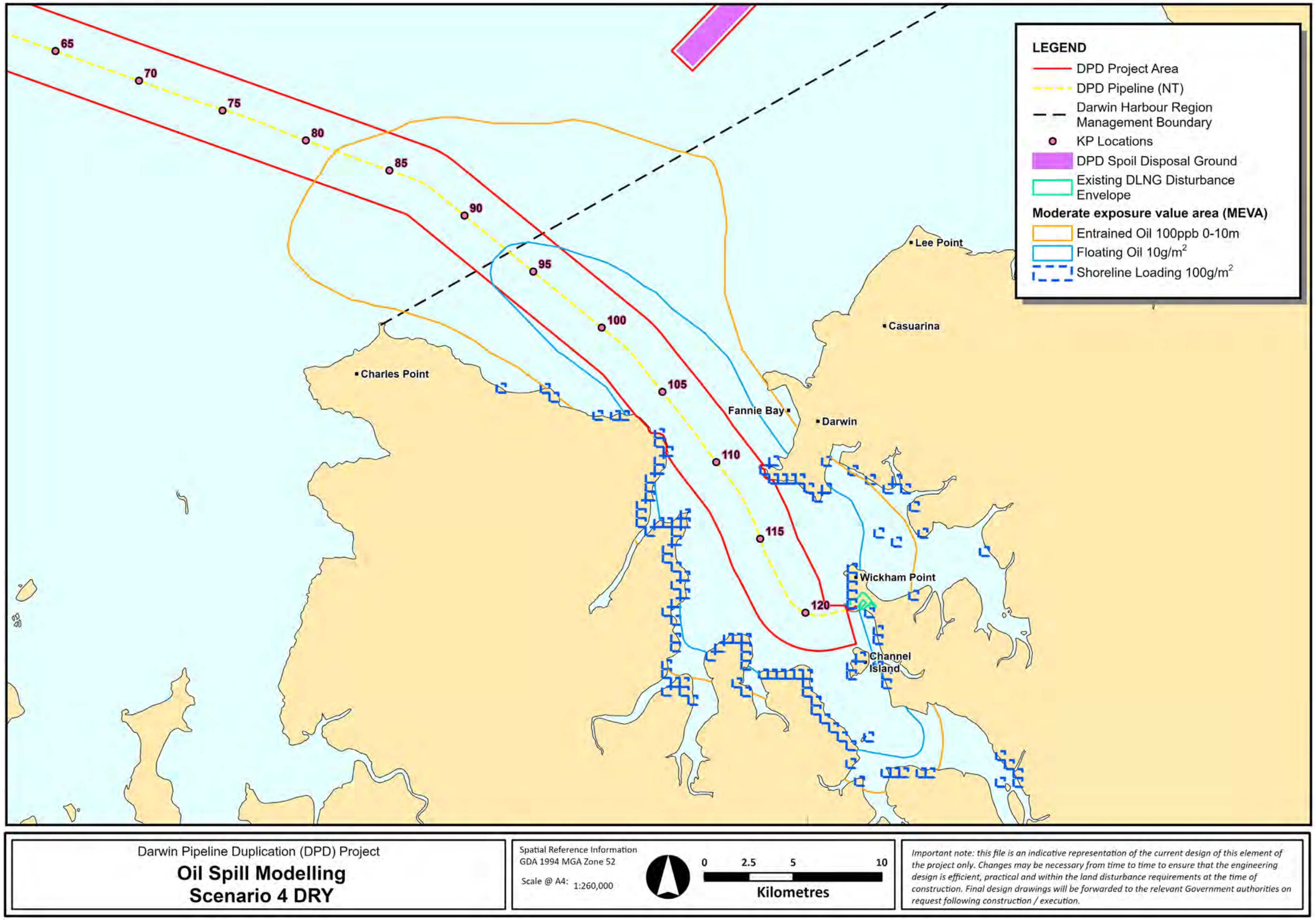

Figure 8-26 Stochastic MDO spill modelling (100 simulations)– Scenario 4 – dry season (Note: no dissolved oil exposure at MEVA [50ppb])

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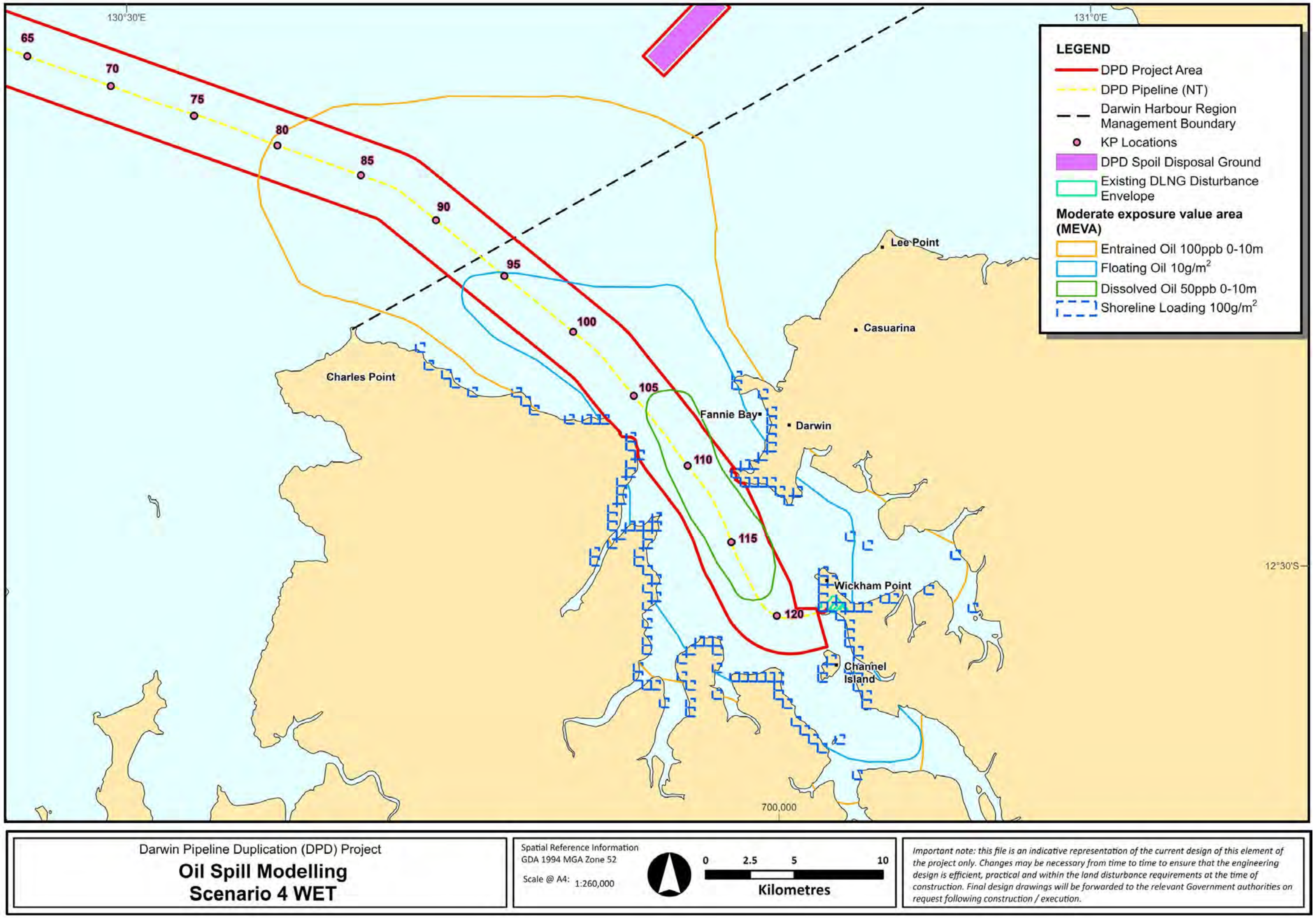

Figure 8-27 Stochastic MDO spill modelling (100 simulations)– Scenario 4 – wet season

8.5.5.9 Potential impacts to water quality

A surface release of MDO to the marine environment would result in a temporary reduction in water quality in the upper surface of the water column (0-10m). As a light hydrocarbon, MDO undergoes rapid spreading and evaporative loss in warm waters, indicating that a surface slick will be temporary although can spread over relatively large areas at low concentrations. The degree to which MDO stays on the surface to evaporate or entrains into the upper water column is dictated by the prevailing metocean conditions. Under moderate winds (5 m/s), 40% of the initial surface slick is predicted to remain as surface oil after 24 hours, decreasing further to approximately 10% after 48 hours and approximately 1% after 72 hours (**Appendix 15**). In moderate strength winds and above, MDO will readily entrain into the surface layer of the water column due to the action of breaking waves. Across the modelled worst-case spill scenarios, the greatest potential scale of water quality impacts (i.e. above a moderate exposure level) is from entrained MDO, followed by floating MDO (refer **Figure 8-20** to **Figure 8-27**), noting that the figures presented do not represent a single credible oil spill, they represent 100 simulations overlaid. Both entrained MDO and floating MDO could reach shallow waters and coastal areas at the mouth of Darwin Harbour and within Darwin Harbour, depending upon volume and location of spill. For a larger spill volume associated with a worst case offshore pipelay vessel collision, entrained MDO above a moderate exposure threshold could also reach Gunn Point and Vernon Islands and the extremity of its distribution during the wet season (**Figure 8-21**). Dissolved MDO, above a moderate exposure level, was predicted to occur over a smaller spatial scale that entrained or floating MDO. The distribution of modelled contours of dissolved MDO suggest that it would be less likely to reach shorelines and shallow areas above a moderate exposure (impact) threshold.

The main impacts from a deterioration in water quality as a result of a MDO release from a vessel collision are impacts to marine fauna and flora. This could occur within the top 10m of the water column or where floating, entrained, or dissolved MDO reaches shallow coastal areas <10m. These are discussed in detail in **Section 9.5.9**. While the location and spatial scale of impacts to shorelines and shallow/intertidal sediments/platforms would depend upon the volume, location and prevailing conditions associated with the spill, worst case spill modelling indicates that impacts (i.e. above a moderate threshold) could occur within Darwin Harbour or at the mouth of Darwin Harbour.

8.5.5.10 Potential impacts to sediment quality

Potential impacts to sediment quality in the vicinity of the release are dependent on the presence of hydrocarbon residue in the water column, which may filter down to sediments or continue to biodegrade on the surface.

There may be potential for impacts to sediment quality should surface, entrained or dissolved hydrocarbons reach shorelines, intertidal platforms and/or shallow sub-tidal soft sediments. The degree of impact is dependent upon the type of substrate, the tidal reach of the shoreline (for shallow sub-tidal soft sediments) and the continued weathering of the MDO. Potential impacts include indirect impacts to foraging habitats for marine turtles, birds and fish. There may also be direct, lethal or sub-lethal impacts to benthic infauna through toxic effects and smothering (**Section 9.5.9**).

8.6 Environmental management

The controls to manage impacts and risks to Marine Environmental Quality are presented in **Table 12-1** and have been carried through to management plans as relevant. Controls have been informed by referral commitments and subsequent feedback and consultation with government and the public and have been reviewed through ENVID workshops (refer **Section 7.4**) and during EMP development. The management table (**Table 12-1**) should be viewed as a consolidated list of measures to avoid or mitigate impacts of the DPD Project.

8.7 Conclusion of residual impacts and risks and predicted outcome

The assessment of residual impacts and risks to Marine Environmental Quality from the Project is summarised in **Table 8-14**. The management measures proposed in **Table 12-1** are considered effective and appropriate to reduce potential impacts to Marine Environmental Quality to a minor level and reduce risks to a low level.

The impact and risk rankings were determined during ENVID workshops and followed the approach outlined in **Section 7.4**. The residual rankings are in the acceptable range as per Santos requirements (**Table 7-3** and **Table 7-4**) and impacts and risks have also been reduced to as low as reasonably practicable.

Santos considers that the development of the Project will be consistent with the NT EPA's objectives for water quality, sediment quality and biota.

Table 8-14 Residual impact and risk rating for Marine Environmental Quality

Aspect	Potential impact	Residual impacts and risks rating
Planned events[1]		
Seabed disturbance	Disturbance of seabed during trenching and spoil disposal activities resulting in an increase in sedimentation and reduction in water quality	Minor
Contingency treated seawater discharge	Reduce water quality because of discharge of chemically treated seawater	Negligible
Discharge of water from backflushing activities during FCGT	Reduce water quality because of discharge of water with higher sediment load when backflushing filters	Negligible
Unplanned events[2]		
Invasive marine species	Introduction of IMS impact the environment by modifying existing habitats and decreasing biodiversity Consequence assessment: Major Likelihood assessment: Unlikely	Low
Hydrocarbon spill	Impact to Marine Environmental Quality from loss of hydrocarbons (MDO/marine grade oil (MGO)) from: + A bunkering incident Consequence assessment: Minor Likelihood assessment: Possible + A vessel collision Consequence assessment: Moderate Likelihood assessment: Unlikely	Low

1 All planned events have been rated as they will occur or are a planned contingency, therefore only the activity's consequence (ranging from negligible to critical) has been considered for the risk assessment, refer to **Table 7-3**.

2. The assessment of the unplanned events considered both the likelihood (refer **Table 7-2**) and the consequence (refer **Table 7-3**) of an activity, and therefore the residual risk rating has been calculated using **Table 7-4**.

9 Marine Ecosystems

This section provides further assessment of DPD Project impacts and risks to the NT EPA environmental factor of Marine Ecosystems identified since the referral submission. It addresses relevant additional information requirements requested by the NT EPA and submissions received on the referral from government departments and the public, using additional data and studies, conducted since the original submission of the referral.

9.1 Environmental objective

The NT EPA environmental objective for Marine Ecosystems is to protect marine habitats so as to maintain environmental values, including biodiversity, ecological integrity and ecological functioning.

9.2 Additional information required

As described in **Table 1-1**, the NT EPA requested additional information surrounding Marine Ecosystems to further understand the magnitude of potential impacts and the effectiveness of environmental management and mitigation measures, specifically:

+ Provide the outcome of additional benthic habitat surveys of the proposal footprint and zone of influence in Darwin Harbour and the proposed spoil disposal site;
+ Revise the assessment of potential impacts to benthic habitats (including seagrass meadows in Fannie Bay, Shoal Bay and Casuarina Coastal Reserve) using the benthic habitat survey data and sediment dispersion model outputs;
+ Provide an underwater noise assessment conducted using contemporary best practice, including interpreted outcomes of underwater noise modelling and modelling of cumulative noise resulting from the proposal and existing activities at sensitive receptors.
+ Provide a detailed draft marine megafauna management plan for construction that includes:
  - Baseline (pre-construction) cumulative noise within the zone of influence of the proposal and relevant parameters to be monitored to detect impacts;
  - Noise trigger levels for relevant parameters (and description of their derivation) corresponding to actions that must be taken in the event that monitoring indicates that construction activities are likely to impact protected species; and
  - Management actions to be applied if noise triggers are exceeded in accordance with the environmental decision-making hierarchy.
+ Provide an assessment of potential impacts to important subsea structure/s within the Charles Point RFPA and the measures that would be applied to ensure impacts are not significant;
+ The monitoring program for the draft DSDMP must provide for the assessment of cumulative impacts associated with trenching/dredging and spoil disposal, including from the addition of concurrent or consecutive dredging programs. The DSDMP should include:
  - A communications strategy for engaging with government authorities and other proponents undertaking or proposing to undertake dredging in the harbour; and
  - A proposed approach to managing dredging in coordination with other

proponents/dredging projects to avoid significant cumulative impacts to Darwin Harbour from dredging activities.

The additional information in this section incorporates results from the project-specific sediment dispersion modelling (refer to **Appendix 3**), underwater noise modelling (refer to **Appendix 8** and **Appendix 9**), treated seawater discharge modelling (refer to **Appendix 5**) and hydrocarbon spill modelling studies (refer to **Appendix 15**). It also draws on the results of the benthic habitat survey carried out in June 2022 (refer to **Appendix 6**) and further comparison against the current benthic habitat mapping e.g. undertaken by AIMS in 2019 (Galaiduk et al., 2019) and revised in 2021 (Udyawer et al., 2021) and undertaken by INPEX Browse Ltd (2011).

9.3 Legislation, policy and guidance

The following Commonwealth and NT legislation and other policies and guidance documentation apply to the Project.

Commonwealth

+ *Environment Protection and Biodiversity Conservation Act 1999*
+ *Biosecurity Act 2015*

Northern Territory

+ *Territory Parks and Wildlife Conservation Act 1976*
+ *Fisheries Act 1988*
+ *Environment Protection Act 2019*
+ *Marine Act 1981*
+ *Ports Management Act 2015*

Other Relevant Policies and Guidelines

+ NT EPA Environmental Factors and Objectives: Environmental impact assessment general technical guidance (NT EPA, 2021c);
+ Matters of National Environmental Significance, Significant impact guideline 1.1 (DoE, 2013);
+ National Light Pollution Guidelines for Wildlife including marine turtles, seabirds and migratory shorebirds (DoEE, 2020)
+ National Strategy for Reducing Vessel Strike on Cetaceans and Other Marine Megafauna (DoEE 2017b);
+ Relevant *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) related recovery plans, conservation advice and management plans;
+ Anthropogenic Pressures on Darwin Harbour: An IMMRP Monitoring Plan (Version 1). Technical Report No. 11/2020 (Radke and Fortune, 2020);
+ Guidelines for the environmental assessment of marine dredging in the Northern Territory (NT EPA, 2013);
+ Darwin Harbour Strategy (DHAC, 2020);

- Darwin Harbour Water Quality Protection Plan (DLRM, 2014);
- National system for the prevention and management of marine pest incursions (DAFF 2010); and
- Anti-fouling and in-water cleaning guidelines (DENZMPI 2015).

9.4 Environmental values

This section provides additional information on existing environmental values within the Project area that were not included in the NT EPA referral. A benthic habitat survey has been undertaken since submission of the referral and the results have been included in the SER to assist with determining the existing environmental values within the Project area and subsequent impact assessment. The following key additional studies and reports (in addition to others) have been reviewed and used to develop the SER:

- RPS (2022a). Santos Barossa DPD- Pipeline Benthic Survey Report (full report provided in **Appendix 6**).
- Sinclair Knight Merz (SKM). 2011. Ichthys Gas Field Development Project. Assessment of Potential Impacts to Mud Crabs in Darwin Harbour. Report prepared by Sinclair Knight Merz Pty Limited, Perth, for INPEX Browse, Ltd., Perth. Western Australia.
- Saunders, T., Johnson, D., Johnston, D., and Walton, L. 2021. Mud Crabs (2020): *Scylla spp*., *Scylla serrata, Scylla olivacea*. Fisheries Research and Development Corporation (FRDC). Status of Australian Fish Stocks Reports. [Accessed: 24/01/22]. MUD CRABS 2020 (fish.gov.au).
- Bardon, A. (2018). Darwin Harbour scientist calls for research funds as dolphin populations drop. Available at https://www.abc.net.au/news/2018-11-30/darwin-harbour-dolphin-population-decline-worries-scientist/10157960.
- Palmer, C., Parra, G., Roger, T., and Woinarski, J. (2014). Collation and review of sightings and distribution of three coastal dolphin species in waters of the Northern Territory, Australia. Published in Pacific Conservation Biology: PCB contents 20(1).pmd (researchgate.net).
- Groom, R, Dunshea, G, Griffiths, A, and Mackarous, K. (2017). The distribution and abundance of Dugong and other marine megafauna in Northern Territory, November 2015. Department of Environment and Natural Resources, Darwin.
- Radke, L., J. Fortune, S. Townsend, J. Schult, G. Staben, M. Skarlatos-Simoes, C. Palmer and P. Dostine (2019). Development of Pressure Indicators for Darwin Harbour. Report No. 25/2019D. NT Department of Environment and Natural Resources, Palmerston.
- Udyawer, V., Radford, B., Galaiduk, R., Brinkman, R. and Streten, C. (2021) Chapter 5. Predictive modelling of Darwin Harbour's benthic community. Pp 43-70 In: Streten, C. (editor). Revised predictive benthic habitat map for Darwin Harbour. Report prepared for Department of Environment, Parks and Water Security. Australian Institute of Marine Science, Darwin, 127 pp.

9.4.1 Primary productivity

Primary productivity in Darwin Harbour is mostly associated with the mangrove communities fringing the harbour, the microphytobenthos found in mudflats and the phytoplankton floating in the water column (Cardno, 2014). Microphytobenthos use light penetrating the water column to grow and reproduce and are important sources of food for organisms such as molluscs, worms, small crustaceans and herbivore fish (Cardno, 2014). Phytoplankton concentrations within Darwin Harbour are typically low, with the inner harbour being classified as 'oligotrophic' given the low concentrations of bio-available nutrients, high turbidity and low light levels that limit the growth of phytoplankton (Cardno, 2014). Other benthic primary producer habitat in the harbour includes seagrass beds, hard corals and macroalgal beds (refer benthic habitat map, **Figure 9-6**).

9.4.2 Conservation significant marine areas

Charles Point Wide Reef Fish Protection Area

The Charles Point Wide RFPA covers an important deep-water area to protect significant fish aggregation sites from overfishing and barotrauma (NT Government, 2022). The RFPAs are managed by the Department of Industry Tourism and Trade (DITT) Fisheries Division.

DITT-Fisheries Division provided Santos with the coordinates for a known jewfish aggregation area within the RFPA, which is over 2.5 km from the pipeline route and will not be impacted by Project activities.

The total area of the Charles Point Wide RFPA is approximately 88 km^2. Approximately 11.5 km of the proposed pipeline route runs through the Charles Point Wide RFPA (~KP78.5 - ~KP90). During pipeline installation activities, a conservative 5 m disturbance corridor was applied to evaluate impacts along this section of the pipeline route (refer to **Section 9.5.1.3**). A 5 m corridor equates to an area of 0.0575 km^2 within the RFPA (< 0.1% of the area).

Section 7.2 of the NT referral describes the benthic habitat and communities within and around the Project area from surveys previously undertaken for other projects. Additional benthic habitat surveys have been completed by Santos along the proposed pipeline route and surrounding areas in both 2021 and 2022 to verify the benthic habitat present in areas where impacts to these habitats may occur (RPS, 2022a; **Appendix 6**).

Observations of the seabed from the October 2021 and June 2022 surveys supported AIMS benthic mapping (mapped as a mix of bare ground and sponges/filterers/octocorals) with seabed habitats along the pipeline route in the RFPA characterised by silty shelly sand with very sparse to sparse (1-5% coverage) epibiota (mainly soft corals, crinoids and sponges) (refer **Figure 9-1** and **Appendix 6**).

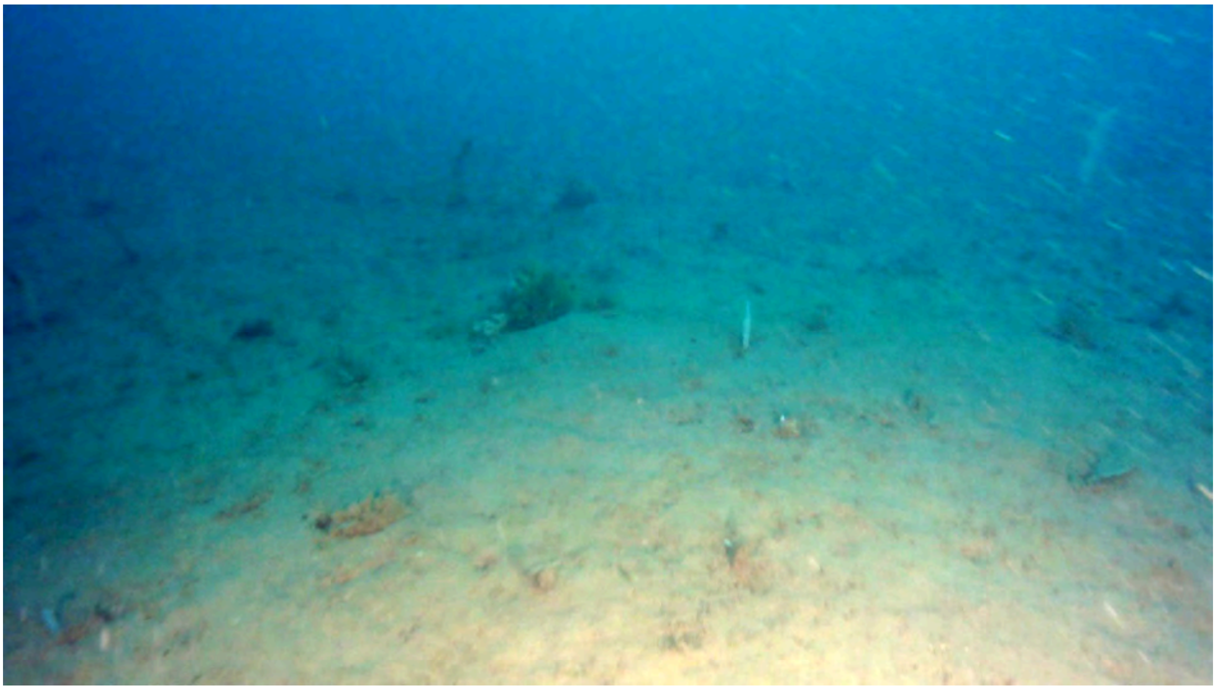

*Figure 9-1 Example image of silty shelly sand habitat with sparse soft corals within the RFPA (site RFPA3, refer **Appendix 6**)*

These observations are supported by the geophysical data collected along the pipeline route within the RFPA which showed mostly flat, featureless seabed with the occasional change in topography as shown in **Figure 9-2.** In contrast to the benthic habitat along the proposed pipeline route, the benthic habitat at the identified fish aggregation area, over 2.5 km away from the pipeline route was identified as low-profile reef with medium to high density biota (RPS, 2022a; **Appendix 6**).

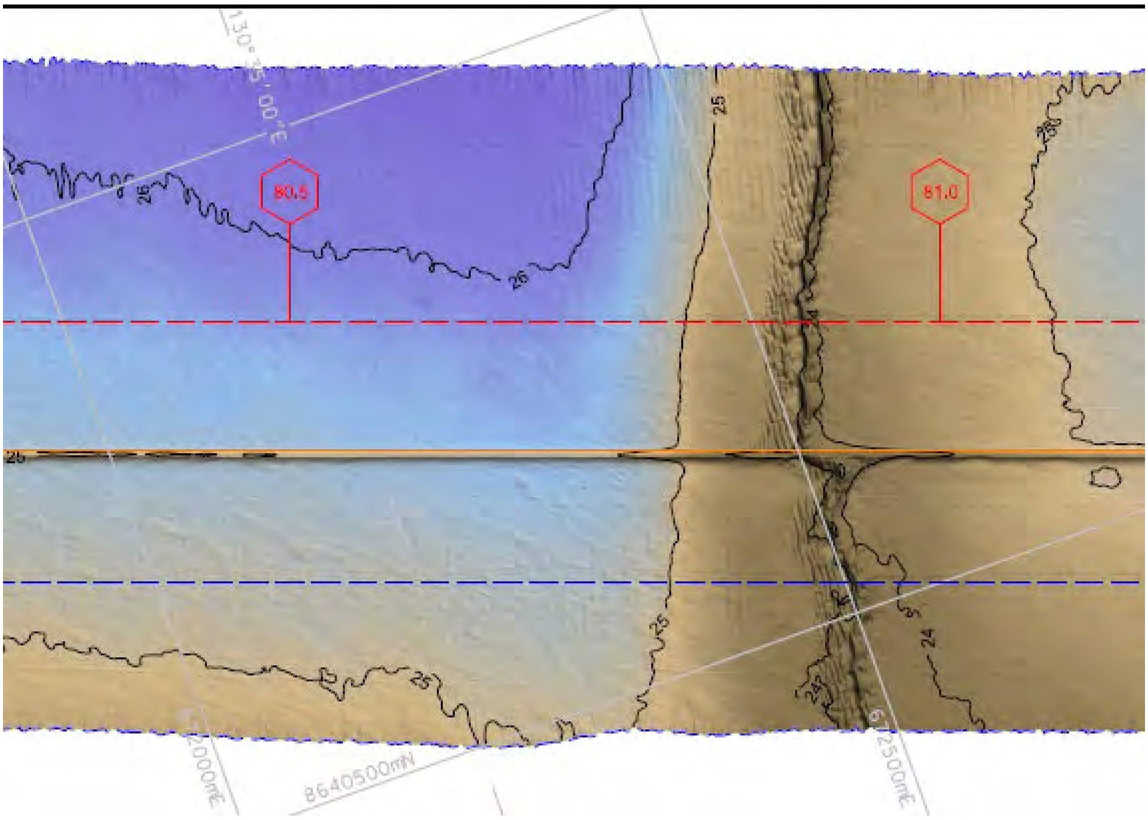

Figure 9-2 Shaded relief of bathymetry between KP80 and KP81 of the pipeline route (red dashed with KP markers) within the Charles Point Wide RFPA

9.4.3 Benthic habitats

Many studies have been undertaken to investigate, describe and map the distribution of benthic habitats across the Darwin Harbour and Bynoe Harbour regions. These include the numerous surveys undertaken as part of the INPEX Ichthys Project (refer INPEX Browse, Ltd., 2011), the predictive mapping completed by AIMS and DENR (Galaiduk et al., 2019), and the more recent AIMS report that presents revised predictive benthic habitat maps (refer Udyawer et al., 2021). Santos has also completed benthic habitat surveys along the proposed pipeline route, dredge spoil disposal ground and surrounding areas in both 2021 and 2022 to verify the benthic habitat present in areas where impacts to benthic habitat may occur (RPS, 2022a, **Appendix 6**).

A video transect survey was conducted between 6 and 10 June 2022. RPS conducted the survey using a ROV to collect benthic imagery. The objectives for this survey were to expand the benthic habitat survey data along the proposed pipeline route, including within the Charles Point Wide Reef Fish Protection Area, and ground-truth areas of potential sensitive habitat adjacent to the pipeline route (as predicted by AIMS 2021 and 2019 habitat mapping). The survey was undertaken in conjunction with a marine archaeological survey (**Section 11.3**).

Ground-truthing within Darwin Harbour focused on sites predicted to be suitable for rarer, high-value biota types (e.g. macroalgae, hard corals and seagrass) that were closest to the proposed pipeline route (and therefore had the greatest potential to be influenced by the DPD Project construction activities, including trenching). This included an area west of the pipeline route where the route comes closest to the shoreline of Cox Peninsula (including sites HAB 1-4), an area west of the pipeline route where the route comes closest to Weed Reef (including sites HAB 6-8) and sites close to the shore crossing (HAB 9 and 10) (refer **Figure 9-3**). Results from these surveys showed that the selected sites, which were predicted as suitable for macroalgae, seagrass and/or hard coral by AIMS (2021) mapping typically did not show presence of these biota types (refer to **Figure 9-3** to **Figure 9-5**). In addition to these benthic habitat ground-truthing sites, a number of benthic habitat monitoring sites used by INPEX during the Ichthys project were ground-truthed. These included hard coral sites (INPHCMAN, INPHCWED, INPHCCHI, INPHCSSI and INPHCNEW) and seagrass sites (INPSGWOD and INPSGCPW) (**Figure 9-3** to **Figure 9-5**). Surveys of these sites generally confirmed the presence of seagrass or hard coral, as expected, although seagrass was observed at very low densities. The additional sites surveyed along the pipeline route within Darwin Harbour in June 2022 provided results consistent with surveys in October 2021 in that sites comprise a mix of hard substrate and sediments, supporting varying densities of filter-feeding biota such as soft corals, hydroids, crinoids and sponges, but with an absence of photosynthetic biota such as hard corals, seagrass and algae (RPS, 2022a – **Appendix 6**).

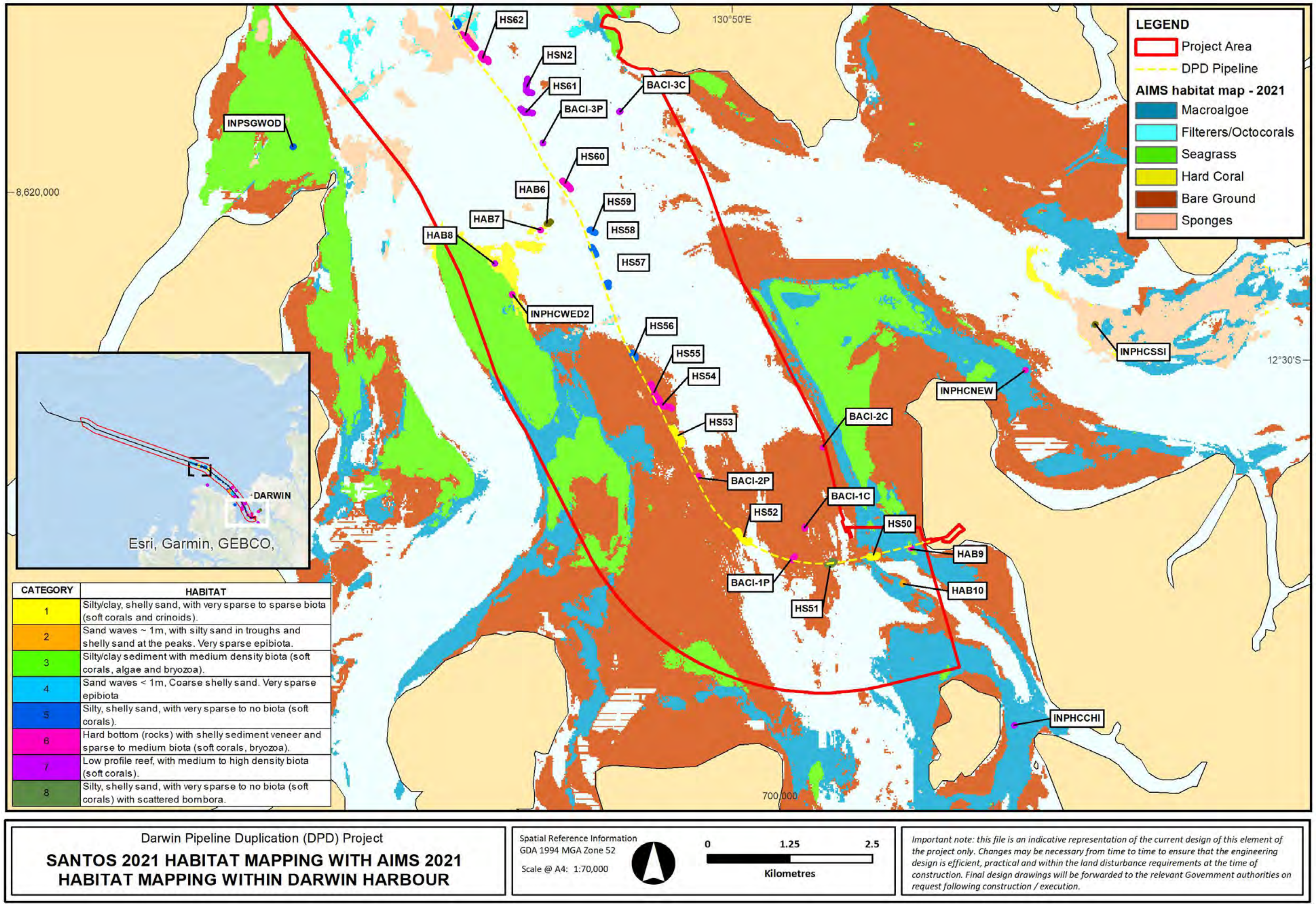

Figure 9-3 RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021)

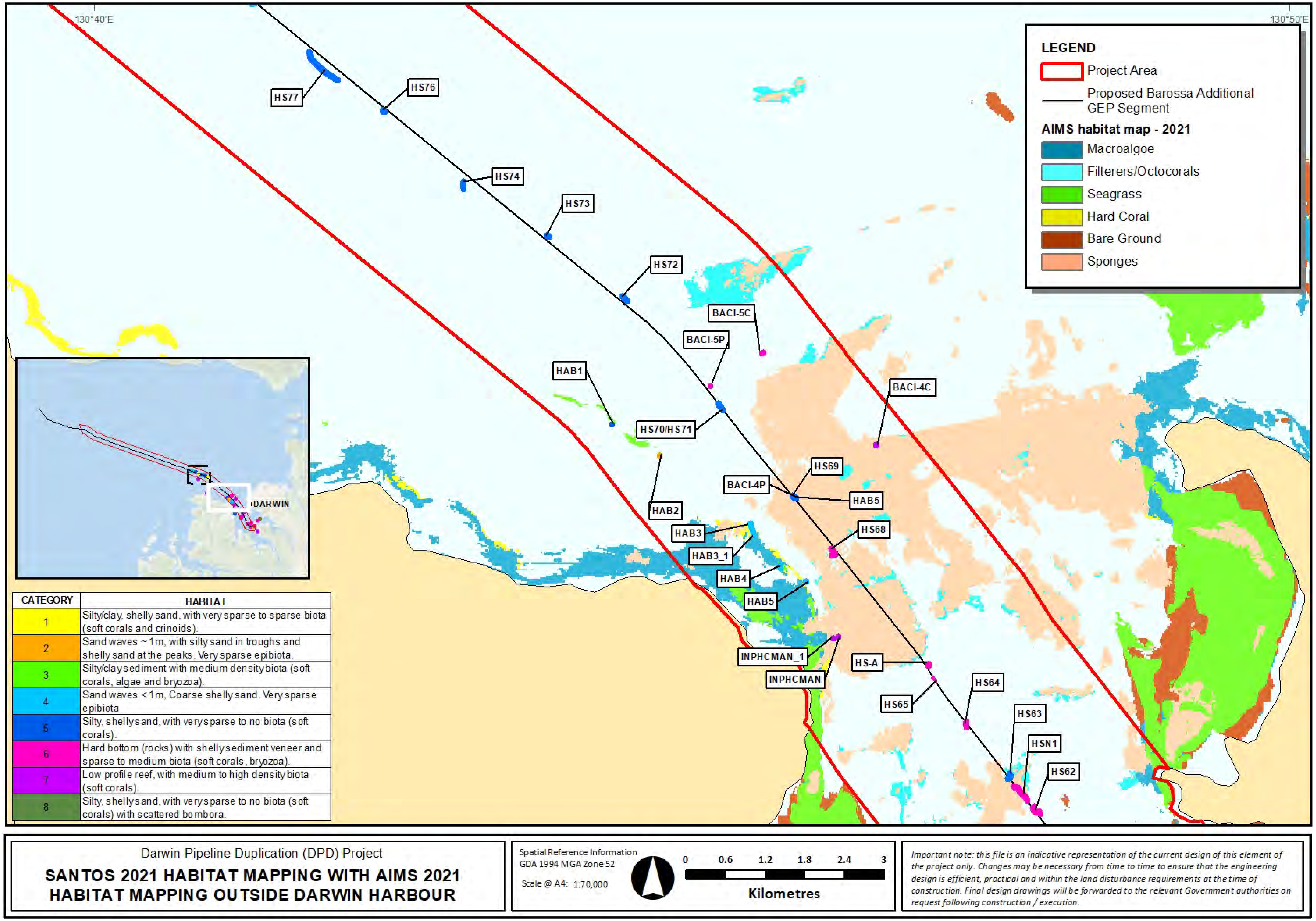

Figure 9-4 RPS surveys habitat mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021)

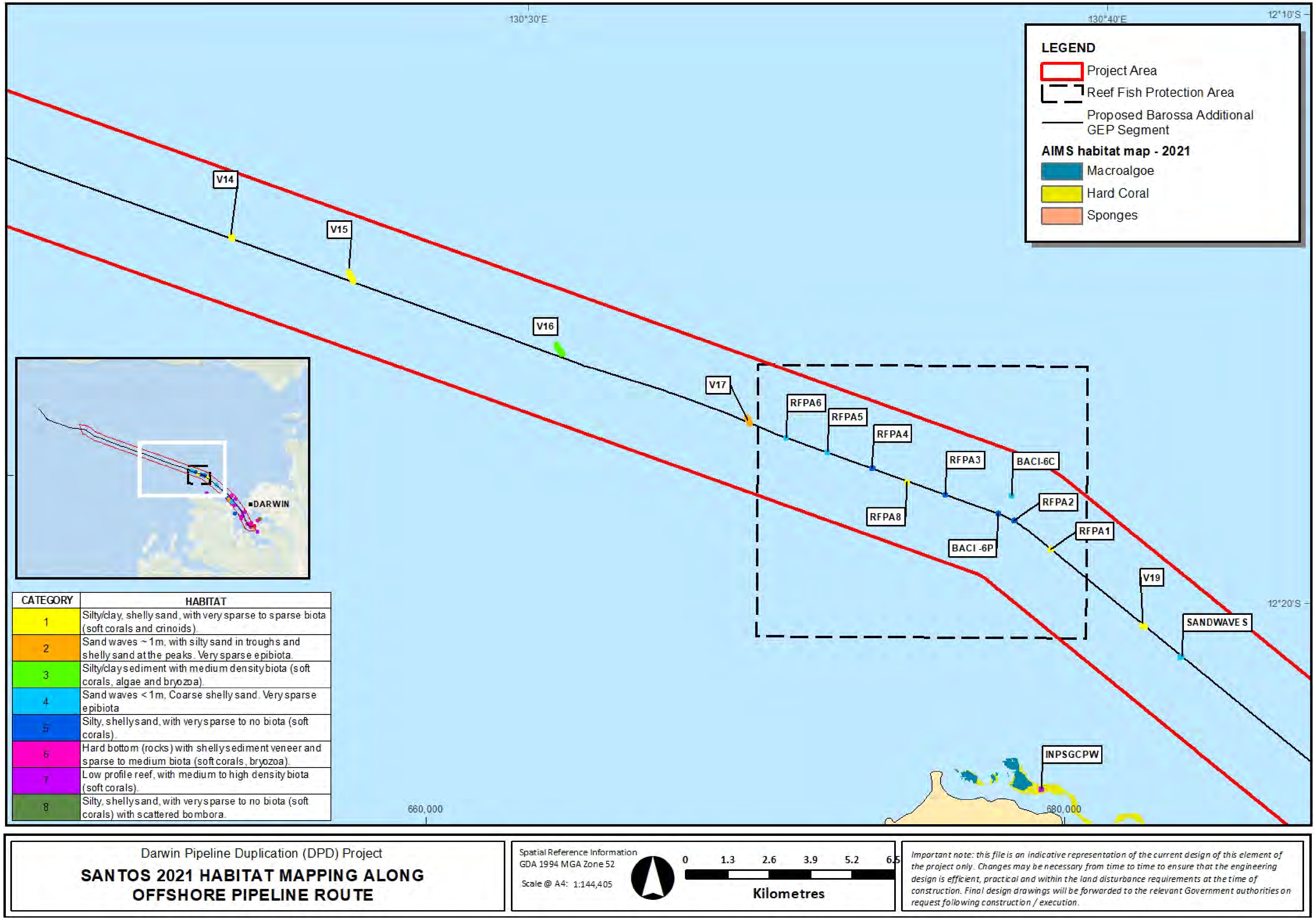

Figure 9-5 RPS surveys habitat mapping along offshore pipeline route

In its 2019 report (Galaiduk et al., 2019), AIMS presented the modelled and mapped distribution of individual benthic community types and used these data to create a map showing the combined spatial distribution of the major benthic habitat classes present in the Darwin and Bynoe Harbour region. It was this benthic habitat mapping (specifically, the more robust combined habitat map produced by AIMS) that was used to undertake the impact assessment presented in the NT EPA referral. AIMS reported that the models had high accuracy and high predictive power, which gives high confidence in the accuracy of the mapping outputs. However, AIMS did note that there was a high proportion of misclassified predictions for rare benthic classes. i.e. benthic classes that had fewer observations recorded during field surveys. While those benthic classes (macroalgae, seagrass and hard corals) are not widespread in Darwin Harbour, there was limited shallow water and intertidal bathymetry data available, which may have impacted the accuracy of the 2019 models developed for those benthic classes.

In an effort to extend the spatial coverage of the benthic community models and address the availability of shallow water data, AIMS revised its predictive habitat mapping in 2021 (Udyawer et al., 2021) using additional shallow water bathymetry data, data from additional benthic community surveys, and data (mainly from the intertidal zone) provided by the Department of Environment, Parks and Water Security (Case et al., 2021).

To inform the impact assessment of Project activities, Santos combined the shallow water habitat maps from AIMS 2021 report (Udyawer et. al., 2021) with the deeper water habitat maps from the 2019 report (Galaiduk et al., 2019) to form a single, combined habitat mapping layer, refer **Figure 9-6**.

For both the 2019 and 2021 predictive mapping, AIMS modelled the relationship between the biota classes and bathymetry-related environmental variables. However, where the 2019 mapping predicted the observed occurrence and distribution of each habitat type, the 2021 mapping took a more general approach and according to AIMS, the mapping outputs *"…represent the potential fundamental ecological niche for the habitats analysed based on environmental suitability derived from the model covariates, however, do not represent the realised ecological niche (i.e., whether a habitat will or will not be found at any location at any point in time)"* (Udyawer et al., 2021 page 70). AIMS also stated that *"There are a range of important biological factors not included in the modelling, such as recruitment, population process, connectivity, and disturbances. These are likely to affect how much of the fundamental niche is occupied."* Therefore, the mapping outputs from the 2021 report only presents a potential distribution of the different benthic classes and do not necessarily reflect the actual distribution of the different benthic classes. This became evident when comparing AIM's predicted habitats with the field data collected by Santos (RPS, 2022a), with observed habitat not always aligning with the predictions. For example, where AIMS mapping predicted areas near Mandorah as being potential hard coral and potential seagrass habitat, the habitats were actually observed to be bare sand and sand waves. Where AIMS mapping predicted large areas of 'sponges' habitat with small patches of filter feeders/octocorals only near the harbour entrance, the Project surveys recorded filter feeders and octocorals at sparse densities across almost all soft substrate types. Moving north (in AIMS predicted 'sponges' habitat), the seabed habitats were observed to be changing to silty, shelly sand, with very sparse to no conspicuous epibiota. Nearer the shoreline crossing, large areas of AIMS map show 'bare ground', whereas the Project survey found a mosaic of habitats, comprising 'silty, shelly sand with very sparse to no conspicuous epibiota', 'consolidated rocks with a shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)', and 'silt/clay and shelly sand with sparse to very sparse epibiota (soft corals and crinoids)'.

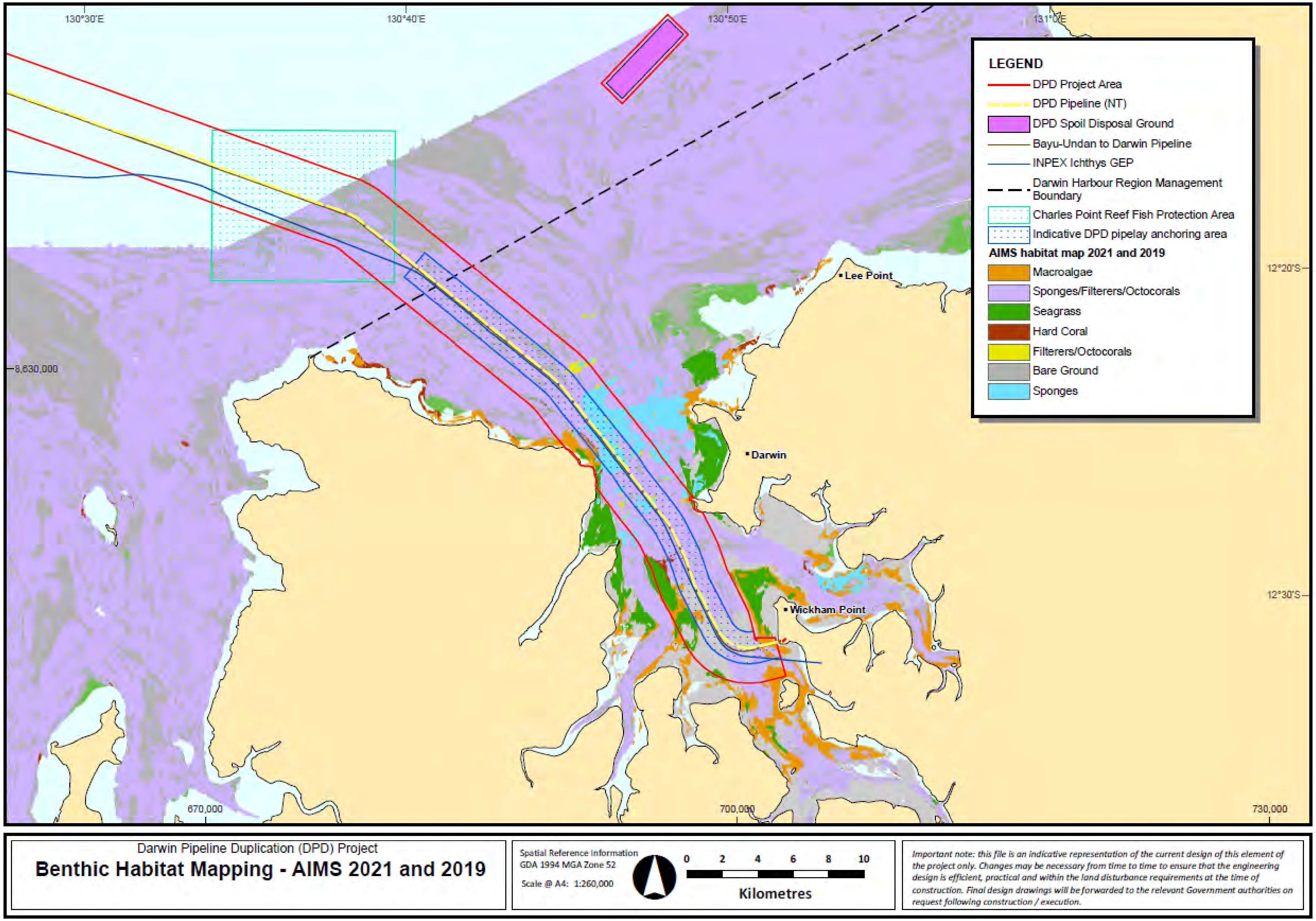

Figure 9-6 Combined AIMS 2021 and 2019 habitat mapping data used to inform the impact assessment sections

Review of other available habitat maps for the area found better alignment between the Project survey and the benthic habitat map prepared for the INPEX Ichthys project (INPEX Browse Ltd, 2011). This is likely because the seabed had higher sampling intensity compared to that used to develop AIMS predictive maps. Furthermore, the habitat classifications from the INPEX maps are more detailed, including both biological and seabed habitat information, and habitat descriptions provide information on relative predicted abundance of organisms. This facilitates a more direct comparison with the Project data, and although there are still disparities, it is easier to determine whether the outcomes from specific locations are relatively comparable or not.

Whilst AIMS mapping provides greater spatial coverage of potential habitats and has helped inform the impact assessment, the report (Galaiduk et al., 2019) states that the habitat distributions of autotrophic communities (primary producer biota) such as seagrass, macroalgae and hard coral) are highly depth correlated and predicted in areas at shallower depths (<10 m). Therefore, it is not unexpected to find some deviations between the survey findings and AIMS mapping. Consequently, by combining the mapping with survey data to ground truth the presence of potentially sensitive habitats, there is a high degree of confidence in the impact assessment for evaluating whether the DPD Project will encounter sensitive habitats or primary producer benthic habitat such as seagrass/hard coral or macroalgae along the route, the trenching zones and expected pipelay anchoring areas (which is predominantly >10 m).

Further details of such comparisons are made below in the impact assessment sections.

9.4.4 Threatened species

For the purposes of the NT EPA referral a high-level desktop assessment was undertaken to determine the likelihood of occurrence of the EPBC listed species occurring in the Project area based on search results using the Commonwealth Protected Matters Search Tool (PMST). The process was adopted based on a likelihood assessments undertaken in Darwin Harbour during previous infrastructure projects being the Darwin Ship Lift Facility and Marine Industries Project and the Ichthys Project, as per the following:

+ KBR (2018), Kellogg, Brown & Root Pty Ltd (KBR), 2018, Darwin Ship Lift Facility and Marine Industries Project –Notice of Intent, prepared for Northern Ship Support Pty Ltd
+ AECOM (2021), AECOM 2021 Draft Environmental Impact Statement. Darwin Ship Lift prepared for Department of Chief Minister and Cabinet.
+ Acer Vaughan Consulting Engineers and Consulting Environmental Engineers 1993, Draft Environmental Impact Statement, Darwin Port Expansion – East Arm, Prepared for the NT Department of Transport & Works, Darwin, NT.
+ INPEX 2010, Ichthys Gas Field Development Project: Draft Environmental Impact Statement, INPEX Browse, Ltd.
+ URS 2002, Darwin 10 MTPA LNG facility: public environmental report, Report prepared by URS Australia Pty Ltd for Phillips Petroleum Company Australia Pty Ltd, Darwin, NT.

An assessment of likelihood of the species occurring within the DPD Project area was determined based on documented records and the species habitat requirements with respect to habitat features within the Project area.

The criteria applied to define the likelihood of occurrence for marine megafauna was:

+ Unlikely: the species has not been recorded within Darwin Harbour or surrounding waters; and/or its current known distribution does not encompass Darwin Harbour, and surrounding water; and/or suitable habitat is generally lacking from the Project area.
+ Potential: the species has not been recorded within Darwin Harbour or surrounding waters although species' distribution incorporates Darwin Harbour and surrounding waters; and potentially suitable habitat occurs in the Project area.
+ Likely: the species has been recorded within Darwin Harbour or surrounding waters in the past 10 years; and suitable habitat is present within the Project area.
+ Known to occur: the species has been recorded (directly by commissioned surveys or from database records) within the Project area in the past 10 years.

The likelihood of occurrence has been revised and updated after the submission of the NT referral. The updated likelihood of occurrence assessment has been included in **Appendix 17**. The following updates have been made:

+ Green turtle (*Chelonia mydas*) – Likelihood of occurrence was previously **unlikely**, this has been updated to **likely**.
+ Hawksbill turtle (*Eretmochelys imbricata*) – Likelihood of occurrence was previously **unlikely**, this has been updated to **likely**.
+ Leatherback turtle (*Dermochelys coriacea*) – Likelihood of occurrence was previously **unlikely**, this has been updated to **potential**.
+ Loggerhead turtle (*Caretta Caretta*) – Likelihood of occurrence was previously **unlikely**, this has been updated to **potential**.
+ Oceanic whitetip shark (*Carcharhinus longimanus*) – Likelihood of occurrence was previously **potential**, this has been updated to **unlikely.**
+ Shortfin mako (*Isurus oxyrinchus*) – Likelihood of occurrence was previously **potential**, this has been updated to **unlikely.**

Additional species identified during the likelihood of occurrence assessment updates include those presented as follows.

+ Golden bandicoot (*Isoodon auratus*) – This species is listed as Endangered under the TPWC Act and listed as Vulnerable under the EPBC Act. This species is **unlikely** to occur.
+ Purple crowned fairy wren (*Nalurus coronatus*) – This species is listed as Endangered under the TPWC Act and listed as Vulnerable under the EPBC Act. This species is **unlikely** to occur.
+ Grey nurse shark (*Carcharias taurus*) – This species is not listed under the TPWC Act and listed as Vulnerable under the EPBC Act. This species is **unlikely** to occur.
+ Scalloped hammerhead (*Sphyrna lewini*) – This species is not listed under the TPWC Act and listed as Conservation Dependent under the EPBC Act. This species is **unlikely** to occur.
+ Asian dowitcher (*Limnodromus semipalmatus*) – This species is not listed under the TPWC Act and listed as Migratory under the EPBC Act. This species is **unlikely** to occur.
+ Grey plover (*Pluvialis squatarola*) – This species is not listed under the TPWC Act and listed as Migratory under the EPBC Act. This species is **unlikely** to occur.

- Oriental plover (*Charadrius veredus*) – This species is not listed under the TPWC Act and listed as Migratory under the EPBC Act. This species is **unlikely** to occur.

Those species identified as unlikely to occur from the 'likelihood of occurrence' assessment are not discussed any further.

9.4.5 Marine mammals

There are four EPBC Act listed migratory marine mammal species considered likely to occur within the Project area. These are the Australian humpback dolphin (*Sousa sahulensis*); Australian snubfin dolphin (*Orcaella heinsohni*); Indo-pacific bottlenose dolphin (Arafura/ Timor Sea populations) (*Tursiops aduncus*) and the dugong (*Dugong dugon*). None of these species are listed under the TPWS Act. A summary of dolphin and dugong distribution and habitat use within the Project area and NT waters is provided in **Table 9-1**. False killer whales (*Pseudorca crassidens*) are not listed species but have been occasionally recorded in Darwin Harbour.

Some stakeholder submissions raised concerns over the impact that the Project may have on the dolphin and dugong populations in Darwin Harbour (**Table 1-1**).

Dolphin monitoring surveys within Darwin Harbour have been conducted between 2011-2019 to investigate the population dynamics of three species: Australian humpback dolphin (*Sousa sahulensis*), Australian Snubfin dolphin (*Orcaella heinsohni*) and spotted bottlenose dolphin (*Tursiops aduncus*). Initial surveys were conducted between 2011 and 2015 to cover the construction phase of the Ichthys LNG Project. This initial monitoring program was extended once construction was completed as part of a voluntary offset agreement between the Ichthys LNG Project and the NTG. This second program commenced in 2016 and ended in 2019 (Griffiths et al., 2020). The surveys used capture-recapture methods to estimate population parameters for each of the three species. Individual animals were identified by unique markings on their dorsal fins and fluke markings. Final reporting for the monitoring program (Griffiths et al., 2020) found that all three species were shown to occur at low densities, exhibit substantial temporary emigration and have fluctuating population size. The study suggested that all three species of dolphin leave the study area (Darwin Harbour, Bynoe Harbour and Shoal Bay) for prolonged periods and that the study area does not encompass the entire range of most individual dolphins (Griffiths et al., 2020). Results from the monitoring program highlight a negative trend in abundance for all three species over time. The monitoring program was unable to explain the reasons for the observed year to year variation and overall decline but suggested that the decline could be due to population dynamics and environmental factors, including anthropogenic factors (Griffiths et al., 2020).

The conclusion from the final report (Griffiths et al., 2020) was the monitoring was unlikely to be suitable for long term surveillance monitoring due to the mobility of species and lack of reasons that could be attributed to changes in abundance.

Dugong aerial surveys have been undertaken over the Darwin-Bynoe Harbour region as part of an INPEX-led Ichthys LNG Project Nearshore Environmental Monitoring Plan (Cardno, 2015b). The survey was conducted for the NT coastline, including the area of offshore NT waters transited by the Project pipeline (outside of Darwin harbour). Results from the survey for the area relevant to the Project (i.e., West_3) estimated the dugong density to be 0.02 per km² compared to the largest dugong density along the NT coast being estimated at 0.85 Dugongs per km² in area East_2 (Groom et al., 2017). Figure 3 of the report shows that the area of relevance to the Project has one of the smallest relative densities per km² for dugongs, inshore dolphins and turtles, with turtles being far more abundant than either dugongs or inshore dolphins (Groom et al., 2017). Dugong presence is generally related to the presence of seagrass. Cardno (2015b) found dugong densities to be highest associated with seagrass habitat between Lee Point and East Point. Dugong densities with the inner Darwin Harbour were observed to be far lower with highest abundance in the vicinity of Weed Reef (Cardno, 2015b). **Section 9.4.3** describes the benthic habitat communities relative to the Project including seagrass. The aerial survey also recorded other marine megafauna, including 1,393 dolphins along the survey transect and 32 false killer whales and three humpback whales off the survey transect (Groom et al., 2017). Given that the aerial survey was conducted along the entire NT coastline (approximately 10,953 km), the small number of whales sighted indicate that these are likely to be more prevalent in deeper waters outside of the Project area.

Table 9-1 Description of EPBC Act listed migratory mammal species potentially present within the Project area

Species	Distribution and habitat	Breeding areas	Diet
Australian snubfin dolphin	The Australian snubfin dolphin is a recently identified species which was previously combined with the Irrawaddy dolphin (*Orcaella brevirostris*) and is considered endemic to Australia occurring in shallow coastal and estuarine waters. Australian snubfin dolphins occur only in waters off the northern half of Australia, from approximately Broome on the west coast to the Brisbane River on the east coast (Parra et al. 2002). Only a single record for the Australian snubfin dolphin exists outside Australia, and comes from Daru, Papua New Guinea (Beasley et al. 2002). Within Australia, Biologically Important Areas (BIAs) for the Australian snubfin dolphin (breeding, foraging and resting) have been designated along the Kimberley coastline in WA and in NT waters. **Northern Territory** The Australian snubfin dolphin is widely distributed across NT coastal waters, with populations considered in a heathy state, as per the findings of a conservation assessment by the NT Department of Natural and Environmental Resources (DENR) (Palmer et al. 2017). From aerial surveys undertaken in 2014 and 2015, the Australian snubfin dolphin was identified as having an area of occupancy (AOO) of 24,900 km2 and was calculated to occupy 89% of NT coastal waters (Palmer et al. 2017). Highest densities of sightings were from Pellew Islands, Groote Eylandt, English Company Islands/Arnhem Bay and Fog Bay (Palmer et al. 2017), these sites primarily on the east coast of NT. BIAs (breeding, foraging) have been designated at Darwin Harbour, South Alligator River, East Alligator River and Coburg Peninsula (DSEWPaC, 2012).	**Northern Territory** For the three coastal dolphin species (including the Australian snubfin dolphin), calving occurs mainly in the months of October to April (Palmer, 2010). BIAs (breeding, foraging) have been designated in NT, within Darwin Harbour, South Alligator River, East Alligator River and Cobourg Peninsula (DSEWPaC, 2012). Given the results of NT-wide surveys of the species showing wide distribution, occurrence within nearly all coastal waters and highest densities at sites not currently designated as BIAs (Palmer et al. 2017), there are potentially important breeding sites not currently recognised as BIAs. **Project area** Calving in the Darwin Harbour BIA occurs in the months of October to April (Palmer, 2010). The proportion of dolphin calves sighted has varied considerably during monitoring years (Flora and Fauna Division, 2019).	The Australian snubfin dolphin is considered an opportunistic, generalist feeder which preys on a variety of schooling, bottom dwelling and pelagic fish and cephalopods that are generally associated with mangroves, seagrass, sandy bottom or rocky coral reefs in shallow coastal waters and estuaries of tropical regions (Parra, 2013) **Project area** Within the Darwin Harbour foraging has been identified as the dominant behaviour for dolphins, which is generally recorded in water depths ranging from 0.7 m to 25 m (Palmer, 2010). While foraging may occur in the Project area, there are no specific habitats that are considered unique or key for this species given its generalist feeding behaviour and wide use of coastal habitats for foraging.

Species	Distribution and habitat	Breeding areas	Diet
	Project area The Project area overlaps the Darwin Harbour BIA for Australian snubfin dolphins. This species has been monitored in the Darwin Harbour region (comprising Bynoe Harbour, Darwin Harbour and Shoal Bay) between 2011 and 2019 as per the Coastal Dolphin Monitoring Program (Griffiths et al., 2020). This study found populations of this, and the other coastal dolphin species, occurred at low densities but similar to average densities across NT coastal waters, and exhibited fluctuating temporary emigration across sites. The study noted that over the monitoring period population sizes fluctuated but showed a decline over time. The study was unable, however, to explain the reasons for year-to-year variation in abundance and declines, citing potential factors as population dynamics, environmental factors or anthropogenic factors.		
Spotted bottlenose dolphin	Spotted bottlenose dolphins are found in tropical and sub-tropical coastal and shallow offshore waters of the Indian Ocean, Indo-Pacific Region and the western Pacific Ocean (Möller & Beheregaray 2001; Rice 1998; Ross & Cockcroft 1990; Wang et al. 1999). The species is distributed continuously around the Australian mainland and have been confirmed to occur in estuarine and coastal waters of eastern, western and northern Australia (Hale et al. 2000; Möller & Beheregaray 2001; Ross & Cockcroft 1990). BIAs for the species have been designated along the Kimberley Coast in WA, in NT waters and down the entire east coast of Australia from Cape York to past the NSW-Victorian border. Northern Territory The species is widely distributed across the NT with populations considered in a heathy state as per the findings of a conservation assessment by the DENR based on 2014/2015 surveys (Palmer et al., 2017). The species was identified as having an area of occupancy (AOO)	**Northern Territory** For the three coastal dolphin species (including the spotted bottlenose dolphin), calving occurs mainly in the months of October to April (Palmer, 2010). BIAs (breeding, foraging) have been designated in NT, within Darwin Harbour and at Cobourg Peninsula (DSEWPaC, 2012). Given the results of NT-wide surveys of spotted bottlenose dolphins showing wide distribution, occurrence within nearly all coastal waters and highest densities at sites not currently designated as BIAs (Palmer et al., 2017), there are potentially important breeding sites not currently recognised as BIAs.	The spotted bottlenose dolphin is considered an opportunistic, generalist feeders which preys on a variety of schooling, bottom dwelling and pelagic fish and cephalopods that are generally associated with mangroves, seagrass, sandy bottom or rocky coral reefs in shallow coastal waters and estuaries of tropical regions (Parra, 2013) **Project area** Within the Darwin Harbour foraging has been identified as the dominant behaviour for dolphins, which is generally

Species	Distribution and habitat	Breeding areas	Diet
	of 17,600 km^2 and occurred within 84% of NT coastal waters (Palmer et al. 2017). Highest densities were recorded from Limmen Bight, Nhulunbuy, Caledon Bay, Maningrida, Fog Bay, Anson Bay, and Cape Ford (Palmer et al., 2017), these sites distributed across west, north and east coasts of NT. BIAs have been identified for the spotted bottlenose dolphin (foraging, provisioning of young, feeding and breeding) in Darwin Harbour and at Cobourg Peninsula (DSEWPaC, 2012). **Project area** The Project area overlaps the Darwin Harbour BIA for this species. This species has been monitored in the Darwin Harbour region (comprising Bynoe Harbour, Darwin Harbour and Shoal Bay) between 2011 and 2019 as per the Coastal Dolphin Monitoring Program (Griffiths et al., 2019). This study found populations of this, and the other coastal dolphin species occurred at low densities but similar to average densities across NT coastal waters and exhibited fluctuating temporary emigration across sites. The study noted that over the monitoring period population sizes fluctuated but showed a decline over time. The study was unable to explain the reasons for year-to-year variation in abundance and declines, citing potential factors as population dynamics, environmental factors, or anthropogenic factors.	**Project area** Calving in the Darwin Harbour BIA occurs mainly in the months of October to April (Palmer, 2010). The proportion of dolphin calves sighted has varied considerably over the years with calving rates increasing from 2017 to 2018, where over the previous years the rate has generally been low (Flora and Fauna Division, 2019).	recorded in water depths ranging from 0.7 m to 25 m (Palmer, 2010). While foraging may occur in the Project area, there are no specific habitats that are considered key for this species given its generalist feeding behaviour and wide use of coastal habitats for foraging.

Species	Distribution and habitat	Breeding areas	Diet
Australian humpback dolphin[2]	Australian humpback dolphins are found in tropical/subtropical waters of the Sahul Shelf from northern Australia to the southern waters of the island of New Guinea (Jefferson and Rosenbaum, 2014). In Australia, humpback dolphins are thought to be widely distributed along the northern Australian coastline from approximately the Queensland-New South Wales border to western Shark Bay, Western Australia (Parra & Cagnazzi, 2016). Along the Australian coast, Australian humpback dolphins are more likely to be found in relatively shallow and protected coastal habitats such as inlets, estuaries, major tidal rivers, shallow bays, inshore reefs and coastal archipelagos, rather than in open stretches of coastline (Parra & Cagnazzi, 2016). **Northern Territory** These species are widely distributed across the NT with populations considered in a heathy state as per the findings of a conservation assessment by the NT DENR conducted in 2017 based on 2014/2015 surveys (Palmer et al. 2017). The Australian Humpback dolphin was identified as having an area of occupancy (AOO) of 16,900 km2 as well as a calculated extent of occurrence of 88% of NT coastal waters (Palmer et al. 2017). Highest densities of sightings were from Groote Eylandt, English Company Islands, Kakadu National Park, Melville Island (Aspley Straight) (Palmer et al. 2017) which are located on northern and	BIAs for Australian humpback dolphins (breeding, foraging) have been designated in NT, within Darwin Harbour; Port Essington, Cobourg Peninsula; East Alligator River region and South Alligator River region (DSEWPaC, 2012). Given the results of NT-wide surveys of Australian humpback dolphins showing wide distribution, occurrence within nearly all coastal waters and highest densities at sites not currently designated as BIAs (Palmer et al. 2017), there are potentially important breeding sites not currently recognised as BIAs. **Project area** In the Darwin Harbour BIA, calving occurs mainly in the months of October to April (Palmer 2010). The proportion of dolphin calves sighted has varied considerably over the years with calving rates increasing from 2017 to 2018 for the	Across Australia, humpback dolphins have been observed feeding in a wide range of inshore-estuarine coastal habitats including rivers and creeks, exposed banks, shallow flats, rock and coral reefs as well as over submerged reefs in waters at least up to 40 m deep (Parra & Cagnazzi, 2016). **Project area** Within the Darwin Harbour foraging has been identified as the dominant behaviour for dolphins, which is generally recorded in water depths ranging from 0.7 m to 25 m (Palmer 2010). While foraging may occur in the Project area, there are no specific habitats that are considered unique or key for this

[2] As per species SPRAT profile, the Australian humpback dolphin (*Sousa sahulensis*) was previously included with Indo-Pacific humpback dolphin (*Sousa chinensis*), *Sousa sahulensis* was elevated to a species in 2014 and is now used for humpback dolphins in the waters of the Sahul Shelf and northern Australia to southern New Guinea. Indo-Pacific humpback dolphin is now used to refer to humpback dolphins in the eastern Indian and western Pacific Oceans only. Therefore, humpback dolphins in this report are herein referred to under Australian humpback dolphin (*Sousa sahulensis*).

Species	Distribution and habitat	Breeding areas	Diet
	eastern coasts of NT. BIAs (foraging, feeding and breeding) have been designated for the Australian humpback dolphin in Darwin Harbour; Port Essington, Cobourg Peninsula; East Alligator River region and South Alligator River region (DSEWPaC, 2012). **Project area** The Project area overlaps the Darwin Harbour BIA for Australian humpback dolphins. This species has been monitored in the Darwin Harbour region (comprising Bynoe Harbour, Darwin Harbour and Shoal Bay) between 2011 and 2019 as per the Coastal Dolphin Monitoring Program (Griffiths et al., 2019). This study found populations of this, and the other coastal dolphin species occurred at low densities but similar to average densities across NT coastal waters and exhibited fluctuating temporary emigration across sites. The study noted that over the monitoring period population sizes fluctuated but showed a decline over time. The study was unable, however, to explain the reasons for year-to-year variation in abundance and declines, citing potential factors as population dynamics, environmental factors or anthropogenic factors.	Australian humpback dolphins, where over the previous years the rate has generally been low (Flora and Fauna Division, 2019).	species given its generalist feeding behaviour and wide use of coastal habitats for foraging.
Dugong	The dugong has a very large and fragmented Indo-West Pacific range that extends between about 26-27° north and south of the equator (DCCEEW, 2023), encompassing some 860,000 km² of shallow marine habitat across 128,000 km of coastline (Marsh et al. 2011). Their range includes the coastal waters of between 38-44 nations and territories (Marsh et al., 2011). In Australia, dugongs are known to occur in coastal and inland waters from Shark Bay in Western Australia across the northern coastline to Moreton Bay in Queensland (Marsh et al. 2002, 2011). The winter range includes about 24,000 km of Australia's coast, which represents about 19% of the global extent of occurrence along coastline habitats (Marsh et al. 2011).	Dugongs are diffusely seasonal breeders, and the seasonality of breeding is more marked in the sub-tropics (mostly spring, early summer calving) than in the tropics. Usually, a single calf is born after a gestation period of about 14 months and nursed for 18 months or more. **Project area** There is no available evidence to suggest that the Project area or Darwin Harbour	Dugongs are seagrass community specialists, and the range of the dugong is broadly coincident with the distribution of seagrasses in the tropical and sub-tropical waters in their Australian range. **Project area** Ichthys Nearshore Environmental Monitoring Program from 2012 to 2014 recorded dugong abundances highest from

Species	Distribution and habitat	Breeding areas	Diet
	Northern Territory The NT supports a moderate population compared with the Torres Strait, which is the largest global population (Groom et al. 2017). Specific areas supporting Dugongs in the NT include: the northern coast (Daly River to Millingimbi, including Melville Island and Vernon Islands and the Darwin region); and the Gulf of Carpentaria, including the Sir Edward Pellew Group of Islands, the mouth of the Limmen Bight River, and the waters between Blue Mud Bay and Groote Eylandt (Marsh et al. 2008; Grech et al. 2011). The distribution and abundance of dugongs is generally associated with extensive seagrass and algal habitats, as such they are usually found in coastal areas such as shallow protected bays, mangrove areas and leeward of large inshore islands where seagrass grows (O2 Marine, 2019). Aerial surveys conducted by Groom et al. (2017) in 2015 found that the Sir Edward Pellew Island Group and Limmen Bight on the east coast of the NT have the highest population estimates for dugongs in NT consistent with earlier survey results from 2007 and 2014. There are no BIAs for dugongs in the North Marine Region (DSEWPaC, 2012). **Project area** Dugong monitoring was undertaken as part of the Ichthys Nearshore Environmental Monitoring Program from 2012 to 2014 across three areas (blocks), representing Bynoe Harbour, Darwin Harbour/Hope Inlet and Vernon islands and surrounds. Population estimates calculated from sightings across these blocks ranged from approximately 120 to 300 individuals (calculated from post-dredging phase monitoring) with a clear preference of dugongs for shallow waters (0-10m) and with far fewer sightings in the inner Darwin Harbour (demarcated as a line from Mandorah to East Point) than in the outer Darwin Harbour (Cardno, 2015b). Highest dugong abundances from these surveys were recorded	represents a critical breeding or calving area.	seagrass meadows at Casuarina Beach and Lee Point in the outer Darwin Harbour (outside of the Project area) indicating these areas as foraging habitats. Dugongs have been observed foraging on reef flats with algae between Channel Island and the western end of Middle Arm Peninsula (INPEX Browse, 2010) and could be expected to forage in other shallow areas (<10 m) within the Darwin Harbour with seagrass and/or algae, including Weed Reef.

Species	Distribution and habitat	Breeding areas	Diet
	from seagrass meadows at Casuarina Beach and Lee Point in the outer Darwin Harbour and outside of the Project area. Within the inner harbour, dugongs were observed in highest abundance at Weed Reef (Cardno 2015b)		

9.4.6 Marine turtles

All marine turtle species in Australian waters are EPBC Act listed threatened species. There are four species of marine turtle that are likely to occur in the Project area and two species that have the potential to occur. A summary of the distribution and habitat use of these species within the Project area and NT waters is provided in **Table 9-2**. This information has come from further review of relevant reports and consultation with turtle experts at Pendoley Environmental (refer **Appendix 14**).

Table 9-2 Description of listed marine turtles potentially within the Project area

Species	Distribution and habitats	Breeding areas and nesting seasons	Diet
Flatback turtle	The flatback turtle is found only in the tropical waters of northern Australia, Papua New Guinea and Irian Jaya, and is one of only two species of sea turtle without a global distribution. There are no estimates of population size for the flatback turtle. They feed in the northern coastal regions of Australia, extending as far south as the Tropic of Capricorn. Their feeding grounds also extend to the Indonesian archipelago and the Papua New Guinea coast. Flatback turtles prefer shallow, soft-bottomed seabed habitats away from reefs. Post-hatchling flatback turtles do not have an oceanic dispersal phase, this species remains within the relatively shallow Australian continental shelf waters (Salmon et al. 2009). **Northern Territory** Flatback turtles are the most widely spread nesting marine turtle species in the Northern Territory, nesting on a wide variety of beach types around the entire coastline. **Project area** Flatback turtles prefer shallow, soft-bottomed seabed habitats away from reefs; being habitat represented within the Project area. The Project area intersects 'habitat critical to the survival of the flatback turtle species'. This habitat was mapped by consensus of a panel of experts in marine turtle biology and according to the EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DoE, 2013), is defined as areas necessary: + for activities such as foraging, breeding or dispersal. + for the long-term maintenance of the species. + to maintain genetic diversity and long-term evolutionary development. + for the reintroduction of populations or recovery of the species. Nesting habitat critical to the survival of Flatback turtles includes at least 70 per cent of nesting for the stock (i.e. these marine areas are extensive).	All known breeding sites of this species occur only in Australia. Flatback turtles' nest on inshore islands and the mainland from Queensland to northern Western Australia. There are four major nesting areas in Australia, representing four genetic breeding stocks. The largest nesting concentration of flatback turtles is in the north-eastern Gulf of Carpentaria and western Torres Strait. In the western Northern Territory (and possibly eastern Kimberley) there is a mid-winter peak nesting season and low-density summer nesting. **Northern Territory** The flatback turtle is considered the most widespread nesting turtle species in the NT and important nesting locations have been identified in various bioregions within the Northern Territory. Flatback turtles' nest on a wide variety of beach types around the entire coastline. Through surveys held between 1994 and 2004, Chatto and Baker (2008) have identified 46 distinct areas within the Northern Territory that are confirmed (a total of 18), or inferred as highly likely to represent (28 sites), significant nesting areas for the flatback turtle. The majority of these sites are on islands. Arnhem Land rookeries include Cobourg Peninsula and Greenhill Island, Field Island and McCluer Island. West of Darwin, significant nesting occurs in Fog Bay. Other significant sites include Turtle Point, North Perron Island and Bathurst and Melville Islands. Within the Darwin region most turtle nesting is associated with flatback turtles. There is a nesting site located at Casuarina Beach. This nesting site is located approximately 8 km east of the DPD Pipeline and approximately 15 km south of the spoil disposal ground. The Cox Peninsula beaches and Mandorah Beach are infrequently used for nesting, which border the Project area. Monitoring undertaken for the Ichthys project found that the mangroves and mudflats throughout the shoreline of inner Darwin Harbour do not provide suitable habitat for nesting turtles (INPEX Browse, Ltd, 2010a). Other turtle nesting sites include Turtle Point in Joseph Bonaparte Gulf, Bare Sand Island and Quail Island, which are considered more significant on a regional scale than Casuarina	The flatback turtle is carnivorous, feeding mostly on soft bodied prey such as sea cucumbers, soft corals and jellyfish. They feed mainly in subtidal, soft bottomed habitats. **Project area** Based on existing habitat mapping and benthic surveys conducted for the DPD Project (refer **Section 9.4.3**) there is considered to be foraging habitat (soft sediments and soft corals) within the Project area and under the proposed pipeline route.

Species	Distribution and habitats	Breeding areas and nesting seasons	Diet
		Beach (Chatto and Baker, 2008) and are located near the mouth of Bynoe Harbour (~50 km from Darwin). Systemic and intensive turtle monitoring conducted on Casuarina Beach between 1997 and 2006 recorded 107 nests along 8 km of beach. Of these 104 nest belongs to flatback Turtles. The number of nests recorded ranged from 7 to 20 each year, and confirms this as a low-density nesting beach. This beach is recognised for its value as a public education program and not as a significant turtle nesting site (Chatto and Baker, 2008). While peak nesting for flatback turtles in the NT is reported to occur between June-September, a study undertaken by Chatto and Baker (2008) found that flatback turtle nesting predominantly occurred between May and October; however, it was noted that at locations such as Casuarina Beach nesting was recorded in small numbers throughout the year. A more recent study undertaken by Pendoley 2022a, found that records over the last 30 years demonstrate the low importance of beaches surrounding Darwin Harbour to nesting turtles, including Wagait Beach and Mandorah on Cox Peninsula, and Casuarina Beach in Darwin. Specifically in regard to flatback turtles within the wider Arafura Sea genetic stock. **Project area** No nesting beaches, although the Project area intersects a BIA representing a 60 km inter-nesting area. This is an extensive area extending south of the Daly River to Goulburn Islands in the north, inclusive of Bathurst and Melville islands (>800 km of coastline).	
Olive Ridley turtle	The Olive Ridley turtle has a worldwide tropical and subtropical distribution, including northern Australia. The turtle is the most numerous of all marine turtles in the world. **Northern Territory** The current area of occurrence is estimated to be in excess of 10 million km². Olive Ridley turtles typically occur in shallow soft bottomed habitats of protected waters. In Australia, they occur along the coast from southern Queensland and the Great Barrier Reef, northwards to Torres Strait, and across to the Joseph Bonaparte Gulf in Western Australia. A 'habitat critical to the survival of the Olive Ridley species occurs around the south-western side of Bathurst Island, extending 20 km seaward and approximately 5-10 km north of the Project area. A substantial part of the immature and adult population forage over shallow benthic habitats, though large juvenile and adult Olive Ridley turtles have been	The Olive Ridley turtle is the most numerous of all marine turtles in the world, largely due to a few, very substantial, nesting aggregations found in Costa Rica, Mexico and India. **Northern Territory** No large rookeries of Olive Ridley turtles have been recorded in Australia. Detailed information on the size of nesting and foraging populations is unknown although an estimate of the nesting population for Australia is 1,000-5,000 females annually. Chatto and Baker's long-term study of nesting turtles in the Northern Territory (Chatto & Baker 2008) found that Olive Ridley turtles were the second most widespread nesting species (after flatbacks) in the Northern Territory, though they nest in low numbers through much of their range. On some beaches, however, such as along the northern coast of Bathurst and Melville islands, and some islands in north-eastern Arnhem Land,	The Olive Ridley turtle is carnivorous, known to feed on shellfish, small crabs, molluscs, shrimp, tunicates, jellyfish and salps. **Project area** Based Existing habitat mapping and benthic surveys conducted for the DPD Project (refer **Section9.4.3**) there is likely suitable foraging habitat of soft sediment seabed within deeper parts of the Project area, including under the proposed pipeline route. There are no records of foraging behaviour of Olive Ridley turtles within Darwin Harbour and little in the outer region, this is likely because foraging habitat is located in water depths usually greater than 10 m (WWF, 2005).

Species	Distribution and habitats	Breeding areas and nesting seasons	Diet
	recorded in both benthic and pelagic foraging habitats. Foraging habitat can range from depths of several metres to over 100 m. **Project area** The Project area does not intersect with a BIA or habitat critical to the survival of the species. Olive Ridley turtles typically occur in shallow soft bottomed habitats of protected waters; being habitat represented within the Project area.	they nest in nationally significant numbers (Chatto & Baker 2008). An Olive Ridley turtle BIA inter-nesting area is located south-east of Darwin Harbour, approximately 10 km from the Project area. This BIA is near the turtle nesting sites of Bare Sand Island, Quail Island and Indian Island, located near the mouth of Bynoe Harbour (~50 km from Darwin), however these sites are not considered significant on a regional scale with infrequent nesting recorded (Chatto and Baker, 2008). Within the Darwin area there is not expected to be any Olive Ridley turtle nesting based on past records (Chatto and Baker, 2008) In Northern Australia nesting occurs all year round, although most nesting occurs during the dry season from April to August. Hatchlings emerge from the nests about two months after laying (DoEE, 2017a). **Project area** No nesting beaches or defined inter-nesting area.	
Green turtle	Green turtles are found in tropical and subtropical waters throughout the world. The global population of green turtles is estimated to be very large (~2 million). Green turtles spend their first five to ten years drifting on ocean currents (pelagic phase). They then settle in shallow benthic foraging habitats such as tropical tidal and sub-tidal coral and rocky reef habitat or inshore seagrass beds. The shallow foraging habitat of adults contains seagrass beds or algae mats on which green turtles mainly feed. Green turtles can migrate more than 2,600 km between their feeding and nesting grounds. **Northern Territory** Green turtles nest, forage and migrate across tropical northern Australia. The total Australian population of green turtles is estimated to be more than 70 000 individuals, distributed across seven regional populations. Aerial turtle surveys undertaken for the INPEX nearshore environmental monitoring program (NEMP) estimated a population size of between 500 and 1,000 for the Darwin region (Buckee et al, 2014). Turtles were primarily observed in shallow waters (<10 m), with the highest densities recorded between East Point and Lee Point, and near Gunn Point (Cardno, 2015b). Turtles were also sighted throughout Darwin Harbour, although at lower densities. It is likely that the majority of turtles observed in the harbour during these surveys were green turtles, as they accounted for 74% of sightings during fine scale land-based observations (INPEX Browse Ltd, 2018). **Project area**	The green turtle has the most numerous and widely dispersed nesting sites of the seven turtle species, known to nest in 80 countries. The largest green turtle nesting populations in the world are found at Tortuguero on the Caribbean coast of Costa Rica (~30,000 females nest per season on average) and Raine Island on the Great Barrier Reef in Australia (peak nesting of up to 60,000 females). **Northern Territory** In Australia, there are seven regional populations of green turtles that nest in different areas; the southern Great Barrier Reef, the northern Great Barrier Reef, the Coral Sea, the Gulf of Carpentaria, Western Australia's north-west shelf, the Ashmore and Cartier Reefs and Scott Reef. The Gulf of Carpentaria has two main nesting areas, the Wellesley Island Group, with major rookeries at Bountiful, Pisonia and Rocky Islands, and the Eastern Arnhem Land, Groote Eylandt and Sir Edward Pellew Islands area. Nesting occurs year-round, with a mid-year peak in nesting activity. The key nesting and inter-nesting areas (where females live between laying successive clutches in the same season) are Coburg Peninsula, between Nhulunbuy and northern Blue Mud Bay (East Arnhem Land), Groote Island, offshore islands including Crocker Island, Goulburn Island, Sir Edward Pellew Islands, Bathurst and Melville Islands, Wessel and English Islands, and Rocky Island.	Adult green turtles eat mainly seagrass and algae, although they will occasionally eat other items including mangroves. Young turtles tend to be more carnivorous than adults. During their pelagic phase (while drifting on ocean currents), young green turtles also eat plankton. **Project area** Based on existing habitat mapping and benthic surveys conducted for the DPD Project (refer **Section 9.4.3**) there is likely suitable foraging habitat of macroalgae and seagrass in some shallow water (<10 m) areas within the Project area but no such habitat under the proposed pipeline route.

Species	Distribution and habitats	Breeding areas and nesting seasons	Diet
	Turtle surveys for the INPEX NEMP indicate that green turtles occur within the Project area in Darwin Harbour and likely forage in shallow waters <10m with suitable habitat within the Project area (Cardno, 2015b).	Within the Darwin Harbour area there is not expected to be any green turtle nesting based on past records (Chatto and Baker, 2008). **Project area** No nesting beaches or defined inter-nesting area	
Hawksbill turtle	Hawksbill turtles are found in tropical, subtropical and temperate waters in all the oceans of the world. Hawksbill turtles spend their first five to ten years drifting on ocean currents. During this pelagic (ocean-going) phase, they are often found in association with rafts of Sargassum (a floating marine plant that is also carried by currents). They then settle and forage in tropical tidal and sub-tidal coral and rocky reef habitat. The hawksbill turtle is known to migrate up to 2,400 km between foraging areas and nesting beaches. **Northern Territory** The total population of hawksbill turtles in Australia is unknown. In Australia the main feeding area extends along the east coast, including the Great Barrier Reef. Other feeding areas include Torres Strait and the archipelagos of the Northern Territory and Western Australia, possibly as far south as Shark Bay or beyond. hawksbill turtles also feed at Christmas Island and the Cocos (Keeling) Islands. In the NT, abundance is concentrated around north-eastern Arnhem Land and Groote Eylandt. The hawksbill turtle utilises Darwin Harbour regularly but occur in lower abundances compared to the green turtle (Whiting 2001, 2003). In the Darwin Harbour, immature and adult sized hawksbill turtles have been reported as using the rocky reef habitat at Channel Island but may also utilise other habitats (Whiting 2001). **Project area** Hawksbill turtles are likely to be present in the Project area due to their known distribution within Darwin Harbour and occurrence of suitable foraging habitat.	Global nesting is mainly confined to tropical beaches. While scattered, low density nesting still occurs throughout the tropics, only five geographic regions host more than 1,000 nesting females annually: Mexico, Seychelles, Indonesia and two in Australia. **Northern Territory** Australia supports the largest hawksbill turtle nesting aggregations worldwide, with estimates of over 4,000 females nesting annually in Queensland, over 2,500 in the Northern Territory, and ~2,000 in Western Australia. In the Northern Territory (NT), most nesting occurs on islands rather than mainland beaches. The key nesting and inter-nesting areas (where females live between laying successive clutches in the same season) in the NT area: Coburg Peninsula, between Nhulunbuy and northern Blue Mud Bay (East Arnhem Land), Groote Island, Sir Edward Pellew Islands, and Wessel and English Islands. A globally important rookery occurs on an archipelago to the north-east of Groote Eylandt. Although hawksbill turtles breed throughout the ear, the peak nesting period in Arnhem Land is between July and October. Hawksbill turtle nesting is not common in Darwin Harbour. **Project area** No nesting beaches or defined inter-nesting area	The Australian stocks of hawksbill turtles are omnivorous, eating a variety of animals and plants including sponges, hydroids, cephalopods (octopus and squid), gastropods (marine snails), cnidarians (jellyfish), seagrass and algae. Sponges make up a major part of the diet. During their pelagic phase (while drifting on ocean currents), young hawksbill turtles eat plankton. **Project area** Based on existing habitat mapping and benthic surveys conducted for the DPD Project (refer **Section 9.4.33**) and the omnivorous diet of hawksbill turtles, there is likely suitable mixed biota foraging habitat within the Project area including under the proposed pipeline route.
Leatherback turtle	The leatherback turtle has the widest global distribution of any reptile. The leatherback turtle is a pelagic feeder, found in tropical, subtropical, and temperate waters throughout the world. This species has an unusually wide latitudinal range as adults can withstand cold (10 °C) water. It is a highly pelagic species, venturing close to shore mainly during the nesting season, and is capable of diving to several hundred metres. Limited data indicates that leatherback turtles concentrate in areas where currents converge with steep bathymetric contours, presumably where food is more readily available. Australian leatherback turtles are presumed to migrate to Australian waters from nesting populations in Indonesia, Papua New Guinea, and the Solomon Islands (INPEX 2010).	Nesting beaches are primarily located in tropical latitudes around the world. Globally, the largest remaining nesting aggregations are found in Trinidad and Tobago, West-Indies (Northwest Atlantic) and Gabon, Africa (Southeast Atlantic). No large rookeries have been recorded in Australia. Scattered nesting has been reported in Queensland, New South Wales and Arnhem Land. **Northern Territory** Nesting sites have been found at Cobourg Peninsula, Manangrida and Croker Island in the Northern Territory. Only very small	The leatherback turtle is carnivorous and feeds mainly in the open ocean on jellyfish and other soft-bodied invertebrates. Soft bodied creatures such as jellyfish and tunicates, occur in greatest concentrations at the surface in areas of upwelling or convergence. **Project area** Based on surveys, there is unlikely to be suitable habitat within the Project area.

Species	Distribution and habitats	Breeding areas and nesting seasons	Diet
	The species has been recorded feeding in the coastal waters of all Australian States (Hamann et al. 2006). The species is most commonly reported from coastal waters in central eastern Australia (from the Sunshine Coast in southern Queensland to central NSW); south-east Australia (from Tasmania, Victoria, and eastern South Australia) and in southwestern Western Australia. It is regularly seen in southern Australian waters. The current area of occurrence in Australia is estimated to be ~6 million km². No estimates of the numbers of leatherback turtles that forage in Australian waters are available. **Northern Territory** As an oceanic species, the species is unlikely to occur within the Darwin Harbour (Whiting 2001). **Project area** Based on surveys, there is unlikely to be suitable habitat.	numbers of nests are laid per year in the Northern Territory and thus would only be a minor contributor to the global population. The species is unlikely to use beaches within the Darwin Harbour for nesting (Whiting 2001). **Project area** No nesting beaches or defined inter-nesting area.	
Loggerhead turtle	The loggerhead turtle has a global distribution throughout tropical, sub-tropical and temperate waters. Loggerhead turtles forage in subtidal and intertidal coral and rocky reefs and seagrass meadows in inshore waters, as well as in deeper soft-bottomed habitats. Females can migrate up to 2,600 km from feeding areas to traditional nesting beaches. In Australia, they occur in coral reefs, seagrass beds and muddy bays and estuaries in tropical and warm temperate waters off the coast of Queensland, Northern Territory, Western Australia and New South Wales. The current area of occurrence is estimated to be ~1.5 million km^2. In Australia, small loggerhead turtles live at or near the surface of the ocean and move with the ocean currents, with much of their feeding in the top 5 m of water, before recruiting to their chosen inshore or neritic feeding area. **Northern Territory** Loggerhead turtles are expected to be infrequent visitors of the Darwin Harbour (Whiting 2003). The loggerhead turtle is more likely to occur in oceanic areas outside the Darwin Harbour. **Project area** Based on surveys, there is unlikely to be suitable habitat.	Nesting is mainly concentrated on sub-tropical beaches with major aggregations occurring in Oman, eastern USA, southern Japan, Greece, Turkey, southern Queensland and Western Australia. _Based on the percentage of nesting females per year, approximately 2–4% of the total global population of loggerhead turtles occur in Australia, with the majority occurring in eastern and Western Australia. **Northern Territory** The species is unlikely to use beaches within the Darwin Harbour for nesting. **Project area** No nesting beaches or defined inter-nesting area.	Loggerhead turtles are carnivorous, feeding primarily on benthic invertebrates in habitat ranging from nearshore to 55 m. Typical diet includes gastropod molluscs and clams, and smaller amounts of jellyfish, starfish, corals, crabs, and fish. In their juvenile stage, they feed on algae, pelagic crustaceans, and molluscs. Once they move to the benthic foraging habitat their diet changes. **Project area** Suitable habitat may be present but unlikely to be used given the loggerhead turtle is not a frequent user of the Project area.

9.4.7 Mud crab migration

Mud crabs are a popular target for fishers in the NT and also have a role in the economy and livelihoods for many coastal Indigenous communities, but anthropogenic impacts, including over-harvesting and failure to observe size and other restrictions, may be impacting abundance (Australian Venture Consultants, 2018).

Sinclair Knight Merz (SKM, 2011) carried out an assessment of potential impacts to mud crabs in Darwin Harbour for the Ichthys project, which was a larger project in terms of dredging than the DPD Project. The report described that mud crabs are adapted to live in and migrate within highly turbid environments, as experienced seasonally within Darwin Harbour. The Department of Fisheries also states that mud crabs are highly tolerant of variations in water salinity and temperature (Department of Fisheries, 2013). As noted by Hill et al. (1982) adult mud crabs generally inhabit estuaries and enclosures in mangrove ecosystems and tidal flats influenced by tidal waters. Juveniles are expected to reside in upper intertidal areas and remain there during low tide (Hill et al. 1982). It is thought that movement is dependent on the availability of alternative feeding grounds at high tide (Department of Primary Industry and Resources, 2017).

Spawning and mating of female mud crabs in the NT is known to occur during the wet season when rainfall and water temperatures peak (SKM, 2011). Females are known to move large distances offshore for spawning away from naturally turbid waters of their intertidal habitats (SKM, 2011). It was concluded for the Ichthys project, that any potential effect on migration patterns is likely to be both minimal and temporary, given the scale of impact relevant to the area of available habitat for mud crabs within Darwin harbour (SKM, 2011).

The most recent stock assessment on mud crabs within the Arnhem-west Northern Territory management unit (AWNT), which encompasses all NT waters outside of the Gulf of Carpentaria including the Darwin Region, indicates that in 2019, the stock was above the target reference level, and that the biomass of the stock is unlikely to be depleted and that recruitment is unlikely to be impaired (Grubert et al., 2019 in Saunders et al., 2021). Given this stock assessment was undertaken years after construction and operation of the Ichthys project, it provides evidence that construction of the Ichthys pipeline did not affect the overall population of mud crabs in the area.

DPD Project trenching and pipeline installation works may occur over a 15-month period, which would therefore coincide with mud crab migration during the wet season. However, the migration of mud crabs occurs over a wider extent, with the Project area only consisting of a narrow portion of this.

9.4.8 Existing noise environment in Darwin Harbour

The existing underwater noise environment within Darwin Harbour is influenced by noise from commercial and recreational vessel traffic. Large commercial vessels, such as cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels enter, exit and move around the harbour on a regular basis, as shown by vessel Automatic Identification System (AIS) screenshots (from the AIS Live program) provided in **Figure 9-7**. Vessel movements are concentrated along designated shipping channels and around berthing and anchorage areas. The proposed DPD pipeline route and associated trenching areas are adjacent to these shipping channels and within the area of high-density vessel traffic shown in **Figure 9-8**.

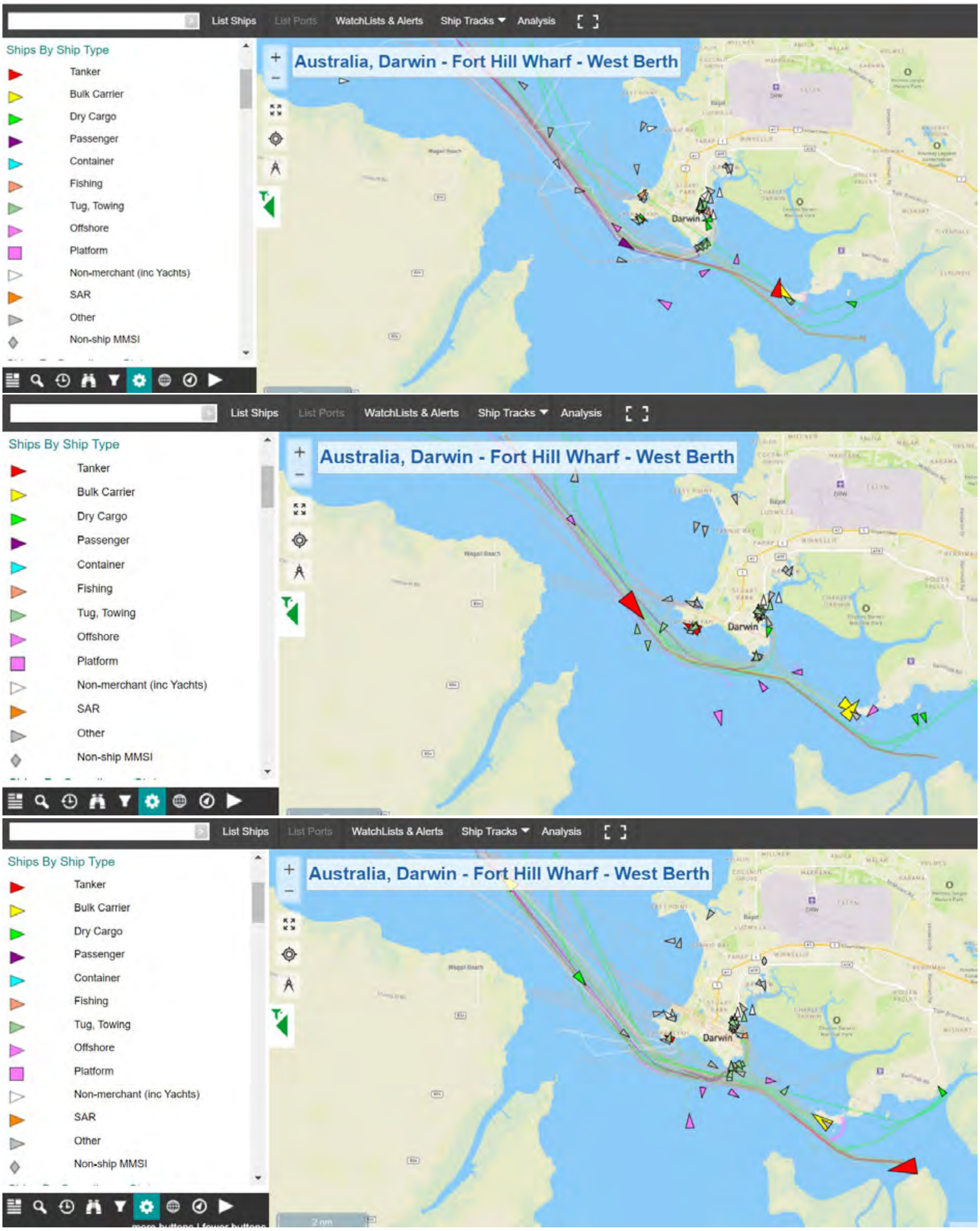

Figure 9-7 Vessel traffic by vessel type in Darwin Harbour on June 6, 7 and 8 2022 from AIS data (AIS Live)

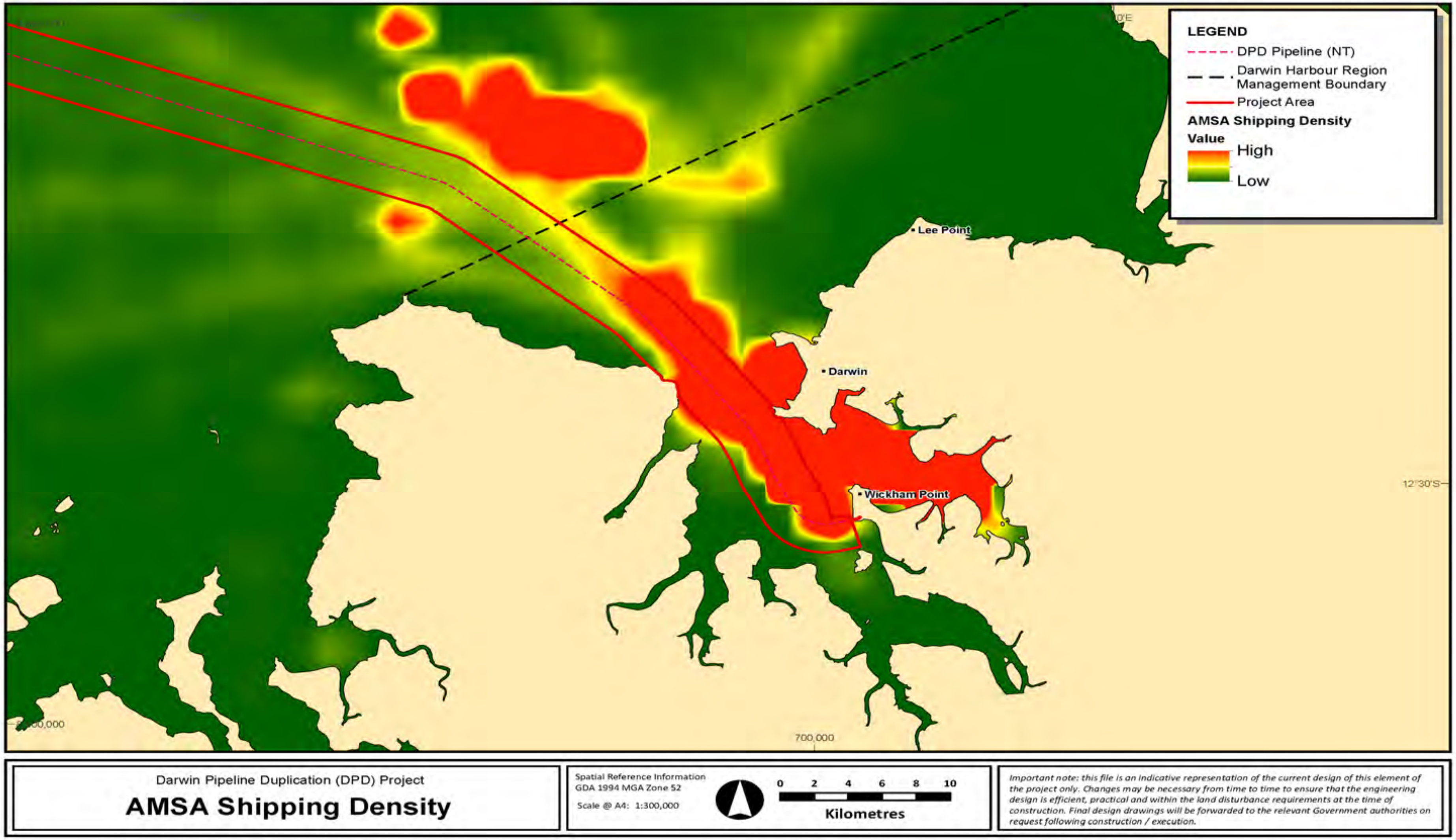

Figure 9-8 AMSA shipping density data for Darwin Harbour from January to May 2022

Typical underwater noise emissions for the types of vessels using Darwin Harbour are provided in **Table 9-3** along with typical source levels from the types of dredging vessels planned to be used for the DPD Project. Trenching vessels (BHD, CSD, TSHD) are expected to produce noise intensities and noise frequencies similar to large commercial vessels that use Darwin Harbour on a daily basis, including cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels (**Table 9-3**).

Underwater noise measurements have been taken in Darwin Harbour by Salgado-Kent et al. (2015) during a period where dredging and piling activities were being conducted in East Arm for the INPEX Ichthys Project. Dredging noise measurements were taken in the vicinity of a Cutter Suction Dredge (CSD) cutting an area of hard rock known as Walker Shoal (Salgado-Kent et al., 2015). These measurements revealed noise levels close to approximately 145 dB re 1 µPa at distances between 630 m and 680 m from the source, which were greater than the levels predicted by underwater noise modelling.

Given seabed hardness is expected to influence the level of noise emitted from a CSD while dredging, an analysis of seabed hardness was undertaken to determine if noise measurements from Walker Shoal would be applicable for the DPD Project. Fugro (2022) undertook a comparative analysis of Walker Shoal geology and seabed refractivity against the geology and seabed refractivity of a representative CSD trenching area between KP104 and KP105 along the DPD route. This assessment compared available refractivity and bore hole data at these locations and concluded that seabed materials at the representative DPD trenching location were significantly weaker than those encountered at Walker Shoal (Fugro, 2022). Interpreted compressional wave acoustic velocities (Vp) ranged between 1,700 m/s to 3,000 m/s for the DPD Project trenching location while for Walker Shoal they ranged between 2,500 m/s and 4,000 m/s. Due the hardness of the rock at Walker Shoal and the fact that a specialised cutting tool was required to be used on the CSD for dredging in this area (INPEX Browse, 2011) it is unlikely that CSD noise measurements collected by Salgado-Kent et al. (2015) would be representative for DPD Project CSD trenching.

Salgado-Kent et al. (2015) found that in the absence of Ichthys project pile driving or dredging in East Arm, the most intense noises dominating the environment were from a range of vessels, and to a lesser extent machinery, operating in the area. Noise emissions from vessels were found to be broadband, with most energy ranging from tens of Hz to several kHz and often reaching 130 to 140 dB re 1 Pa. Underwater noise measurements taken by SVT (2009) and provided within the Ichthys EIS (INPEX Browse 2010) also show relatively high measured background noise levels within East Arm of 150-170 dB re 1 $\mu Pa^2/Hz$. Salgado-Kent et al. (2015) found that in comparison to East Arm, the ambient underwater noise levels in Middle Arm were on average lower, likely due to lesser vessel movements. It is also expected that, all other things being equal, received noise levels from vessel traffic will be lower in shallower areas of Darwin Harbour due to reduced sound propagation in shallow waters. This was found during surveys by SVT (2009) where measured ambient noise levels in the shallower Elizabeth River were lower than those for the broader East Arm.

Table 9-3 Indicative noise levels from typical Darwin Harbour vessels and DPD Project trenching vessels

Vessel Type	Source Level (dB re 1µPa2.s)	Frequency	Reference
Tanker and Bulk Carriers	180-186	Low (10-30 kHz)	INPEX Browse, Ltd, 2011
Offshore vessels (e.g. rig tender vessels)	177	Broadband	INPEX Browse, Ltd, 2011
Powerboats with 80hp outboards (small recreational boats)	156-175	Broadband up to several kHz	INPEX Browse, Ltd, 2011
Cutter Suction Dredge (CSD)	172-185	30Hz>-20kHz	Thomsen et al. 2009
Trailing Suction Hopper Dredge (TSHD)	184-188	30Hz>-20kHz	de Jong et al. 2010 Robinson et al. 2011 Reine et al. 2012
Backhoe Dredge (BHD)	175	30Hz>-20kHz	Reine et al. 2012

9.5 Potential significant impacts

There are a number of planned and unplanned project activities that could result in a significant direct or indirect impact to the values of the marine ecosystem. The sources of impact and risk and the potential impacts from the activities are described below.

Potential impacts and risks on Marine Ecosystems have been determined through the impact and risk assessment process (refer to **Section 7.4**). These impacts and risks are:

+ Seabed disturbance – **Section 9.5.1**;
+ Noise emissions – Section 9.5.2;
+ Light emissions – **Section 9.5.3**;
+ Treated seawater discharge – **Section 9.5.4**;
+ Dropped objects – **Section 9.5.5**;
+ Invasive marine species – **Section 9.5.6**;
+ Marine fauna interaction – **Section 9.5.7**;
+ Hydrocarbon spill – dry gas release – **Section 9.5.8** ; and
+ Hydrocarbon spill – marine diesel oil **Section 9.5.9**.

9.5.1 Seabed disturbance

Habitats that may be influenced directly or indirectly from Project activities have been identified by overlaying the project infrastructure layers, e.g. pipeline route, trenching zones, spoil disposal ground, and the zones of moderate impact (ZoMI) and zones of influence (ZoI) derived from sediment dispersion modelling (refer **Section 8.5.1.4**) over the available habitat information. For this purpose, Santos combined the shallow water habitat maps from AIMS 2021 report (Udyawer et al., 2021) with the deeper water habitat maps from the 2019 report (Galaiduk et al., 2019) into a single, combined habitat mapping layer (refer to **Section 9.4.3**).

A number of Project activities will directly impact the seabed and benthic habitats in the Project area and these and other activities may also result in indirect impacts to the benthic habitats and marine fauna in the Project area. DPD activities that may have a direct impact include:

+ Trenching activities, including trenching, spoil disposal, pre-sweeps, and sand wave rectification;
+ Installation of the pipeline and supporting infrastructure, including the foundation for the ILT and concrete mattresses and rock backfill;
+ Anchoring by the nearshore pipelay vessel in shallower water; and
+ Construction of temporary causeways at the shoreline.

To understand and evaluate potential direct impacts to the benthic habitats, the Project infrastructure footprints were overlaid over the combined habitat layer (AIMS 2021 and 2019 data, **Figure 9-9**) to calculate the areal extents of the different habitat categories that may be impacted by different activities. These areas were also calculated and presented as a percentage of the total area of the infrastructure footprint (refer summary in **Table 9-4**). Where sensitive habitats (e.g. seagrass) were predicted to occur under or near infrastructure footprints, benthic habitat data collected during the Santos field surveys were compared against the predicted mapping data to verify whether the predicted habitat data accurately reflected the actual habitat present. In some cases, field data verified that some sensitive habitats were not present in areas where the modelling had predicted they may be present. In such situations, field verified data were used in preference to model data.

To provide some insight into whether the predicted impacts to habitat may impact the availability of each benthic habitat within Darwin Harbour, the areas of impact were also calculated as a percentage of the total amount of each habitat predicted to be present in Darwin Harbour (refer **Table 9-4,** Note: for this calculation, Darwin Harbour included any AIMS mapped habitats within the Darwin Harbour Region Management Boundary line as shown in **Figure 2-1**). Based on these calculations, trenching and infrastructure footprints combined will impact less than 1% of the benthic habitats across Darwin Harbour and more specifically, < 0.18% of the sponge or sponges/filterers/octocoral habitat, < 0.12%% of the macroalgae habitat and ~0.12% of the bare ground habitat found across Darwin Harbour. Therefore, the Project is unlikely to result in changes the composition of benthic habitats across Darwin Harbour, or have wider impacts on the marine fauna that rely on those habitats.

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Table 9-4 Summary of the areal overlap of Project infrastructure with different benthic habitats.

Benthic Habitat	Trenching, pre-sweep and sand rectification zones (i.e., Zone of High Impact) (includes 20 m buffer) 93.3 Ha			Pipeline installation in deep water (5 m wide footprint used which excludes Zone of High Impact) 29.2 Ha			Pipeline installation in Darwin Harbour (1 m wide footprint used which excludes Zone of High Impact) 0.94 Ha			Spoil ground 649.8 Ha	
Areal extent	Ha	as % of trenching areas	as % of habitat in Darwin Harbour	Ha	as % of pipeline install footprint	as % of habitat in Darwin Harbour	Ha	as % of pipeline install footprint	as % of habitat in Darwin Harbour	Ha	as % of spoil ground area
Bare ground	26.7	28.60	0.120	3.13	37.7	0.014	0.33	35.4	0.0015	53.5	8.2
Hard coral	-	-	-	-	-	-	-	-	-	-	-
Seagrass	-	-	-	-	-	-	-	-	-	-	-
Macroalgae	4.97	5.30	0.115	-	-	-	-	-	-	-	-
Sponge or Sponges/ Filterers/ Octocorals	60.75	65.10	0.157	5.17	62.3	0.013	0.61	64.6	0.0016	596.3	91.8

Note: Habitat areas are expressed as hectares (Ha) and as a percentage of the infrastructure area. Areas where there were no habitat data, e.g. beyond Darwin Harbour, are not presented.

9.5.1.1 Trenching zones

The Project has four trenching zones, three planned pre-sweep areas and a sand wave rectification area located along the pipeline route (refer **Figure** 2-4). To calculate the potential direct loss of benthic habitats (i.e., within the Zone of High Impact), the habitats present within each zone were identified. To be conservative, the widest predicted width for any trenching zone (the top of the trench is predicted to be 40 m wide) was used as the width for all zones and a 20 m buffer either side was also applied when determining the potential direct losses. AIMS mapping identified that over 65% of the habitat present in the trenching, pre-sweep and sand wave rectification zones (plus buffer) is low density sponge, filter feeder and octocoral habitat, 28.6% is bare ground, with 5.3% macroalgae (refer **Table 9-4** and **Figure 9-6**). While the habitat mapping identified the environment may be suitable for macroalgae and seagrass in trenching zones near the shoreline, a survey transect over this area (refer **Figure 9-10**) verified that while there was some macroalgae present, it was not as expansive as the mapping indicated and there was no seagrass present. The habitat in this nearshore area is sand veneer with patches of rock, macroalgae (20% coverage), sponges (10-20% coverage), and low to medium density epibiota (5-40% coverage) (RPS, 2022a). Similarly, the INPEX benthic habitat mapping determined the habitat in the nearshore area in trenching zone 1 was sand/sand communities (refer **Figure 9-10**). There are no unique, or sensitive habitats in the trenching, pre-sweep or sand wave zones surveyed and/or predicted and the habitats present are expansive across Darwin Harbour and well represented in other locations, both within the harbour and regionally. While habitats will be directly impacted by trenching activities, impacts will be over a comparatively small area compared to the extent of similar habitat in the immediate vicinity. Furthermore, the placement of project infrastructure is also expected to provide additional habitat and structure that will provide its own value to the marine ecosystem and the species present, refer to **Section 9.5.1.3** for more discussion on this point.

9.5.1.2 Spoil disposal

The habitat present in the spoil disposal ground (plus a 20 m buffer) is predicted to be 91.8% low density sponge, filter feeder and octocoral habitat and 8.2% bare ground (refer **Table 9-4** and **Figure 9-6**). This evaluation is supported by the benthic habitat field survey completed across the area (RPS, 2022a, **Appendix 6**). There are no unique, or sensitive habitats and the habitats present are well represented regionally. While the habitats present will be directly impacted during the disposal of spoil, the spoil itself will provide similar habitat for marine species to colonise. No contaminants of concern were found in the sediments along the pipeline route or at the potential spoil disposal ground, with elevated levels of arsenic considered to be naturally occurring. Therefore, the sediments along the pipeline route are considered to be suitable for unconfined ocean disposal, as per the National Assessment Guidelines for Dredging (NADG, 2009) and Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory. Consultation with the Amateur Fisherman's Association of the Northern Territory (AFANT) (refer **Section 4**) has revealed that the addition of dredge spoil to the INPEX spoil ground adjacent from the DPD Project spoil ground and from the Ichthys project dredging campaign has created fish habitat and enhanced recreation fishing opportunities in the area. It is therefore possible that the disposal of spoil from the DPD Project in the adjacent spoil ground may create similar habitat for recreational fishing species.

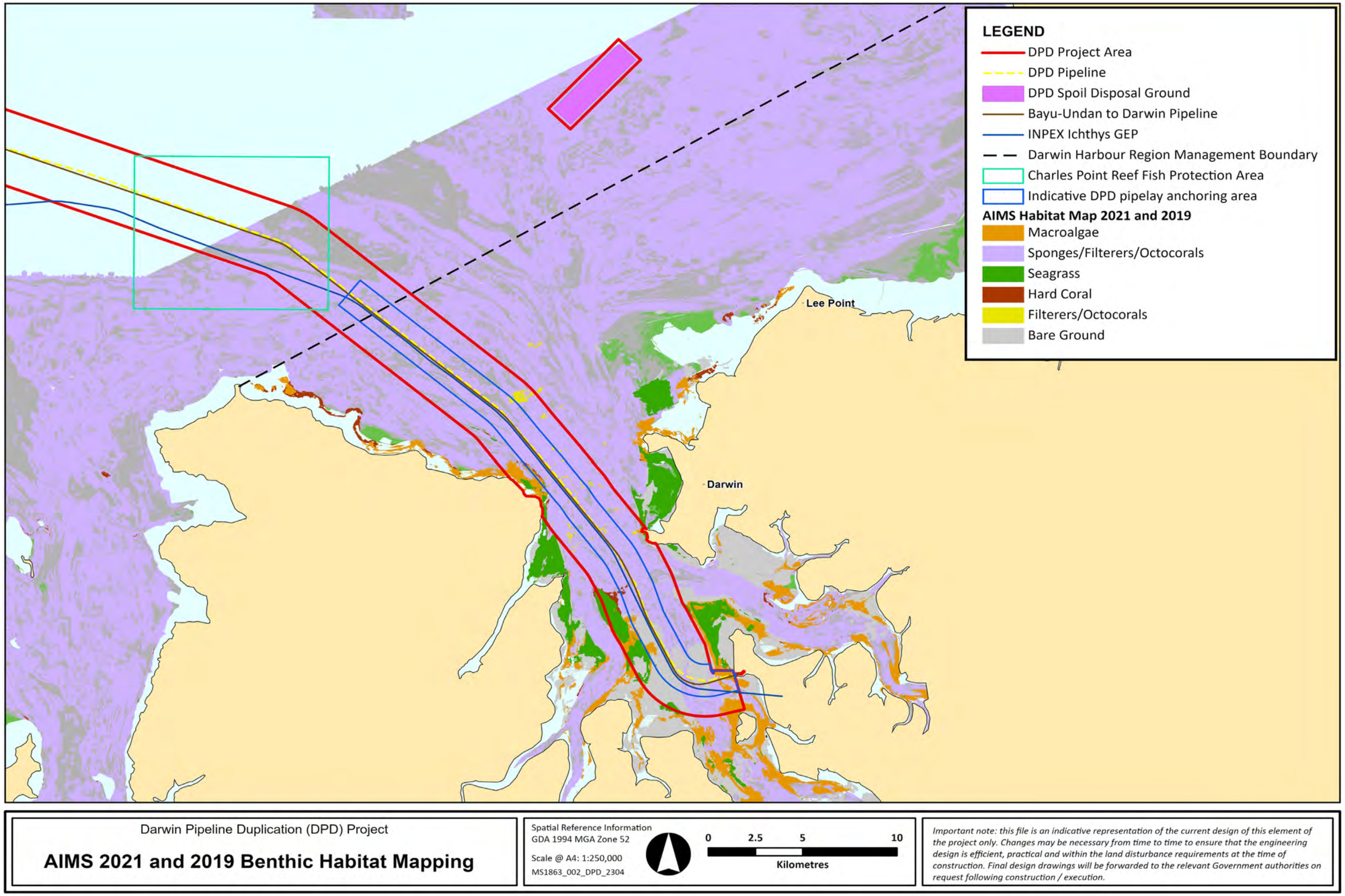

Figure 9-9 Project activities and infrastructure overlaid over mapped benthic habitat

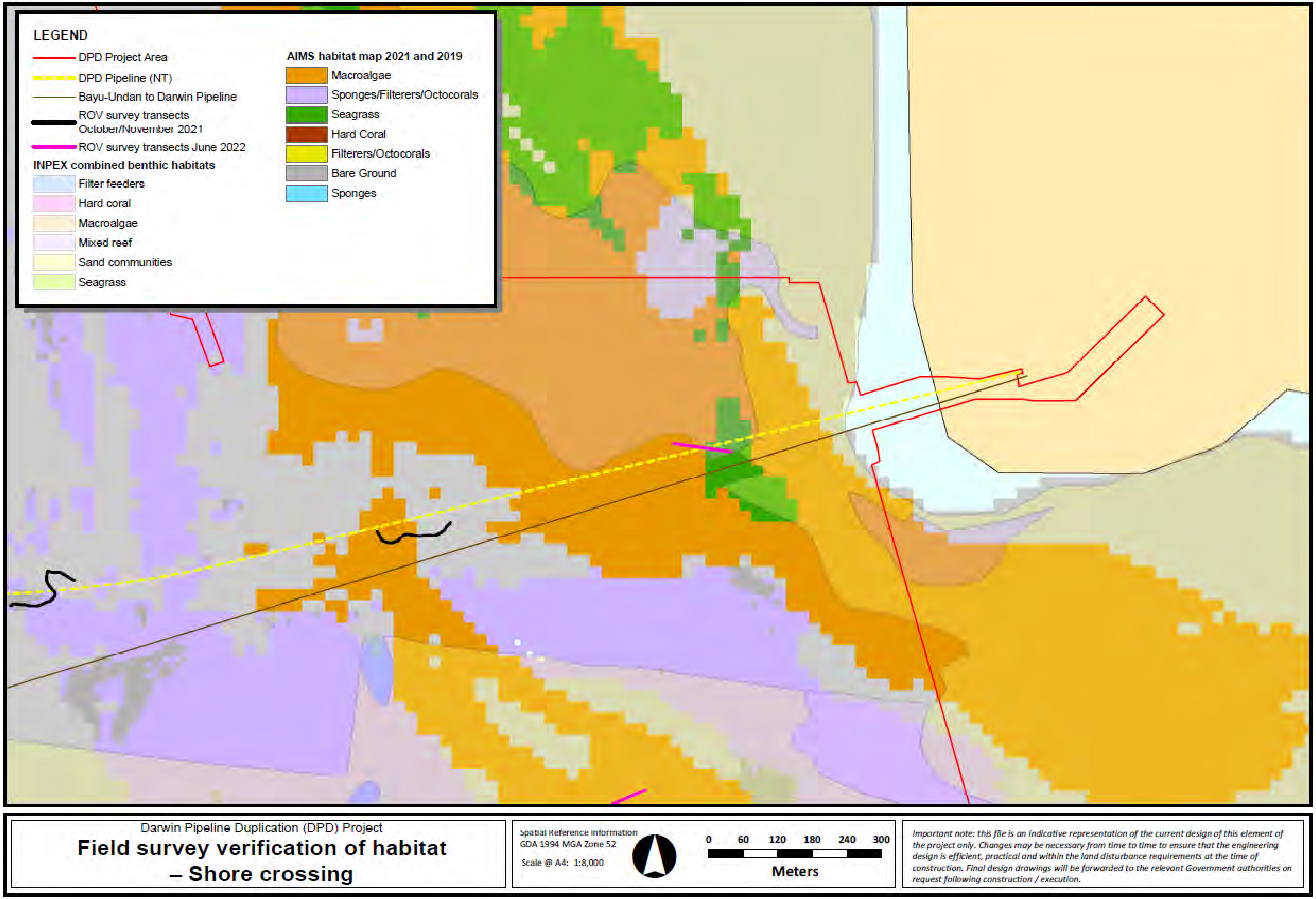

Figure 9-10 Field survey transect verified the nearshore habitat was not AIMS predicted seagrass and macroalgae, but more comparable to INPEX sand community habitat

9.5.1.3 Pipeline and infrastructure

When the pipeline is laid directly on the seabed, there is the potential for some minor lateral movement of the pipeline until sections become embedded with sediment. Consequently, there is potential for the seabed and benthic habitats to be impacted over a wider area than the immediate pipeline footprint. For the section of pipeline being laid directly on the seabed (from the NT waters boundary in deeper water extending through the sand wave rectification zone to the most offshore trenching zone, zone four at ~KP103.5), a 5 m wide footprint was used to conservatively assess the direct, ongoing impacts to benthic habitats from installation of the pipeline. There is no continuous habitat data available for part of this area, so the impact assessment for that assessment is qualitative and based on the benthic habitat data collected during dedicated field surveys (RPS, 2022a; **Appendix 6**). For the area that has continuous habitat mapping data, 62.3% of this section is low density sponges, filterers and octocorals and 37.7% is bare ground (**Table 9-4** and **Figure 9-6**). Benthic habitat surveys in 2021 and 2022 confirm that the benthic habitats along the pipeline route further offshore than the continuous mapping are of similar habitat, i.e., a mix of find sand veneer with some rubble and small rocks, sand waves or fine sand with scattered rocks and rubble with low density filterers (RPS, 2022a; **Appendix 6**).

When the pipeline is laid in and between trenching zones, there is much less potential of lateral movement. Given this, a narrower footprint of one metre was used to assess the ongoing, direct impacts to benthic habitats from the pipeline from ~KP103.5 to the shore crossing. The benthic habitats under this footprint (and not previously considered in the trench, sand wave and pre-sweep zones) are primarily low density sponges, filterers and octocorals (64.6%) and bare ground (35.4%) (**Table 9-4** and **Figure 9-6**). These are the most common habitats found within the harbour and are well represented, both within the harbour and regionally. While they will be directly impacted by placement of the pipeline and project infrastructure, that infrastructure will provide additional habitat for marine species to colonise and use (refer below).

Benthic habitats found under the footprints of other project infrastructure such as mattresses and supporting infrastructure, including the foundation for the ILT and concrete mattrasses are also a mix of low density sponges, filterers and octocorals and bare sand.

Rock backfill to stabilise the pipeline will be placed within the extent of the trenching zones and as such, no additional impacts to benthic habitats will occur. Based on the current design the top of the rock backfill is below or very close to the natural seabed level. There is one section of the proposed pipeline route at the shore crossing, from KP121.37 to KP122.48 (~110 m in length), where the top of the proposed berm design will be up to 1.5 m above the natural seabed level in some small lengths over the section.

As presented in **Section 9.4.2**, the seabed in the Charles Point Wide RFPA is largely flat and featureless with occasional small changes in topography and characterised by silty shelly sand with very sparse to sparse (1-5% coverage) epibiota (mainly soft corals, crinoids and sponges). The pipeline will be laid bare on the seabed in this area, so impacts to seabed and benthic habitats will be low (i.e., no trenching, it will take the pipelay vessel an estimated 6 days to lay the pipe through the extent of the RFPA). DITT-Fisheries Division identified a known jewfish aggregation area within the RFPA; however, this is over 2.5 km from the pipeline route and will not be impacted from any seabed disturbance resulting from the Project activities. Further to this, the habitat associated with the identified fish aggregation site was identified as low profile relief with medium to high density biota (RPS, 2022a; **Appendix 6**). This type of habitat was not found to be present along the pipeline route.

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Overall, there are no unique, or sensitive habitats along the Project pipeline route and the habitats present are well represented in other locations, both within the harbour and regionally. While they will be directly impacted by placement of project infrastructure, that infrastructure will provide additional habitat for marine species to colonise as has been observed along other gas pipelines.

A recent study by AIMS documented distinct fish assemblages associated with the existing Bayu-Undan to Darwin pipeline that differed from the surrounding predominantly bare habitat fish assemblages (McLean et al., 2021). The fish assemblages observed on and around the pipeline were of higher diversity than those found off the pipeline (McLean et al., 2020). Sessile biota growing on the pipeline also included potential prey for marine turtles, such as soft corals and sponges. Sessile biota growing on the pipeline were observed to be present at much lower densities, or absent, from the habitats surrounding the pipeline (McLean et al., 2021). Therefore, it is concluded that any direct impacts from installing project infrastructure will be mitigated to some extent by the provision of additional habitat and structure for marine species colonise and use.

9.5.1.4 Anchoring of pipelay vessel

A Dynamically Positioned (DP) pipelay vessel will be used to lay the offshore sections of the pipeline. A DP vessel is depth restricted so can only operate until approximately KP91-KP92 before an anchored pipelay vessel will be required to complete pipelay through the harbour to the shore crossing.

Anchoring during pipelay is dependent on the site and seabed conditions, e.g. water depth, substrate type, potential for anchors to drag, and is heavily weather dependent. An anchor spread is used to provide sufficient holding power for the vessel during pipelay and includes forward and rear anchors placed closer to the centreline of pipelay, and breast anchors which can be 500 m to 900 m from the vessel. To calculate the potential impact on benthic habitats (i.e., the temporary placement of anchors and anchor lines), a 900 m buffer either side of the pipeline route was used to identify the habitats that may be present in the anchoring zone. The adoption of anchor exclusion areas will be implemented to avoid sensitive habitats and known heritage sites.

The habitats in the anchoring zone were determined from benthic habitat mapping to be approximately 70% sponges, filter feeders and octocorals, approximately 28% bare ground, approximately 2% macroalgae. The mapping identified <1% hard coral and seagrass (**Figure 9-6**). Upon closer inspection of the location of the potential seagrass and hard coral habitat, two areas were identified as requiring further investigation due to their presence within the anchoring zone: an area near Weed Reef and an area off Mandorah.

These two areas were targeted during the June 2022 field survey and the data collected verified that no seagrass was present, nor were hard coral present in the locations near Mandorah (refer **Figure 9-11**). The benthic habitats present along the three transects surveyed in that area were sand waves and large sand ridges/banks or sand with some gravel and all transects have very low density macroalgae and octocorals (<1%) (RPS, 2022a; **Appendix 6**).

Similarly, patches of potential hard coral habitat in the anchoring zone near Weed Reef (**Figure 9-12**) were also surveyed to verify the habitats present. Site Hab6 (closest to the pipeline) consisted of mobile sediments with high and low relief patchy rock covered with turf (40-50% cover) with sponges and other filter feeders and low-density hard coral comprising 1-5% of the area. Site Hab7 consisted of patchy rock with high relief ridges and outcrops with a thick sediment veneer, again with turf (40-50% cover), sponges and other filter feeders and some hard coral comprising 5-10%. Interestingly, no seagrass was observed along any of the transects at or near Weed Reef.

Given the presence of patchy rock and high relief ridges and the presence of hard coral (albeit in low density), anchors will not be laid on sensitive habitats in this area through the implementation of anchor exclusion zones.

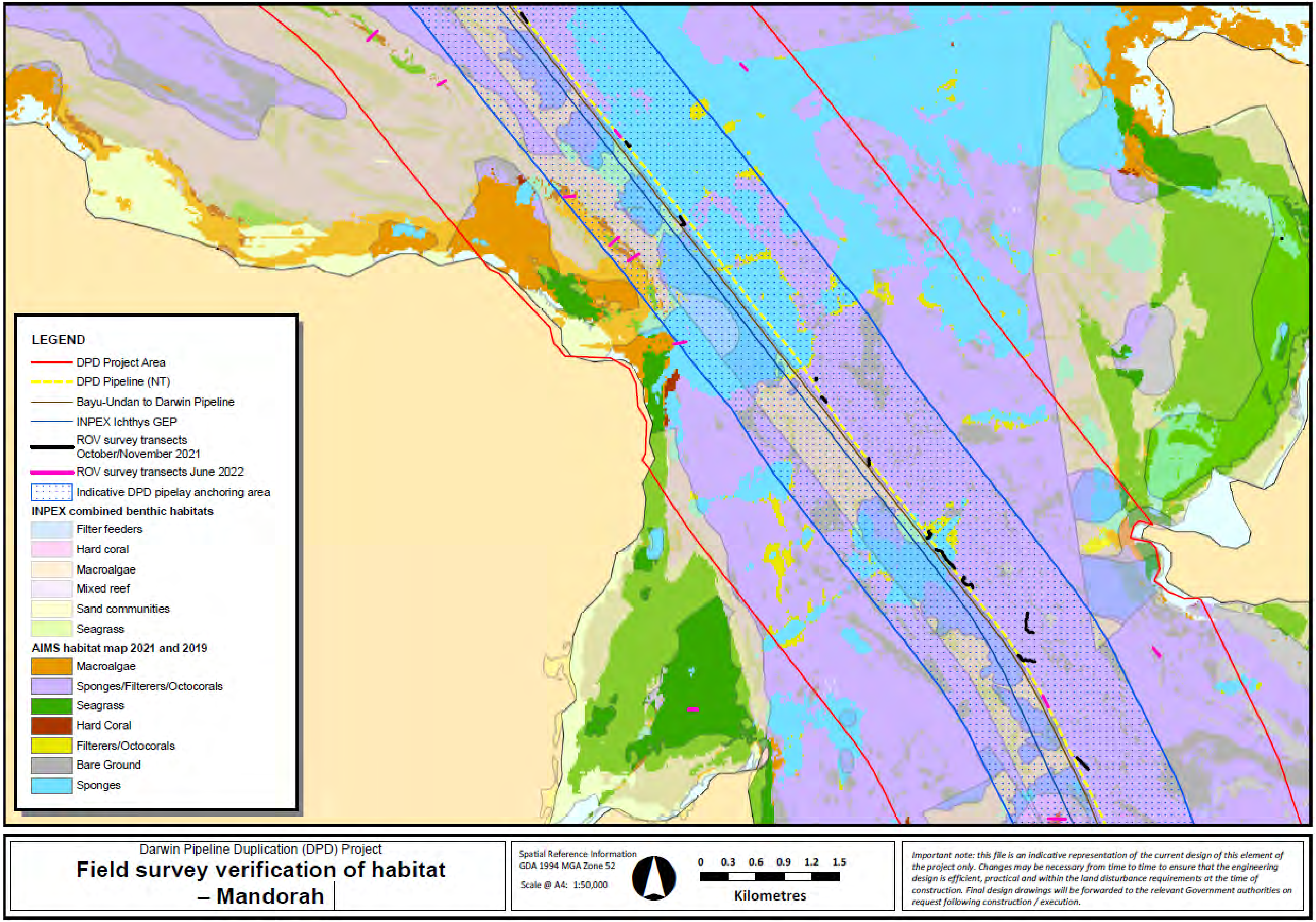


Figure 9-11 Benthic habitat survey locations off Mandorah. Survey data verified assessed the benthic habitat present in the potential anchoring zone

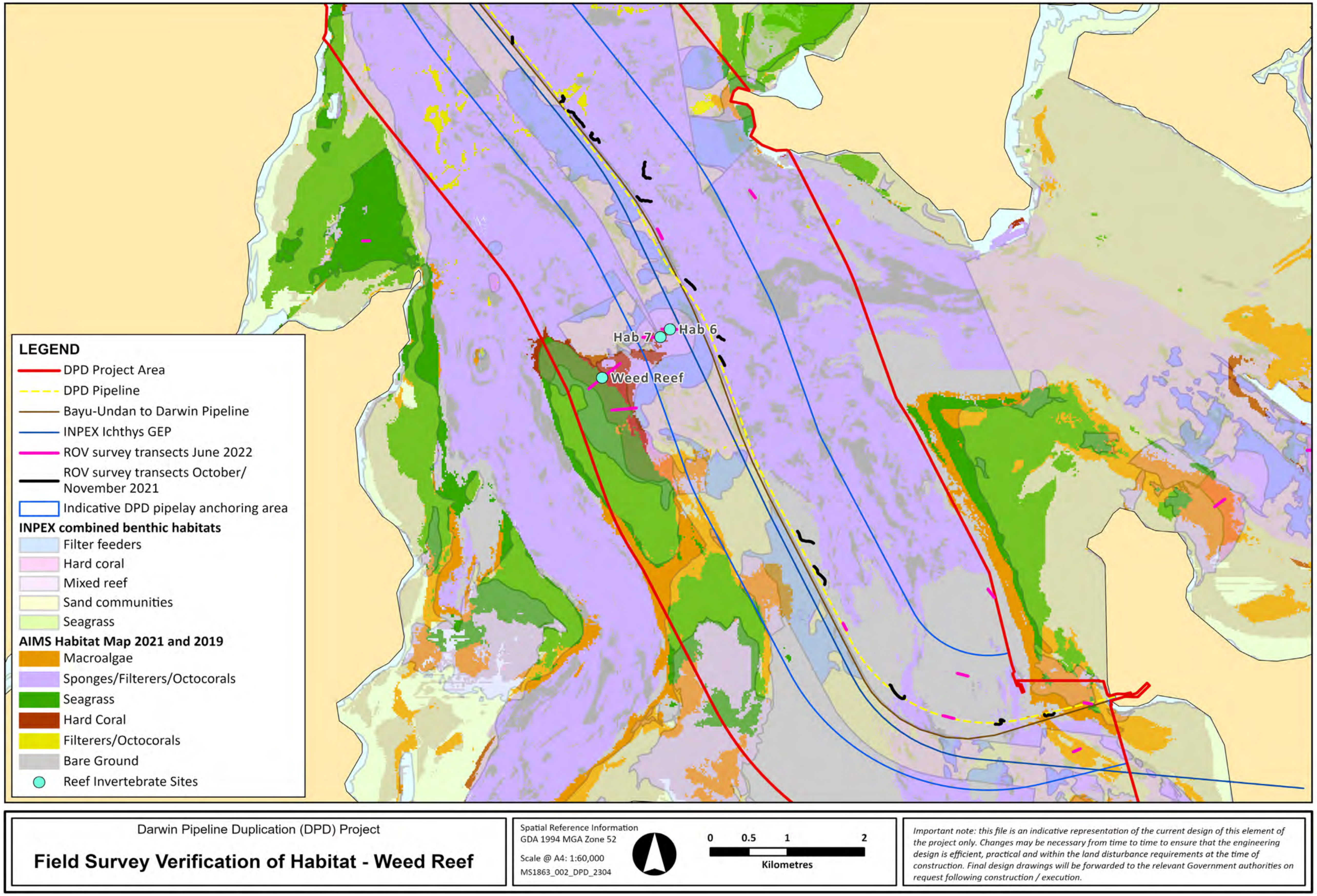


Figure 9-12 Field survey verification of habitat – Weed Reef

9.5.1.5 Temporary causeways

Section 2.3 provides details of the temporary causeways. The temporary causeways will be no greater than 200 m long by 25 m wide. As described in the previous section, while mapping (**Figure 9-10**) identified potential macroalgae and seagrass habitat near the shoreline, a survey transect over this area verified that while there was some macroalgae present, it was not as expansive as the mapping indicated and there was no seagrass present. The habitat in this nearshore area is sand veneer with patches of rock, macroalgae (20%), sponges (10-20%), and low to medium density epibiota (5-40%). Consequently, while construction of the temporary causeways will directly impact the benthic habitats present, it is a relatively small area of habitats that are widely represented elsewhere in the harbour. It is expected that upon removal of the temporary causeways, the habitat and wider ecosystem will return to pre-impact conditions over a short time period.

9.5.1.6 Indirect impacts to benthic habitats

In addition to direct impacts from seabed disturbances associated with Project activities, the increase in turbidity and sedimentation from trenching and spoil disposal activities has the potential to indirectly impact benthic habitats, e.g. through reduced light for photosynthesis by benthic primary producers, and/or smothering of habitats from sedimentation.

Based on the results of the sediment dispersion modelling presented in **Section 8.5.1**, and applying the SSC thresholds for different benthic habitats and locations (**Table 8-2**) no indirect impacts from increased SSC is predicted. No exceedance of SSC thresholds for a Zone of Influence (ZoI) or a Zone of Moderate Impact (ZoMI) is predicted to occur for trenching and soil disposal in either the winter/dry season, or the summer/wet season. While sedimentation thresholds for ZoI and ZoMI were reached, the predicted ZoMI for sedimentation from the trenching and disposal operations for both seasonal scenarios is restricted to the trenching and spoil disposal footprints, which are also within the Zone of High Impact (ZoHI) where direct impact will occur. The predicted ZoI for sedimentation from spoil disposal operations for both seasonal scenarios is also restricted to within the spoil disposal footprint, i.e., where direct impact will occur. For the trenching operations, the ZoI is largely restricted to the trenching footprints. Modelling has predicted that the ZoI may extend a short distance beyond the trenching footprint in some areas. For example, at trenching zone 3, the ZoI may extend in an irregular pattern up to 95 m beyond the trenching zone. The benthic habitats in the ZoI beyond the trenching footprint are a mix of bare sand, low density sponges/filterers/octocorals and sponge habitat. Consequently, the restricted spatial extent of SSC and the sediment above impact thresholds means that activities are not expected to impact benthic habitats, including sensitive habitats such as hard coral, seagrass and mangroves since they are not present in any of the modelled ZoMI/ZoIs

9.5.1.7 Impacts to marine fauna from seabed disturbance

Benthic habitats also provide a range of functions for different fauna inside and outside the harbour including functioning as refuge, feeding and reproductive areas. A study undertaken by the Department of Land Resource Management in 2012 (Gomelyuk, 2012) reported that the most diverse and abundant fish biodiversity and abundance was found for both coral and deeper filter feeder communities in the Harbour, with the highest values found at Darwin Harbour entrance, in the area to the south-west from Channel Island and at South Shell Island.

Compared to bare sand or substrate, sessile filter feeders, such as bivalves, molluscs, sponges and coral, can provide more complex habitat, more diverse fish assemblages and may provide foraging material for marine turtles. Based on all available mapping and field data, filter feeder habitat is well represented across the harbour. The narrow footprint of the pipeline and the location of the trenching, pre-sweep and sand wave rectification zones overlays less than 1% of the filter feeder habitat present across Darwin Harbour. Direct disturbance to these areas is, therefore, unlikely to have a significant impact on the abundance and availability of filter feeder habitat and consequently, unlikely to impact the marine fauna that utilise these habitats. Furthermore, the presence of the pipeline and the rockfill used to protect and stabilise the pipeline will provide additional habitat, supplementing any loss from placement of the infrastructure.

In terms of listed marine megafauna species, DPD Project construction activities are not expected to disturb critical seabed habitats used for foraging. Dolphins within Darwin Harbour are transient and likely to be opportunistic in their feeding behaviour (**Table 9-1**), the seabed habitats that will be directly disturbed by the DPD Project are not known as key dolphin foraging habitat and are well represented in Darwin Harbour. Dugongs are known to feed on seagrass, and to a lesser extent macroalgae, within Darwin Harbour and adjacent coastal areas, with seagrass beds offshore from Lee Point and Casuarina Beach considered key areas (**Table 9-1**). Neither direct or indirect impacts to known seagrass beds within or outside Darwin Harbour are expected from DPD Project construction activities, including trenching and spoil disposal. There is potential for a small area of macroalgae to be disturbed along the pipeline route at the shore-crossing location at Wickham Point (based on habitat mapping and ground-truthing), however, the relative proportion of this area compared to total habitat in Darwin Harbour is very low (<0.2%, **Table 9-4**). Therefore, the DPD Project is not expected to have a significant impact on dugong foraging habitat. Similarly, green turtles are known to occur and forage within Darwin Harbour on shallow macroalgae areas (refer **Table 9-1**) and the same conclusion applies. The other turtles that occur, and may also forage within, Darwin Harbour are flatback turtles and hawksbill turtles (**Table 9-1**). Given their broader diets and known feeding within deeper seabed habitats supporting filter feeders (e.g. sponges and soft corals), there is the potential that the seabed directly disturbed by the DPD Project could be used as foraging habitat for these species. However, given the habitat (sponge or sponges/filterers/octocorals) is well represented within Darwin Harbour and offshore waters, and the DPD Project disturbance is less than 1% of this total available habitat (**Table 9-4**), significant impacts to the foraging of these species is not expected. It should also be noted that the pipeline and associated infrastructure will provide a hard surface for recolonisation of biota that flatback and hawksbill turtles can forage on (refer **Section 9.5.1.3**) and therefore any loss of foraging habitat could be partially or completely offset by this new habitat.

As presented above, AIMS documented distinct fish assemblages associated with the existing Bayu-Undan to Darwin pipeline that differed from the surrounding fish assemblages (McLean et al., 2021). The fish assemblages observed on and around the pipeline were of higher diversity than those found off the pipeline (McLean et al., 2020). Sessile biota growing on the pipeline also included potential prey for marine turtles, such as soft corals and sponges. Given the localised area of construction activities occurring at any given time during the DPD Project construction window, the relatively small area of direct seabed disturbance relative to overall habitat availability in Darwin Harbour and there being no evidence of impacts to mud crab recruitment and catches within Darwin Harbour related to previous pipeline installation campaigns, it is considered unlikely that the DPD Project will have any significant effect on mud crab migration and population numbers within Darwin Harbour.

9.5.1.8 Impacts to primary productivity

As discussed in **Section 9.5.1**, direct impacts to the seabed will occur from laying the pipeline on the seabed, trenching required to stabilise and protect the pipeline, spoil disposal activities, and the construction of the temporary causeways and from shallow water pipelay barge anchoring. The hard coral and seagrass locations will be included in the Project exclusions zones when managing anchoring in the shallower waters. The sediment dispersion modelling indicates that there will be no indirect impacts to these habitats from either increased SSC or sedimentation, (refer **Section 9.5.1.6**). While it is recognised that elevated suspended sediments can trap phytoplankton and zooplankton and subsequently remove them from the primary production cycle as the suspended sediments settle out on the seafloor, the narrow spatial extent of the area of elevated suspended sediments and short-term nature of the trenching and spoil disposal activities is unlikely to result in any significant impact to the primary production cycles.

As described in **Section 9.5.1.1**, there are some macroalgae and low to medium density epibiota present in trenching Zone 1 and Zone 2 near the shoreline (though field surveys determined it was not as expansive as AIMS mapping predicted) and there is also a small amount of mangrove regrowth at the shore crossing location which was cleared during installation of the Bayu-Undan to Darwin pipeline. Consequently, there will be some direct impact to these primary producer habitats in this area and direct impact to the benthic fauna/infauna and nutrient/trophic processes within the sediment present in the trenching zones.

Given the need to stabilise and protect the pipeline in the shallow water and given the narrow footprint and presence of these habitats beyond this footprint across Darwin Harbour and wider region, the DPD Project activities are not expected to have a significant impact on these benthic primary producer communities.

These conclusions are supported by the results of the INPEX Nearshore Environmental Monitoring Program (NEMP) which monitored dredging-related impacts to marine plant productivity by measuring:

+ Leaf litter fall in the tidal flat assemblage of mangrove communities;
+ Phytoplankton biomass within the water column; and
+ Intertidal microphytobenthos biomass in intertidal mudflats.

No detectable dredging-related impacts were found during the monitoring program and dredge-related sediments did not contribute to sedimentation at levels that may influence primary production in mangroves at the monitoring locations. . It also found that changes in leaf litter fall detected are attributable to and consistent with seasonal dynamics (Cardno, 2014).

Differences detected in Chlorophyll-a (Chl-a) and pheophytin concentrations (a proxy for microphytobenthos biomass) in intertidal sediments between baseline and dredging monitoring impact sites were determined to be unrelated to dredging activities within Darwin Harbour, as some of the control sites also showed similar patterns of variability between baseline and dredging monitoring. It was therefore suggested that these differences were as a result of natural variability (Cardno, 2014).

Phytoplankton productivity was measured by monitoring Chl-a fluorescence concentrations in the water column. The NEMP found no clear link between turbidity and surface Chl-a fluorescence concentrations at any of the monitoring sites which indicates no impacts to phytoplankton biomass from dredging-related turbidity. The patterns indicate that multiple factors may influence phytoplankton productivity in the harbour and was therefore not solely attributed to dredging activities (Cardno, 2014).

9.5.2 Underwater noise emissions

Underwater noise emissions have the potential to affect Marine Ecosystems and marine fauna that occur within or transit through the Project area, including marine mammals, reptiles, sharks/rays and other fish. Marine fauna potentially impacted and particularly sensitive to underwater noise include EPBC Act listed threatened (marine turtles) and migratory species (dolphins and dugongs). Marine fauna use sound for a range of functions such as social interaction, foraging and orientation. Marine fauna respond variably when exposed to underwater noise from anthropogenic sources, with effects dependent on a number of factors, including distance from the sound source, water depth and bathymetry, the animal's hearing sensitivity, type and duration of sound exposure and the animal's activity at time of exposure.

Broadly, the effects of sound on marine fauna can be categorised as:

+ Acoustic masking – Anthropogenic sounds may interfere with, or mask, biological signals, therefore reducing the communication and perceptual space of an individual. Auditory masking impacts may occur when there is a reduction in audibility for one sound (signal) caused by the presence of another sound (noise). For this to occur the noise must be loud enough and have a similar frequency to the signal and both signal and noise must occur at the same time.
+ Behavioural response – Behavioural impacts will depend on the audible frequency range of each potential receptor in relation to the frequency of the noise, as well as the intensity of the noise. Behavioural changes vary significantly and may include temporary avoidance, increased vigilance, reduction in foraging and reduced vocalisations.
+ Physiological impacts – Auditory threshold shift (temporary and permanent hearing loss) – marine fauna exposed to intense sound may experience a loss of hearing sensitivity, or even potentially mortal injury. Hearing loss may be in the form of a temporary threshold shift (TTS) from which an animal recovers within minutes or hours, or a permanent threshold shift (PTS) from which the animal does not recover.

Research has found that the noise levels at which physiological impacts such as TTS and PTS occur is dependent on whether the noise being generated is classed as impulsive or non-impulsive.

The definition of these two categories is as follows:

+ **Impulsive** – sounds produced are typically transient, brief (less than one second), broadband and consist of high peak pressure with rapid rise time and rapid decay (NOAA, 2018). This noise source is associated with activities such as pile driving, seismic activities and underwater blasting and results in some of the most powerful sounds produced underwater (Yelverton et al., 1973; Young, 1991).
+ **Non-impulsive** – sounds produced can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have the high peak sound pressure with rapid rise / decay times that impulsive sounds do (NOAA, 2018). This type of noise source is associated with activities such as dredging, vessel noise, drilling and some construction activities.

There will be a period of increased noise emissions during construction activities due to the operation of vessels and equipment, operation of survey and positioning equipment and from helicopters supporting the installation activity. Underwater noise emissions will be temporary and relatively short in duration as vessels move along the linear construction corridor. During operations, the only noise emissions will be vessel-based and indistinguishable from any other vessel activity within and on the approach to Darwin Harbour. As such, noise emissions during operations are unlikely to have a significant impact on marine mammals. The increase in vessel traffic from the Project is not expected to contribute significantly to the vessel movements within the Darwin Harbour (refer **Figure 2-9**).

Noise associated with vessel activity that could impact marine fauna includes noise generated by vessel thrusters, engines and propellers, as well as noise emitted onboard which is converted to underwater noise through the hull (i.e., from heavy machinery, pipe construction works). The main source of vessel noise will be from propellers or thrusters.

Helicopters will also generate noise and the main source of noise emissions from helicopters is the engines and the rotor blades. Strong underwater sounds are detectable for only brief periods when a helicopter is directly overhead during take-off and landing (Richardson et al. 1995).

Noise will also be generated during the Project from trenching, installation activities including span rectification activities, placement of the Project pipeline and stabilisation and protection structures (including mattresses and rock placement).

Of these activities, and in discussion with underwater noise modellers, trenching activities using a combination of TSHD, CSD and BHD (including rock breaking using hydraulic tools) were considered the most significant sources of Project underwater noise. These activities have been modelled to quantify noise emissions and marine fauna exposures to inform impact assessment and marine fauna noise management measures including the development of a Marine Megafauna Noise Management Plan (MMNMP; **Appendix 7**). An overview of the modelling approach is presented below with the full technical reports presented in **Appendix 8** (Talis Consultants, 2023) and **Appendix 9** (Connell et al., 2023).

Underwater noise modelling initially conducted for the Project (Talis Consultants, 2023; **Appendix 8**) included for dredging vessel noise emissions (TSHD, CSD and BHD), vibratory hammer (sheet piling) noise emissions and hydraulic hammer (BHD rock breaking) noise emissions. Since completion of that modelling, further definition of the Project scope was developed by Project contractors, including removal of the need to construct a cofferdam (and associated sheet piling) and further detail made available on the type and specification of rock breaking tools. For rock breaking from the BHD, an Xcentric Ripper tool is considered the base case option with a hydraulic hammer proposed as a contingency only.

To better represent underwater noise emissions and fauna exposure from the use of BHD rock breaking tools, additional underwater modelling was undertaken for an Xcentric Ripper (Xcentric Ripper XR-60) and a hydraulic hammer (Epiroc HB 10000) (Connell et al., 2023; **Appendix 9**). The results presented in **Section 9.5.2.3** for an Xcentric Ripper and a hydraulic hammer have been taken from that modelling. Since sheet piling is no longer required for the Project, the vibratory hammer modelling results included in Talis Consultants (2023) (**Appendix 8**) have not been presented below.

9.5.2.1 Underwater Noise Modelling Scenarios

The following Project underwater noise sources/scenarios have been modelled:

+ **Trenching**: trenching will be undertaken using a combination of a TSHD, a CSD and a BHD. The following indicative 24-hour cycle times for each type of trenching vessel were modelled:
  - **TSHD** – The TSHD will alternate between trenching activities and spoil disposal at the offshore spoil ground. Cycle times are dependent on distance from spoil ground but

nominally have been modelled as 3 hours trenching noise (non-impulsive noise, continuous noise), 2 hours transit to spoil ground and back (i.e. 'no noise' period) repeated over period of 24 hours.

- **CSD** – 10 hours cutting (non-impulsive, continuous noise), 2 hours downtime over 12 hours (2x 12-hour cycles per 24h).
- **CSD + TSHD** – The cycles for TSHD and CSD were applied at the same trenching location to conservatively assess cumulative effects of these vessels if they were operating side by side.
- **BHD** (in an area requiring rock breaking) - 4 hours of rock breaking modelled using an Xcentric Ripper (non-impulsive, continuous noise) and a hydraulic hammer (impulsive noise), 4 hours no noise (switching between rock breaking tool and excavating tool) and 4 hours digging (non-impulsive, continuous noise) over a 12-hour period and repeated (2x 12-hour cycles per 24h) i.e., cumulative total of 8 hours each of rock breaking, digging and no noise.
- **BHD** (hydraulic hammer sensitivity analysis) - In addition to modelling a Xcentric Ripper and a hydraulic hammer noise for 8 hours per 24 hours, a sensitivity analysis on the effect of reducing operation time for the hydraulic hammer was undertaken, since the modelled PTS/TTS ranges for this tool were relatively large. The sensitivity analysis modelled reduced operation times of 6, 4 and 2 hours per 24 hours for the hydraulic hammer.

Trenching scenarios have been modelled at three representative locations **(Figure 9-14)**:

+ Location 1 - BHD excavating and rock breaking (Xcentric Ripper or hydraulic hammer) in an area of hard rock;
+ Location 2 - TSHD operating at a middle harbour trenching zone. This area was also relatively close to Weed Reef compared to other trenching zones. Weed Reef is a known hard reef area supporting greater diversity of biota (including hard corals) and may support higher marine fauna abundance.
+ Location 3 - TSHD (alone) and TSHD/ CSD (operating together) operating in an outer harbour trenching zone. This zone was relatively close to Cox Peninsula shallow water and shorelines which support a higher diversity of biota and may support higher marine fauna abundance.

The sound source locations and levels used for each modelling scenario are shown in **Figure 9-14** / **Table 9-5** and **Table 9-9** respectively.

Table 9-5 Noise Modelling Locations and Scenarios

Location	Scenario	Easting (GDA94, MGA Zone 52) (m)	Northing (GDA94, MGA Zone 52) (m)	Recurring Cycle Time over 24 Hours
Location 1	BHD (Excavating)	701 366	8 614 382	Two x 4 hours of digging over 24 hours.
	BHD (Rock breaking)			Two x 4 hours rock breaking over 24 hours.
Location 2	TSHD	696 636	8 620 225	3 hours trenching and 2 hours transit/ spoil dump.

Location	Scenario	Easting (GDA94, MGA Zone 52) (m)	Northing (GDA94, MGA Zone 52) (m)	Recurring Cycle Time over 24 Hours
Location 3	TSHD	692 710	8 625 712	3 hours Trenching and 2 hours transit/ spoil dump
	Concurrent operations – TSHD and CSD			TSHD (3 hours trenching and 2 hours transit/ spoil dump). CSD (10 hours of cutting and 2 hours downtime).

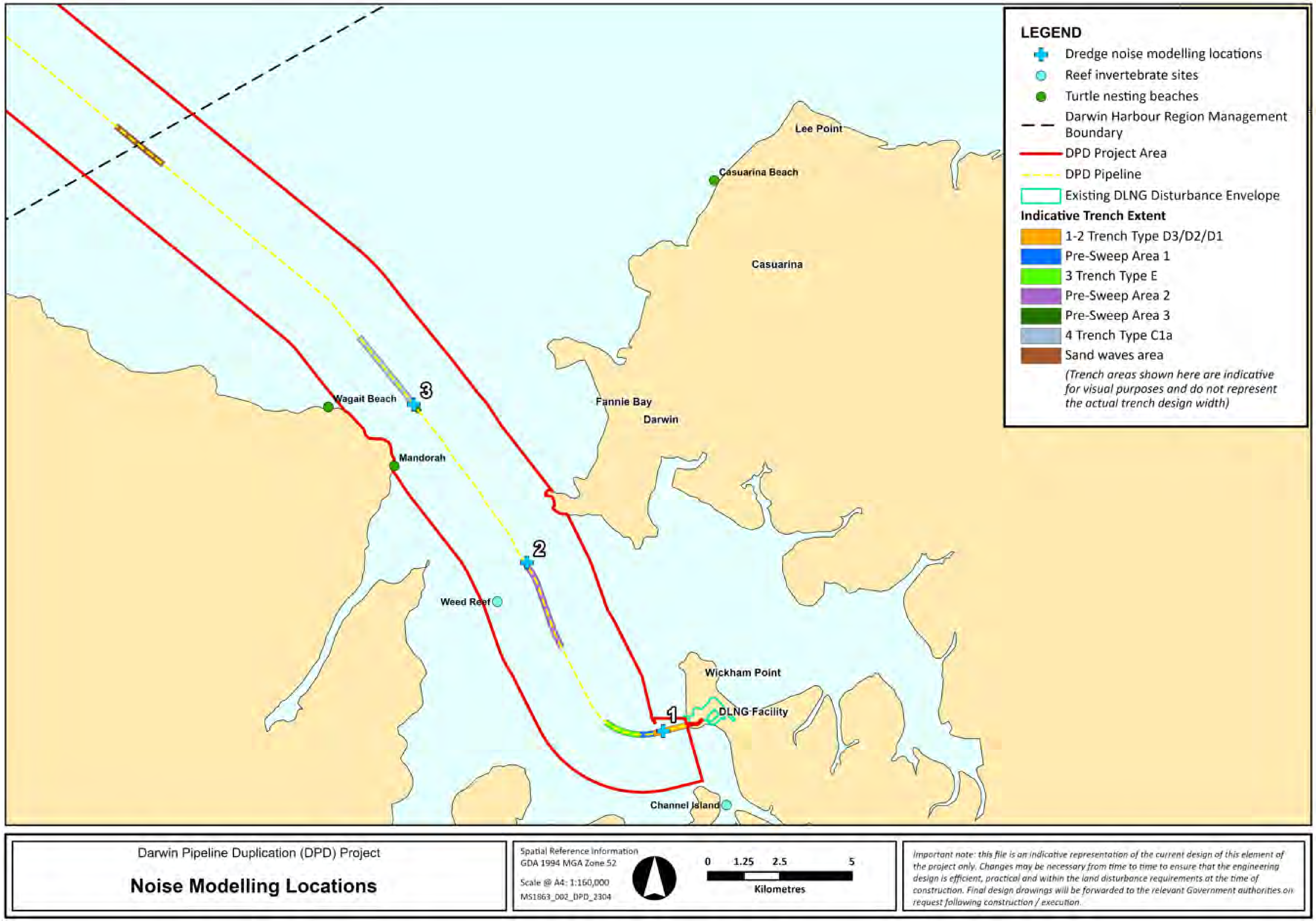


Figure 9-13 Location of modelled noise sources

Source type	Source Level
TSHD	184 dB re 1µPa @1m (based on Reine et al., 2012)
CSD	182 dB re 1µPa @1m (based on Thomsen et al., 2009)
BHD (excavating)	175 dB re 1µPa @1m (based on Reine et al., 2012)
BHD (Xcentric Ripper)	184.8 dB re 1 $\mu Pa^2 \cdot s\ m^2$ (based on Lawrence, 2016)
BHD (hydraulic hammer)	192.4 dB re 1 $\mu Pa^2 \cdot s\ m^2$ (based on Denes et al., 2016)

Table 9-6 Trenching noise source levels

Modelling of 24-hour sound exposure level ($SEL_{24\ hour}$) was conducted for each scenario to provide a conservative determination of PTS and TTS ranges from the cumulative effect of noise to marine fauna of interest over a 24-hour period. This modelling method is considered industry leading practice and is a conservative way of estimating potential effect ranges, as $SEL_{24\ hour}$ assumes the receptor (i.e., fauna) is stationary within the noise field of the noise source. In reality, the marine fauna of interest are highly mobile species which move naturally throughout the harbour and are capable of moving away from a noise source.

$SEL_{24\ hour}$ modelling presented here is based on a mean sea level (MSL) over a 24-hour period to represent average water level throughout the daily tidal cycle. This was considered the most appropriate approach for $SEL_{24\ hour}$ modelling (in comparison to presenting LAT or HAT results) since tide state varies significantly between low and high tide over a 24-hour period in Darwin Harbour (up to an 8 m range) and low and high tides are not representative of water level over a duration of 24 hours (rather they represent extreme water levels present for short periods of time).

Modelling of sound pressure level (SPL) which represents an instantaneous level of noise (in contrast to SEL) has been used for determining behavioural impact ranges to fauna. For SPL modelling, modelled results at high and low tide (as well as MSL) are considered appropriate given SPL is an instantaneous level. Highest astronomical tide (HAT) and Lowest astronomical tide (LAT) were conservatively used as water levels to represent high and low tide states, respectively, although these extremes are rarely reached. Between LAT of 0.0 m and a HAT of 8.0 m, low and high tides are on average (mean level) 2.2 m and 5.9 m, respectively as shown in **Table 9-7** (Williams et al. 2006).

Table 9-7 **Tide heights within Darwin Harbour (Williams et al., 2006)**

Tidal Movement	Tide Height
Highest Astronomical Tide (HAT)	8.0 m
Mean High Water Springs	6.9 m
Mean High Water	5.9 m
Mean High Water Neaps	4.9 m
Mean Sea Level (MSL)	4.0 m
Mean Low Water Neaps	3.1 m
Mean Low Water	2.2 m
Mean Low Water Springs	1.2 m
Lowest Astronomical Tide (LAT)	0.0 m

Further description of the modelling inputs, including bathymetry, seabed types and sound profiles and further description of the noise sources used is presented in Talis Consultants (2023) (**Appendix 8**) and Connell et al. (2023) (**Appendix 9**).

9.5.2.2 Underwater Noise Modelling Thresholds

Available threshold criteria associated with behavioural and physiological impacts for sensitive marine fauna have been derived from a number of sources (NMFS, 2018; NMFS, 2014; Popper *et al.*, 2014; Southall et al., 2019). These thresholds have been used to assess modelling results and determine potential impacts to marine fauna from PTS and TTS as well as to determine potential behavioural effects.

9.5.2.2.1 Noise thresholds for marine mammals

The potential impacts of anthropogenic noise on marine mammals, specifically cetaceans, have been the subject of considerable research. Current data and predictions show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity, as well as frequency band of hearing (Richardson *et al.*, 1995; Wartzok and Ketten, 1999; Southall *et al.*, 2007). To better reflect the auditory similarities between phylogenetically closely related species, but also significant differences between species groups among the marine mammals, Southall *et al.* (2007) assigned the extant marine mammal species to functional hearing groups based on their hearing capabilities and sound production. More recently, U.S. Navy technical reports by Finneran (2016) proposed new auditory weighting functions and the U.S. NMFS (2016, 2018) undertook a comprehensive review of PTS and TTS dual metric criteria for marine mammals and revised the threshold criteria for each frequency-weighted functional hearing category of cetacean. The only marine mammals likely to regularly occur in the waters of Darwin Harbour are dolphins (high frequency functional hearing category) and dugong and the noise effect threshold for these receptors are in **Table 9-8**.

9.5.2.2.2 Noise thresholds for marine reptiles

Marine turtles are considered less sensitive to noise than marine mammals as they do not have an external hearing organ but can detect sound through bone-conducted vibration in the skull with their shell providing a receiving surface (Lenhardt *et al.*, 1985). Morphological studies of green and loggerhead turtles (Ridgway *et al.*, 1969; Wever, 1978; Lenhardt *et al.*, 1985) found that the turtle ear is similar to other reptile ears but has adaptations for underwater listening.

Most studies researching the effect of seismic noise on sea turtles focused on behavioural responses, as physiological impacts are more difficult to observe in living animals. Turtles avoid low-frequency sounds (Lenhardt, 1994) and sounds from seismic surveys (O'Hara and Wilcox, 1990), but these reports did not note received sound levels. In another study, caged green and loggerhead turtles increased their swimming activity in response to an approaching airgun when the received SPL was above 166 dB (re 1 µPa) (McCauley *et al.*, 2000).

There are no known studies that have investigated the effects of noise on crocodiles so the thresholds for turtles are considered applicable also for crocodiles and these are presented in **Table 9-8**.

Table 9-8 Noise impact thresholds for marine megafauna groups in Darwin Harbour

Marine fauna type	Marine hearing group	Hearing bandwidth	Noise type	SEL24hour (Weighted) dB (re 1µ Pa2.s)		SPL Possible Behavioural Disturbance dB (re 1µ Pa)
				TTS	PTS	
Dolphins	High Frequency (HF)	150 Hz to 160 kHz	Non-Impulsive[1]	178	198	120
			Impulsive[1]	170	185	160
Dugong	SI	100 Hz to 50 kHz	Non-Impulsive[1]	186	206	120
			Impulsive[1]	175	190	160
Turtles (and crocodiles)	N/A	100 Hz to 2 kHz	Non-Impulsive[1]	200	220	Relative risk[2]
			Impulsive[1]	189	204	166

Note:

1. Thresholds are derived from Southall et al. (2019); NMFS (2018); Finneran et al. (2017); McCauley et al. 2000 and Popper et al. (2014).
2. Relative risk levels of Low, Moderate and High have been developed by Popper *et al*. (2014) for behavioural effect on turtles exposed to non-impulsive noise. Risk rankings from Popper *et al*. (2014) for 'Shipping and Other Continuous Noise' have been applied to non-impulsive noise, , for turtle behavioural response. Risk ranking are provided in context of distance of Near (N) (10s of metres), Intermediate (I) (100s of metres) and Far (F) (1,000s of metres)

9.5.2.3 Modelled threshold ranges

To evaluate the potential for impact to marine megafauna, the estimated distances from the sound source at which the behavioural and physiological thresholds (as listed in **Table 9-8**) were predicted to be exceeded are presented below for each location and activity. It is important to note that thresholds for non-impulsive noise are different to that for impulsive noise. Furthermore, while impulsive noise thresholds are lower (more conservative) than non-impulsive noise thresholds for physiological injury (PTS and TTS), the reverse is true for behavioural thresholds applied to marine mammals which has a higher threshold for impulsive noise than non-impulsive noise (**Table 9-8**).

Table 9-9 presents the threshold ranges at mean sea level (MSL) between the noise source and the modelled PTS, TTS and behavioural response thresholds for each fauna group for each of the modelled scenarios. Equivalent figures plotting the threshold contours for scenario/fauna groups are provided in Talis Consultants (2023) (**Appendix 8**) and Connell et al. (2023) (**Appendix 9**).

For all scenarios and fauna groups, PTS $SEL_{24\ hour}$ threshold ranges were below 50 m, with the exception of the BHD impulsive noise (hydraulic hammering) scenario, where PTS threshold ranges were 130, 160 and 100 m for dolphins, dugongs and turtles, respectively (**Table 9-9**). Given the mobility of these species, and the threshold ranges for behavioural response being greater than the PTS range for all species, it is unlikely that these species would remain within the predicted PTS ranges for a period of 24 hours. Permanent threshold shift (PTS) injury is therefore considered unlikely for dolphins, dugongs and turtles from Project trenching activities.

TTS $SEL_{24\ hour}$ threshold ranges at mean sea level varied across scenarios and fauna groups (**Table 9-9**). For continuous noise source scenarios (including TSHD, CSD and BHD trenching and BHD rock breaking using an Xcentric Ripper) TTS threshold ranges varied across noise sources and ranged between 40 m and 350 m. Ranges were highest for dolphins (100-350 m), followed by dugongs (70-210 m) and then marine turtles (40-160 m) (**Table 9-9**).

For the BHD hydraulic hammering scenario, TTS threshold ranges were significantly larger than those predicted for the other modelled scenarios; threshold ranges for dolphins, dugongs and turtles were predicted to be 1,830 m, 2,500 m and 950 m, respectively (**Table 9-9**). Given the relatively large size of these ranges and the fact that behavioural response thresholds were predicted to be within these ranges, it is possible that dolphins, dugongs and turtles could remain within the threshold TTS ranges for a period of 24 hours and receive TTS impact, if management measures were not in place to prevent this from occurring.

Given the above, further investigation was undertaken by Connell et al. (2023) (**Appendix 9**) to determine the effect of reducing BHD hydraulic hammering time on the size of PTS and TTS threshold ranges. A summary of this analysis at MSL is presented in **Table 9-10**. PTS and TTS threshold ranges decreased as hammering time decreased. For dolphins, PTS/TTS ranges dropped from 130 m/1,830 m for 8 hours hammering time (per 24 hours) to 30 m/670 m for 2 hours hammering time. For dugongs PTS/TTS ranges dropped from 160 m/2,500 m for 8 hours hammering time to 50 m/840 m for 2 hours hammering time while for turtles, PTS/TTS ranges dropped from 100 m/950 m for 8 hours hammering time (per 24 hours) to 30 m/380 m for 2 hours hammering time. While reducing operation time had a significant effect on reducing PTS/TTS ranges for the hydraulic hammer, the ranges modelled for 2 hours of operation time per 24 hours were still significantly larger that for the Xcentric Ripper tool operated for 8 hours per 24 hours (**Table 9-10**).

For behavioural response thresholds, ranges for marine mammals (dolphins and dugongs) varied from 100s of metres to 10s of kilometres for scenarios modelled at MSL with the highest range being for the Xcentric Ripper tool (14 km for both dolphins and dugongs) (**Table 9-9**). A quantitative threshold for marine turtles was only considered applicable for impulsive noise (i.e. BHD hydraulic hammer scenario). The range for this threshold at MSL was predicted to be 270 m (**Table 9-9**).

In addition to ranges at MSL, quantitative behavioural threshold ranges were also modelled across LAT and HAT (**Table 9-11**). The effect of water level on range size was not consistent between modelling studies (Talis Consultants, 2023; Connell et al., 2023). The greatest marine mammal (dolphin and dugong) behavioural response ranges for each scenario were: 909 m @ HAT for BHD digging; 14,700 m @ LAT for BHD Xcentric Ripper use; 270 m @ LAT for BHD hydraulic hammering; 20,000 m @ HAT for the TSHD at Location 2; 17,878 m @ HAT for the TSHD at Location 3 and 20,000 m @ HAT for the TSHD and CSD operating at the same location (Location 3) (**Table 9-11**). A quantitative behavioural threshold for marine turtles was only considered applicable for impulsive noise. The largest behavioural response threshold range for marine turtles for BHD hydraulic hammering was 90 m at LAT (**Table 9-11**).

Table 9-9 PTS, TTS and behavioural response threshold ranges for each marine megafauna group for each modelled scenario/location at mean sea level

Marine fauna type	SEL 24 hour (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural Response [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Location 1 – Backhoe Dredge digging (non-impulsive noise) (Talis Consultants, 2023; Appendix 8						
Dolphins	178	198	151	<50	120	454
Dugongs	186	206	100	<50	120	454
Turtle	200	220	80	<50	RISK[1]	High (N) Moderate (I) Low (F)
Location 1 – Backhoe Dredge rock breaking with Xcentric Ripper (non-impulsive noise) (Connell et al., 2023;Appendix 9 Appendix 5)						
Dolphins	178	198	100	NR	120	14,000
Dugongs	186	206	70	NR	120	14,000
Turtle	200	220	40	NR	RISK[1]	High (N) Moderate (I) Low (F)
Location 1 – Backhoe Dredge rock breaking with hydraulic hammer (impulsive noise) (Connell et al., 2023;Appendix 9 Appendix 5)						
Dolphins	170	185	1,830	130	160	220
Dugongs	175	190	2,500	160	160	220
Turtle	189	204	950	100	166	270

Marine fauna type	SEL 24 hour (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural Response [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Location 2 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)						
Dolphins	178	198	303	<50	120	1,667
Dugongs	186	206	170	<50	120	1,667
Turtle	200	220	131	<50	RISK[1]	High (N) Moderate (I) Low (F)
Location 3 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)						
Dolphins	178	198	303	<50	120	2,273
Dugongs	186	206	200	<50	120	2,273
Turtle	200	220	120	<50	RISK[1]	High (N) Moderate (I) Low (F)
Location 3 – Trailing Suction Hopper Dredge and Cutter Suction Dredge (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)						
Dolphins	178	198	350	<50	120	3,181
Dugongs	186	206	210	<50	120	3,181
Turtle	200	220	160	<50	RISK[1]	High (N) Moderate (I) Low (F)

NR = threshold was not reached.

[1] Risk rankings from Popper *et al*. (2014) for 'Shipping and Other Continuous Noise' have been applied to non-impulsive noise, for marine turtle behavioural response. Risk rankings are provided in context of distance from sound source; Near (N) (10s of metres), Intermediate (I) (100s of metres) and Far (F) (1000s of metres)

Table 9-10 Influence of BHD hydraulic hammering time on PTS and TTS ranges for each marine megafauna group at mean sea level

Marine fauna type	SEL $_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]	
	TTS	PTS	TTS	PTS
8 hours hammering/ per 24 hours				
Dolphins	170	198	1,830	130
Dugongs	175	206	2,500	160
Turtle	189	220	950	100
6 hours hammering/ per 24 hours				
Dolphins	170	198	1,510	90
Dugongs	175	206	1,790	110
Turtle	189	220	740	60
4 hours hammering/ per 24 hours				
Dolphins	170	185	1,200	60
Dugongs	175	190	1,410	80
Turtle	189	204	580	50
2 hours hammering/ per 24 hours				
Dolphins	170	198	670	30
Dugongs	175	206	840	50
Turtle	189	220	380	30

Santos

Table 9-11 Quantitative behavioural disturbance threshold ranges for marine megafauna across varying tidal states

Marine fauna type	Sound Pressure Level (SPL) Behavioural Threshold (dB re 1µ Pa)	Threshold Range (metres) for tidal state		
		LAT	MSL	HAT
Location 1 – Backhoe Dredge digging (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)				
Dolphin	120	303	454	909
Dugong	120	303	454	909
Location 1 – Backhoe Dredge rock breaking with Xcentric Ripper (non-impulsive noise) (Connell et al., 2023; Appendix 9)				
Dolphin	120	14,700	14,000	13,100
Dugong	120	14,700	14,000	13,100
Location 1 – Backhoe Dredge rock breaking with hydraulic hammer (impulsive noise) (Connell et al., 2023; Appendix 9)				
Dolphin	160	270	220	170
Dugong	160	270	220	170
Turtle	166	90	60	60
Location 2 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)				
Dolphin	120	1,450	1,667	20,000
Dugong	120	1,450	1,667	20,000
Location 3 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)				
Dolphin	120	1,515	2,273	17,878
Dugong	120	1,515	2,273	17,878
Location 3 – Trailing Suction Hopper Dredge and Cutter Suction Dredge (non-impulsive noise) (Talis Consultants, 2023; Appendix 8)				
Dolphin	120	3,000	3,181	20,000
Dugong	120	3,000	3,181	20,000

9.5.2.4 Impacts to marine Megafauna

The potential for physiological impacts to EPBC Act listed marine megafauna (dolphins, dugong and turtles), in the form of PTS and TTS was determined through modelling of the highest underwater noise generating activities associated with the DPD Project, i.e. the operation of trenching vessels, including the use of rock breaking tools. PTS $SEL_{24\ hour}$ threshold ranges of <50 m to 160 m were determined, with range sizes varying across species and modelled scenarios. PTS impact within these ranges requires marine fauna to be within the range for 24 hours. Given the likely behavioural response to avoid the area prior to entering into a PTS zone, and the known mobility of these species, it is unlikely that these species would remain within these ranges for long enough for PTS injury to occur. Nevertheless, the monitoring of Observation and Exclusion Zones around trenching vessels, and appropriate adaptive management measures to ceases trenching if fauna enter exclusion zones will be adopted for the Project to prevent this occurrence (**Section 12**) and have been included in the DPD Project MMNMP (**Appendix 7**).

For the continuous (non-impulsive) noise sources of TSHD, CSD and BHD trenching, and the use of an Xcentric Ripper tool for rock breaking, modelled TTS $SEL_{24\ hour}$ threshold ranges varied between 40 m and 350 m, and were highest for dolphins (100-350 m), followed by dugongs (70-210 m) and marine turtles (40-160m). As with the PTS thresholds ranges, it is unlikely that these EPBC Act listed marine fauna would remain within these ranges long enough (i.e. for 24 hours or greater) for TTS impacts to occur, and there are no known aggregation areas for these fauna within this range of trenching areas. However, the application of observation and exclusion zones, monitored from trenching vessels, will be adopted to avoid TTS impacts (**Section 12**, **Appendix 7**).

Modelling undertaken for hydraulic hammer use predicted that PTS and TTS threshold ranges would be significantly larger than for other trenching sound sources, that is, trenching/digging using a TSHD, CSD or BHD and the use of an Xcentric Ripper rock breaking tool. In particular, the scale of hydraulic hammering TTS ranges (in the order of kms) suggests that TTS impacts would be possible to marine fauna remaining within these ranges for 24 hours or more, particularly given a behavioural response to this impulsive noise source noise may not occur until marine fauna are well within the TTS range. While an Xcentric Ripper tool is considered the base case for rock breaking from the BHD, a hydraulic hammer may be used as a contingency, therefore additional management controls were considered necessary (over and above those proposed for other trenching activities) and have been included in **Section 12** and **Appendix 7**. This includes monitoring of significantly larger observation and exclusion zones and restricting hydraulic hammering to daylight hours only.

Based on the modelled behavioural effect ranges, in particular the continuous noise behavioural effect ranges, there is the potential for species of interest (dolphins, dugongs and turtles) to be affected by noise from dredging vessels on a scale of 100s to 1000s of metres. These ranges are expected to be similar to those associated with noise emissions from large commercial vessels that use Darwin Harbour on a daily basis, as they have similar noise source levels and frequency bands and operate in the same areas (refer **Section 9.4.8**). Given the existing noise environment, it is expected that marine fauna will have developed some level of acclimatisation to vessel noise over a range similar to that modelled for the Project trenching vessels. It is also likely that some masking of Project vessel noise above the marine mammal behavioural threshold of 120 dB re 1µ Pa would occur from other commercial vessels that transit Darwin Harbour. In support of this, ambient noise measurements taken by noise loggers in East Arm by Salgado-Kent et al. (2015) recorded that noise from transiting commercial vessels was frequently in the range of 130-140 dB re 1 µPa. Masking of Project vessel noise by other anthropogenic noise sources would be expected to diminish the range of behavioural effect ranges around Project vessels in areas and times where other vessels are active. While there may be a more prolonged exposure of marine fauna to noise above behavioural threshold levels from slow moving trenching vessels working in an activity area (i.e. a trenching zone) when compared to transiting commercial vessels, trenching activity is expected to be completed relatively quickly, within a period of 2 to 3 months across all trenching areas, and therefore any behavioural effects are considered temporary.

On the basis that physiological impacts (PTS and TTS) to EPBC Act listed marine fauna from Project underwater noise emissions (in particular vessels undertaking trenching activities) will be avoided through the application of industry standard management controls as outlined within a MMNMP, and behavioural response to underwater trenching noise will be temporary and on the same scale as from existing commercial vessel using Darwin Harbour, impacts to marine fauna and Marine Ecosystems from underwater noise emissions are considered to be minor.

9.5.3 Light emissions

DPD Project lighting will create light spill, which has the potential to impact on marine fauna that show avoidance or attraction to lights by potentially changing navigational cues that ultimately affect energy expenditure or alter predation and/or feeding rates. Impacts may include the following:

+ Disorientation, misorientation, attraction or repulsion;
+ Disruption to natural behavioural patterns and cycles;
+ Secondary impacts such as increased predation; and
+ Reduced fitness.

Project vessels will have external lighting to provide a safe working environment and to comply with relevant maritime navigation requirements. Light emissions associated with the Project may pose a potential risk to marine fauna in the open water and nesting turtles on land. Artificial lighting can cause a temporary change in movement patterns and/or behaviour, through attraction or disorientation of individuals. Artificial lighting can affect several marine fauna species, including seabirds and migratory shorebirds, marine turtles, sharks and rays and other fish.

To assess potential impacts from Project vessel light emissions, a desktop assessment was completed to determine the presence and significance of marine turtle nesting activity on beaches surrounding Darwin Harbour and the likely level of impact Project vessel activities may have on marine turtles (refer Pendoley 2022b, **Appendix 14**). In addition, light modelling has been conducted to predict the extent of biologically relevant light spill during pipelay activities conducted by the deep water pipelay vessel and offshore construction vessel, which are considered conservative (worst-case) sources of light spill for all Project vessels. (Pendoley 2022a).

9.5.3.1 Light spill modelling

Light spill from the largest pipelay vessel (Audacia) and construction vessel (Fortitude) that may be used for this Project was modelled for each vessel independently and when operating side by side (Pendoley 2022a).

ILLUMINA light modelling was undertaken for three scenarios:

+ Pipelay vessel alone;
+ Construction vessel alone; and
+ Pipelay vessel and construction vessel located together (cumulative).

Details of the respective vessel's lighting design and luminaire specifications were applied to the ILLUMINA Artificial Light At Night (ALAN) model (Aube et al. 2005). The ILLUMINA model is a 3D model that accounts for line of sight visibility in addition to the glow derived from atmospheric scattering of light. The model also addresses the attenuation/loss of light over landscape scale distances and, consequently, the areal extent and attenuation of light glow across the sky can be modelled. This well-documented, open-source model was selected for its ability to represent light across large areas and distances and across the entire visible spectrum, including biologically meaningful light from 350 nm – 700 nm.

Since light sources (i.e. individual luminaires) can be placed individually within the area of interest, the model is able to replicate specific lighting designs in terms of light type, spectral distribution, height and orientation of individual luminaires, including any shielding, increasing model accuracy. This information was extracted from lighting layout drawings and light manufacturer data sheets for both the deep water pipelay vessel (e.g. Audacia) and construction vessel (e.g. Fortitude). Both models assumed that all exterior lights on the vessels were turned on (apart from search lights which are only used in an emergency situation) with no additional shielding (other than that provided inherently by the vessel structures). Vessels were also orientated north-south. Cloud cover was assumed to be zero, and therefore, the simulation has no contribution of light from cloud reflectance. Model outputs are provided in radiance ($W/m^2/sr$, where W = watts, m^2 =metres squared and sr = steradian).

In the absence of any published or generally accepted units of measurement, or scale, for predicting the potential impact of artificial light at night on turtle hatchlings, the modelled output is considered in terms of the visibility compared to that of the full moon, the brightest natural source of light visible in the region of the horizon. In the absence of any other published or generally accepted units of measurement, or scale, for measuring the impact of ALAN on marine turtles, Pendoley Environmental has developed an approach based on the visibility of the full moon, the brightest natural light source visible within the region of the horizon used by hatchlings during sea finding. The output, in Full Moon Equivalents (FME), is modelled for the Orientation Field of View (OFOV) used by hatchlings during sea finding.

Output from the light model (radiance, units of $Watts/m^2/sr$) were converted to units of full moon equivalents (FME) to provide biological relevance to the radiance output (Pendoley 2022a).

The range of moon brightness across a whole lunar cycle is a realistic representation of the natural ambient light levels that turtles eyes are adapted to. On a new moon, there is little to no ambient light, and this is when there is the greatest risk of mis- or dis-orientation due to artificial light sources. The amount of ambient light present on a full moon is substantial and may override any artificial light cues that could potentially influence behavioural impacts.

Potential impacts are assessed on a scale based on the FME value where values greater than 1 FME are likely to have an impact and values less than 1 FME have varying likelihood of impact down to 0.01 FME (i.e., 1% of the radiance of a full moon), which is considered to have no impact (Pendoley 2022a). Given that the location of the vessel, which does not influence the model outputs, the model results can be applied to the vessel activities modelled anywhere along the pipeline route.

The modelling results showed that the (larger) pipelay vessel will have a larger light glow than the construction vessel. The distance at which impacts from light or light glow are likely, i.e., when FME is 1-10, is restricted to within 160 m of the pipelay vessel, 126 m of the construction vessel, or within 202 m when both vessels are side by side, or (Pendoley 2022a). Consequently, the greatest likelihood of behavioural impacts is when marine turtles are very close to the vessels.

The distance from the vessel when behavioural impact is possible, i.e., FME greater than 0.1, was predicted to occur within 3.3 km of the pipelay vessel, within 2.5 km of the construction vessel and within 4.5 km when both vessels are side by side (Pendoley 2022a). Beyond these distances, light or light glow was predicted to be <0.1 FME which is <10% of the radiance of a full moon. At this range, behavioural impacts are considered unlikely and not considered biologically relevant (Pendoley 2022a).

While light spill modelling was only completed using the lighting characteristics of the pipelay and construction vessels, the combined light spill from these vessels (when side by side) is considered to be the greatest source of light emissions for all Project vessels and therefore, the distances reported can be considered to be conservative estimates for distances at which behavioural impacts from any Project vessel light or light glow could occur.

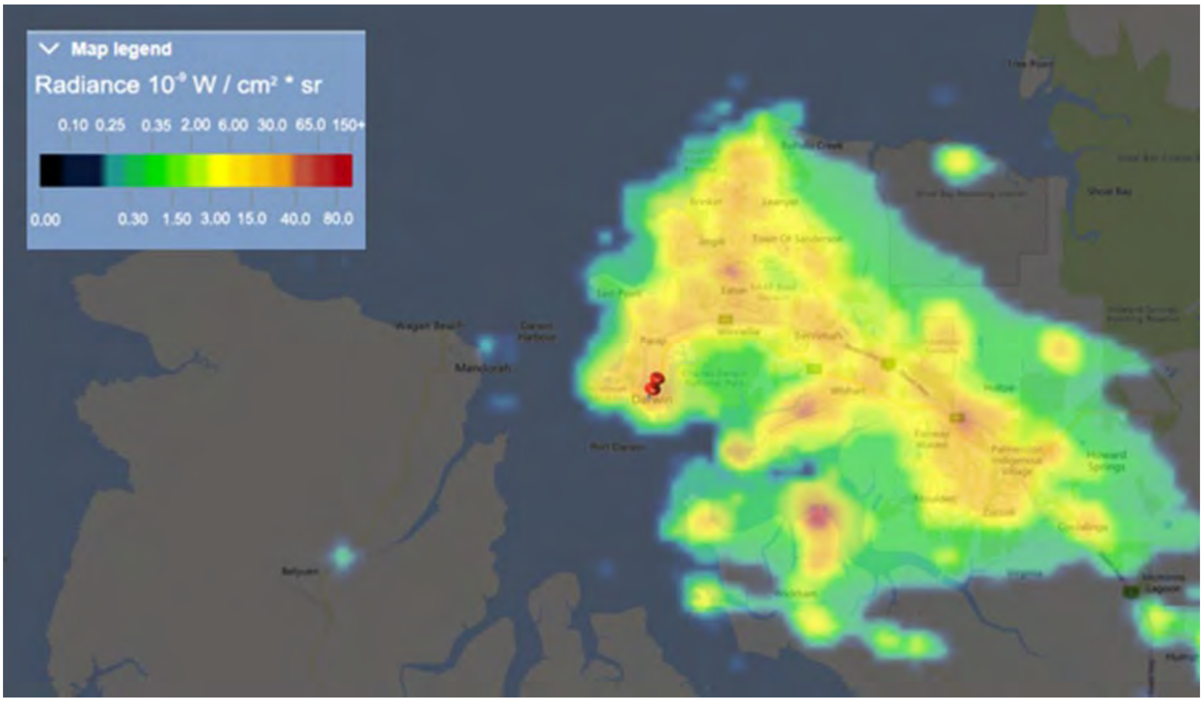
9.5.3.2 Turtle nesting and Project lighting desktop assessment

An assessment on the importance of marine turtle nesting beaches in the vicinity of the Project area was undertaken (Pendoley 2022b, **Appendix 14**) which was informed by information from online resources, published peer-reviewed literature, grey literature and from communications with DEPWS personnel.

Beaches with evidence of marine turtle nesting activity that have the potential to be exposed to Project vessel lighting include Casuarina Beach in Darwin and beaches on Cox Peninsula, including Wagait Beach and Mandorah (**Figure 9-14)**. Nearly all turtle nesting records on these beaches are from flatback turtles however, these beaches have relatively low numbers of flatback turtle nests on a regional and species level scale, and are not considered significant nesting sites (Chatto and Baker, 2008). It is also apparent that the beaches are subject to considerable existing anthropogenic pressures from beach users (as evidenced in records downloaded from the NT Fauna Atlas) and existing anthropogenic light sources. No baseline information is available for the current light conditions (i.e. in full moon equivalent for relevant light wavelengths) on these nesting beaches. Satellite acquired visible infrared imaging radiometer suite (VIIRS) imagery from 2021 of the Darwin Harbour area from www.lightpollution.info (refer to **Figure 9-15**) shows existing anthropogenic sources of lighting in the vicinity of turtle nesting beaches and their relative intensity.

To assess the potential impacts from Project vessel activities, the spatial and temporal patterns of DPD Project vessel usage within Darwin Harbour, with specific reference to lighting impacts on turtle nesting beaches, was undertaken (refer **Appendix 14)**. This divided vessel activity and potential lighting impacts into five activity zones (see **Figure 9-16** and **Figure 9-17**). In each of zones 1, 2 and 3, Project vessels with operational and navigational lighting will be operating at night to conduct pre-lay trenching, pipelay (by nearshore pipelay barge) and rock installation activities. The cumulative activity time with associated light spill within each of these zones is indicatively up to two months, although there will be breaks in between these key activities. In zone 4 and further offshore, pipelay will occur using an offshore pipelay vessel which lays pipe much quicker (2-3 km per day) and will not require trenching and rock installation. Therefore, associated light exposure time will be less. In zone 5, the TSHD and SHBs will be transporting spoil to the offshore spoil disposal ground and therefore there will be periodic but relatively short light exposure in this zone over the duration of trenching (indicatively 2-3 months).

Figure 9-14 Turtle nesting beaches near Darwin Harbour



Source: www.light pollution.info VIIRS (2021)

Figure 9-15 Darwin light pollution from satellite imagery

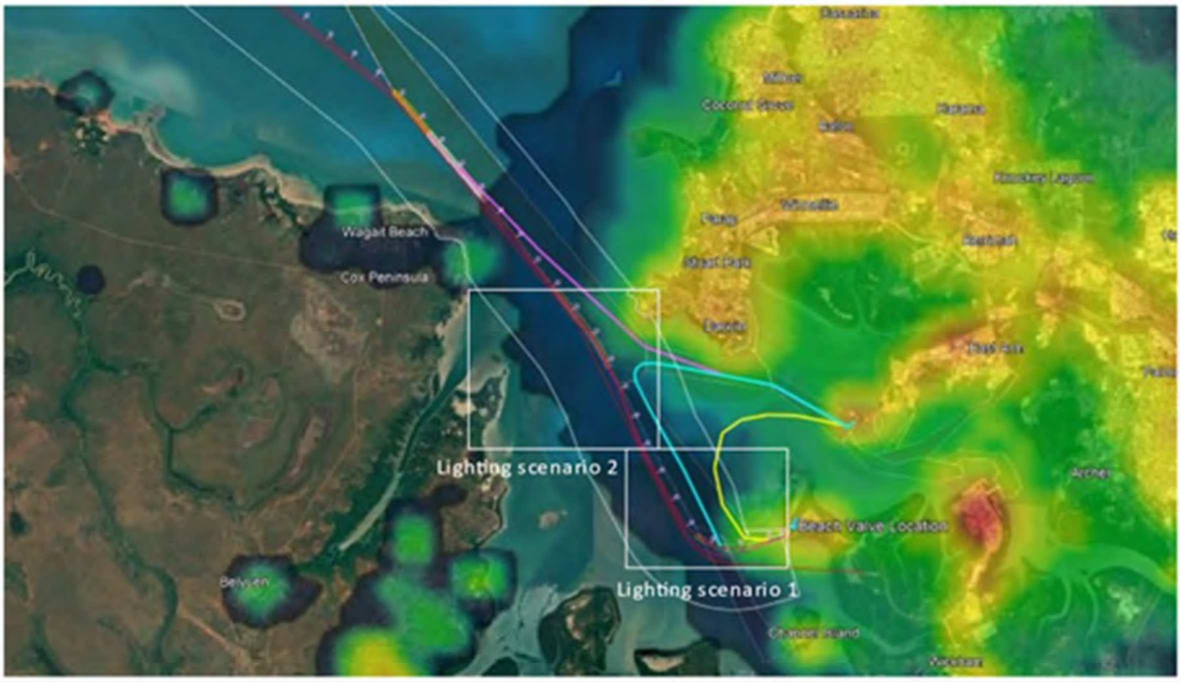


Figure 9-16 Vessel activity zones in Darwin Harbour

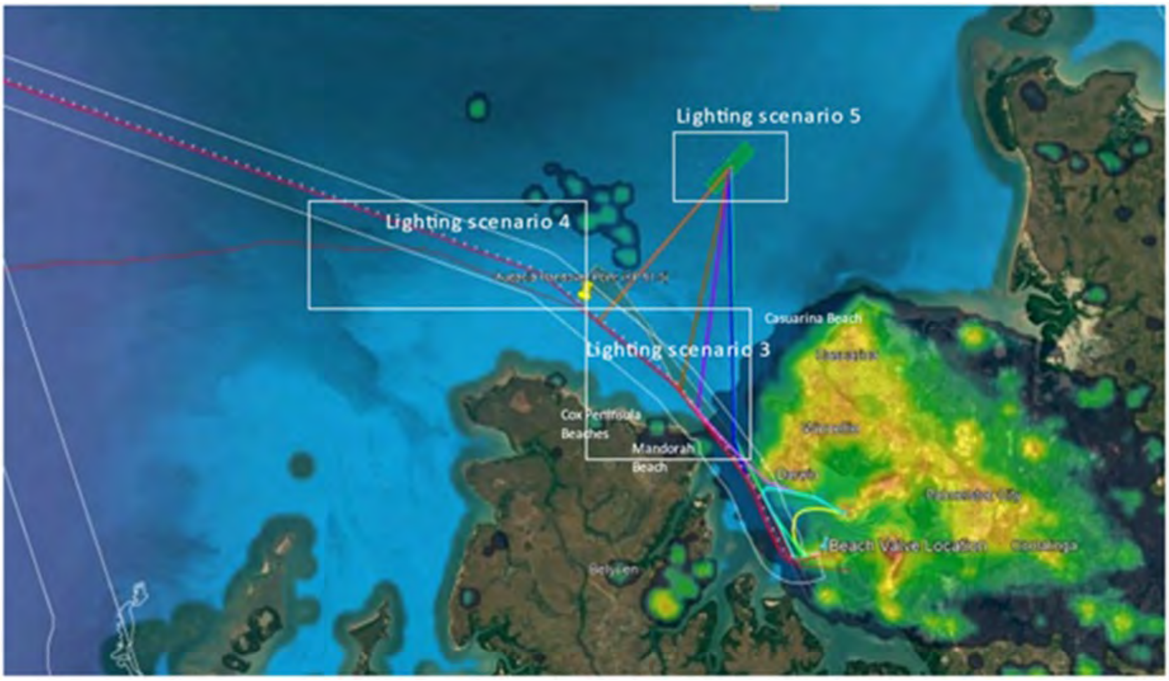


Figure 9-17 Vessel activity zones approaching Darwin Harbour

9.5.3.3 Impacts to marine turtles

Based on the desktop assessment, vessel activities in zone 1 and 2 (**Figure 9-16**) will not have line of sight between the nesting beaches at Casuarina and Cox Peninsula, so pose little risk to turtles. Activity zones 4 and 5 (**Figure 9-17**) are 10-20 km from the beaches and are considered too far away to have an impact. This conclusion is supported by the light modelling results with impacts only considered possible within 4.5 km of the vessels, though light may be visible beyond this range.

The greatest risk of exposure is likely to occur if vessels are operating in the harbour mouth (activity zone 3, **Figure 9-17**) during the May to October nesting season peak. Vessels on the pipeline route in this zone will be ~12 km away from Casuarina Beach, ~4 km away from Wagait Beach, and less than 2 km from Mandorah beach.

In relation to trenching vessels, trenching activity in activity zone 3 is expected to occur over ~24 days (24 h operations) and involve seven slow moving vessels and two transient vessels. Following a break, this activity would be followed by a pipelay activity of ~14 days (24 h operations) involving four slow moving vessels and three transient vessels. Following pipelay, rock installation will occur, utilising two slow moving vessels and a transient vessel over a period of ~14 days (24 h operation).

Despite the combination of trenching, pipelay and rock installation, the desktop assessment concluded the risk of potential impact was low due to the low number of turtles, nests and successfully emerged hatchlings on theses beaches, the short duration of trenching (i.e. expected to be limited to within one nesting season), and as the vessel lights are likely to merge with large amount of light from Darwin and the harbour when viewed from Mandorah and Wagait, rendering them indistinguishable from the onshore lighting.

For vessels in activity zones 4 and 5, 10-20 km away from turtle nesting beaches, the light modelling results indicate behavioural effects are unlikely given the beaches will be too far away (> 4.5 km).

Overall, while light emissions from the vessels may be visible, they are unlikely to result in behavioural impacts on nesting beaches and there is no discernible risk of light emissions from Project vessels causing a significant impact based on presently and publicly available data. This is due to the short-term nature of the Project, the low nesting effort on potential impact beaches and their low reproductive value relative to other rookeries within the wider genetic stock (Pendoley 2022b, **Appendix 14**).

In addition to potential impact to nesting beaches, potential impacts to marine turtle hatchlings once they have left the beaches were also assessed. Once hatchlings enter the ocean, they are thought to employ a survival strategy that involves rapid dispersal away from predator rich nearshore habitats to reach deeper waters where they develop into juveniles. An internal compass set while crawling down the beach, together with wave cues, are used to reliably guide them offshore (Lohmann & Lohmann, 1992; Stapput & Wiltschko, 2005; Wilson et al., submitted). In the absence of wave cues however, swimming hatchlings have been shown to orient towards light cues (Lorne & Salmon, 2007; Harewood & Horrocks, 2008) and in some cases, wave cues were overridden by light cues (Thums et al., 2013, 2016).

Based on the light modelling results, behaviour impacts to hatchlings on the beach are unlikely (Pendoley, 2022a), but there is potential for hatchlings at sea to be attracted to light emissions if they are carried by currents to within approx. 4.5 km.

During that time, there is the potential for:

- Increased energy expenditure as hatchlings swim against currents towards light sources and when entrapped in light spill, with potential effects to individual fitness; and
- Increased risk of predation while silhouetted in areas of light spill.

Any disruption to hatchling dispersal behaviour is expected to represent an insignificant proportion of the total annual number of hatchlings and would not impact turtle populations, nor recovery. Similarly, any increased mortality from predation or increased energy expenditure will likely be limited to a negligible proportion of the annual number of hatchlings for the given genetic stocks.

Although the Project area overlaps important inter-nesting habitat BIAs, the number of inter-nesting individuals likely to be present is expected to be limited given the low-density nesting on Casuarina and Cox Peninsula beaches.

If individual inter-nesting turtles are present, light emissions from any of the vessels are unlikely to be of concern. There is no evidence, published or anecdotal, to suggest inter-nesting turtles are impacted by light from offshore vessels, and nothing in their biology would indicate this as a plausible threat (Pendoley, 2019; Witherington and Martin, 2003).

9.5.3.4 Seabirds and shorebirds

Research indicates that seabirds can be attracted to artificial light. Studies conducted between 1992 and 2002 in the North Sea confirmed that artificial light was the reason that birds were attracted to and accumulated around lit offshore infrastructure (Marquenie et al., 2008) and that lights can attract birds from large catchment areas (Wiesse et al., 2001). Birds may be attracted by the light source itself or indirectly as lighting may attract other marine life creating a food source for birds (Surnam, 2002). Key threats to migratory birds attracted to artificial lighting include alteration of normal behaviours including attraction, disorientation and/or disturbance, and potential collision of birds with illuminated structures (DotEE 2021).

It is considered possible that small numbers of birds may be attracted to the lighting of vessels however impacts are considered to be minimal and temporary given the short duration of construction and vessel activities not being located near any significant nesting sites.

9.5.3.5 Impacts to fish, sharks and rays

Fish and zooplankton may be directly or indirectly attracted to lights. The concentration of organisms attracted to light results in an increase in food source for predatory species and marine predators are known to aggregate at the edges of artificial light halos. Vessel lighting may result in the localized aggregation of fish (including sharks/rays) below the vessel. This could potentially lead to increased predation rates compared to unlit areas. These aggregations are considered localised and temporary due to the nature of the activity (i.e. short duration of works at any one location).

9.5.4 Treated seawater discharge

In the unlikely event of a pipeline wet buckle during pipeline installation requiring an extended period before pipelay can recommence, the pipeline will be filled with treated seawater to preserve the pipeline in the intervening period before pipelay is recommenced. As detailed in **Section 8.5.2**, the seawater will need to be treated with a preservation chemical consisting of a biocide, corrosion inhibitor and oxygen scavenger to preserve the pipeline. While the planned chemical for treating the seawater is either 'Hydrosure' (refer **Table 8-3**) or 'Hydro-3', there may be a requirement to use alternative chemical packages. All chemicals used will be subject to a Santos' approved chemical selection assessment process.

To evaluate whether the dewatering of this treated seawater could have a significant impact on the marine ecosystem, discharge modelling was completed. Refer **Section 8.5.2** for a description of modelling completed and how results were interpreted.

As previously presented in **Section 8.5.2**, the modelling of contingency discharge (both overflow and during filling and dewatering) did not predict any exceedance of the NOEC threshold of 0.06 mg/L (PC99%) over a 48-hour period at any of the three modelled locations. Therefore, in the unlikely event of a wet buckle which then also requires an extended delay before continuing pipelay activities, the discharge of treated seawater is not predicted to have a significant impact on the marine ecosystem.

9.5.4.1 Benthic habitats

Based on the available mapping, including AIMS 2021 and AIMS 2019 mapping outputs, the INPEX Ichthys project mapping and field survey data collected by Santos, the benthic habitats that could occur in the predicted plume extent (from any location along the pipeline) are sponges, filterers and octocorals, and bare ground. The discharge plume is not predicted to intersect with any seagrass, macroalgae or hard coral habitat. While toxic effects from the chemicals in the treated seawater can occur at lower concentrations compared to higher life forms, e.g. NOEC for a fish species is 12.5 mg/L (time weighted average) compared to 1.3 mg/L for algae, as described above, the short duration of the discharge and the rate of dilution both inside and outside Darwin Harbour mean that the plume will not remain at concentrations above the PC99% threshold long enough to have any significant impact on benthic habitats.

As presented above for benthic habitats, the discharge plume is not predicted to intersect benthic primary producer habitat. Furthermore, as no exceedance of the NOEC 99% species protection levels are predicted over 48hr exposure times there is no significant impact predicted to primary productivity.

9.5.4.2 Impacts to marine fauna

If present, mobile animals could pass through the discharge plume. However, as for the benthic habitats, given the short duration of the discharge and the rate of dilution, exposure above the NOEC PC99% thresholds will not be long enough for impacts, as demonstrated in ecotoxicity test, to occur.

9.5.5 Dropped objects

There is potential for small objects, such as PPE, small tools and unsecured deck equipment, to be accidentally lost overboard to the marine environment during pipeline installation activities. Suspended loads (e.g. pipeline joints and concrete mattresses for pipeline stabilisation) may also be accidentally dropped through operator error or mechanical failure. Larger objects, such as A-frames, chemical storage tanks and sea containers, are secured to the vessel deck and cannot credibly be lost overboard.

If an object is dropped overboard, potential impacts would be limited and localised disturbance of the seabed and benthic habitats near the dropped object.

As presented in **Section 9.5.1.4** (Anchoring of pipelay vessel), benthic habitats under the area where lifting and project activities will occur were determined to be predominantly sponges, filter feeders and octocorals, or bare ground, and to a lesser extent, macroalgae. All of these habitats are well represented across Darwin Harbour. Consequently, in the event of a dropped object, no sensitive benthic habitat would be impacted.

While considered highly unlikely due to controls in place, there is a risk that a dropped object event during construction of the pipeline could damage the existing Bayu-Undan to Darwin or Ichthys pipeline resulting in the release of dry gas. The assessment of the potential impacts that may arise from such a dropped object event and controlling measures to prevent this from occurring are discussed in **Section 9.5.8**.

9.5.6 Invasive marine species

As presented in **Section 8.5.4,** vessels are the most common vector for the translocation of IMS in the marine environment. The Aquatic Biosecurity Unit of NT Fisheries undertakes monitoring for early detection, inspections and treatment of high-risk vessels entering Darwin and responding to reported sightings of IMS.

The introduction of IMS could result in impacts to the marine ecosystem including decrease in biodiversity (from the reduction or loss of native marine species) and loss of fishing resources. Once established, IMS may be very difficult to eradicate from an area.

Darwin Harbour is a commercial port where large commercial vessels, such as cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels enter, exit and move around the harbour on a regular basis. Project activities are not considered to have any higher risk of introducing IMS into the area than regular activities within the harbour and the proposed controls are considered effective and appropriate to reduce the risk of introducing IMS and no significant impact to the marine ecosystem is expected.

9.5.7 Marine fauna interaction

The risk of vessel strike to marine fauna is inherent to movements of all vessel types. A review of records of vessel collisions with marine megafauna reported a higher number of collisions with whale-watching boats, naval ships and container ships (DoEE, 2017). The recovery plans and conservation advice for whales (blue, humpback, sei and fin whales) and marine turtles (flatback, Olive Ridley, green, loggerhead, hawksbill, leatherback) recognise vessel strikes/disturbance as a key threat to these EPBC listed species.

The impact from vessel interactions with marine fauna can range from temporary behavioural changes, ranging to severe impacts, such as injury or mortality resulting from vessel strikes. The potential risk of a collision with marine fauna is directly related to the abundance of marine fauna and number and speed of vessels operating in the area. As presented in the National Strategy for Reducing Vessel Strike on Cetaceans and Other Marine Megafauna (DoEE, 2017), the majority of the reported vessel collisions have occurred along eastern or south-eastern Australia, with no reported incidences in NT waters.

Vessel speed has been demonstrated to be a key factor in relation to collision with marine fauna, particularly cetaceans and turtles, with faster moving vessels posing a greater collision risk than slower vessels (Hazel et al., 2009; Jensen and Silber, 2004; Laist et al., 2001; DoEE, 2017). Laist et al. (2001) suggest the most severe and lethal injuries to cetaceans are caused by vessels travelling at 14 knots or faster. Turtles will typically avoid vessels by rapidly diving, however, their ability to respond varies greatly depending on the speed of the vessel. Hazel (2009) reported that the number of turtles that fled vessels decreased significantly as vessel speed increases. Turtles are also adapted to detect sound in water (Popper et al. 2014) and will generally move from anthropogenic noise generating sources, including vessels, within their detection range.

Most Project vessels will be stationary or slow moving due to operational and safety requirements (e.g. pipelaying, trenching). Vessels transiting within the harbour or in/out of the harbour (for example transiting to/from the spoil disposal ground or transferring crew) will operate at greater speeds than vessels undertaking pipelay and trenching activities. All vessels, however, will be governed by Port of Darwin commercial vessel speed restrictions.

Vessels undertaking Project activities may present a hazard to marine fauna that occur near or at the ocean surface such as cetaceans, turtles and dugongs. Such collisions may result in injury to, or the death of, the fauna involved. However, in the unlikely event of an interaction, it is unlikely to threaten the overall viability of marine fauna populations.

Project vessel activities are not considered to have any higher risk of fauna interactions than regular activities within the harbour and proposed controls (**Section 12**) are considered effective and appropriate to reduce the risk of having a significant impact.

Trenching activities do pose a higher risk to marine fauna and TSHDs have been responsible for injuring or killing marine turtles near the seabed through interaction with dredging equipment. In comparison, CSDs and BHDs do not pose this risk as they lack the trailing dragheads found on TSHDs (Dickerson et al., 2004). There are operational aspects for using the TSHD that can reduce the risk of turtle interactions. Turtle ‘tickler’ chains that are designed to move turtles out of the way of the trenching will also be on the trailing arms of the TSHD. Fish and rays that inhabit muddy sediment may also be impacted in a similar way. Given the avoidance behaviour that is likely to be displayed by marine fauna and the controls that will be implemented, interactions that lead to injury or death are considered unlikely during trenching activities.

9.5.8 Hydrocarbon spill – dry gas release from the pipeline

As presented in **Section 9.5.5**, if there were a significant dropped object event during DPD Project construction, there is a possibility that this could impact and damage the Bayu-Undan to Darwin pipeline or the Ichthys pipeline. Furthermore, a third-party dropped object has the potential to damage the DPD Project pipeline (once in operation) resulting in the release of dry gas.

A quantitative risk assessment (INTECSEA, 2021) has been conducted to assess the risk of the DPD Project pipeline from third-party damage (e.g. vessel anchor drop/drag). The pipeline between KP 104 and KP 106 was identified as requiring additional protection from a 21.5 tonne anchor drag event. Justification for this is that the risk of an anchor directly impacting the pipeline is below ALARP already. Rock protection for this section of the pipeline has been designed to ensure the fluke of an anchor of this size cannot penetrate through to the pipeline.

Two other areas were identified to pose a risk to the DPD pipeline from anchoring. These are located between KP 106 and KP 108 and between KP 112 and KP 115. It was determined that this area of the DPD pipeline may be susceptible to damage from a 5-6 tonne anchor drop and drag event from smaller vessels. The analysis determined that the inherent strength and protection of the pipeline was sufficient to prevent an anchor penetrating the pipeline in these areas.

A release from the proposed DPD Project pipeline or the existing Bayu-Undan to Darwin pipeline or the Ichthys pipeline would result in a plume of gas rising rapidly to the sea surface and depending on the size of the rupture, could form a 'bubbling zone' in which the gas bubbles break through the surface with subsequent atmospheric gas plume.

The predominant gas properties interacting with the environment during a gas release include methane gas, higher alkane gases (e.g. ethane, propane and butane), and small quantities of natural gas liquids and waxes. Methane and ethane are considered to be non-toxic (Pubchem, 2004) and are not considered biocidal substances under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation. Propane can be toxic via inhalation at very high concentrations (e.g. greater than 100,000 ppm) (Pubchem, 2004) but is not considered a biocidal agent under REACH legislation. Inhalation toxicity has been reported for n-Butane at concentrations in excess of 300mg/l (PubChem, 2004) but there is a paucity of data on aquatic toxicity, noting that this gas has low solubility with water and will readily partition to the atmosphere. Given the low potential for toxic effects in the marine environment from a dry gas release and the rapid rise and dispersion of gas at the water's surface there is considered to be low potential for significant impacts to Marine Ecosystems from a pipeline rupture and dry gas release. With controls in place to prevent impacts to pipelines during the construction and operation of the DPD Project, the risk to Marine Ecosystems is considered very low.

9.5.9 Hydrocarbon spill – marine diesel oil

Marine Diesel Oil (MDO) characteristics, weathering, and hydrocarbon spill modelling results are presented in **Section 8.5.5**. This section addresses the potential impacts from a release of MDO on Marine Ecosystems including conservation significant areas, benthic habitats and marine fauna. The release of MDO from a Project vessel is considered to be an unlikely event, as it is for commercial vessels that move in, out and within Darwin Harbour on a daily basis. Historical records show that vessel collisions are infrequent events and collisions resulting in rupture and release of fuels even more infrequent. With controls in place as per **Section 12**, including those dictating Darwin Port operations, vessel collisions will be prevented. MDO will be used on Project vessels rather than the more persistent intermediate or heavier fuel oils. Following best practice, conservative worst case spill volumes and exposure thresholds have been adopted for hydrocarbon spill modelling (**Section 8.5.5**) and applied to the risk assessment to Marine Ecosystems presented here. The fuel tank volumes on Project vessels are within the range of fuel and hydrocarbon storage tank volumes present on the large commercial vessels that regularly use Darwin Harbour (Darwin Port, 2020).

9.5.9.1 Conservation significant areas

In the unlikely event of a vessel collision involving the deep water pipelay vessel resulting in a worst case MDO spill of 700 m^3 (Scenario 1), entrained and dissolved hydrocarbons above high and moderate threshold values respectively were predicted to contact the Charles Point Wide RFPA. For the 0 – 10 m water depth, there is a very high probability (100% dry season and 93% wet season) of entrained hydrocarbons above the moderate threshold at maximum concentrations of 7,051 ppb and a low probability (2 – 4%) of dissolved hydrocarbons above the moderate threshold at maximum concentrations of 97 ppb (**Section 8.5.5.5**). However, at the 10 – 20 m water depth, maximum concentrations of entrained hydrocarbons are reduced (15 – 16 ppb) to below the moderate threshold whilst dissolved concentrations are reduced to 10 – 25 ppb, well below the moderate threshold, given the nature of the surface release and the tendency for MDO to become entrained only in the upper layers of the water column through wind and wave action (RPS, 2022c).

Given that hydrocarbon exposure above impact thresholds are not predicted for depths greater than the 10 m range, significant impacts to the environmental values of the Charles Point Wide RFPA, in the unlikely event of a MDO spill, are not expected beyond 10 m to the 30 m seabed depth. The potential impacts to fish from a hydrocarbon spill are discussed in detail in **Section 9.5.9.3**.

Potential impacts to dolphin and marine turtle BIAs are discussed in detail in **Section 9.5.9.6**.

9.5.9.2 Benthic habitats

Mangroves

The sensitivity of mangroves to oil spills has been well recorded, with extensive defoliation and sometimes mortality being noted following a number of oil spills. In general, studies have suggested that damage occurs through the smothering of lenticels (mangrove breathing pores vital for respiration) on pneumatophores or prop roots or by the loss of leaves due to chemical burning (Duke et al., 1999). A comprehensive review of the literature on the impacts of oil spills on mangroves was conducted by Thorhaug (1987), from which it was concluded that while defoliation of mangroves was a common occurrence, massive mortality was not always the ultimate outcome.

Along the coastline of Darwin Harbour there are extensive mangrove communities. Mangroves may be susceptible to impact from hydrocarbons if physical coating of the root system occurs and reduces air and salt exchange. The degree of coating, and thus subsequent impact, is dependent upon the type of hydrocarbon, the energy and tidal reach of the shoreline, the type of substrate and continual weathering of the hydrocarbon. Mangroves may also be impacted by external contact with the hydrocarbon and absorption across cellular membranes. In both cases, potential impacts include yellowing of leaves, defoliation, increased sensitivity to stressors, tree death, reduced growth, reduced reproductive output, reduced seed viability and growth abnormalities.

Given the potential for shoreline accumulation, the spill modelling results showed that there is the potential for mangroves to be contacted by hydrocarbons above the moderate threshold (**Section 8.5.5**).

Seagrass and macroalgae

Seagrass and macroalgae are distributed widely in patches throughout Darwin Harbour (refer **Figure 9-6**) including Middle Harbour (in particular Weed Reef), East Arm, West Arm and Outer Harbour (including seagrass areas located between East Point and Lee Point). Seagrass and macroalgae are generally restricted closer to shorelines and intertidal areas in waters shallower than 10 m. Outside of the harbour, seagrass and macroalgae are associated with the various shoals and banks located between the mainland and Tiwi Islands.

Seagrass and macroalgae are susceptible to physical coating by hydrocarbons of leaves/thalli reducing light availability and gas exchange. The degree of coating depends upon the energy and tidal reach of the shoreline, the type of the receptor and continual weathering of the hydrocarbon. This may lead to bleaching or blackening of leaves, defoliation and reduced growth. Seagrass and macroalgae may also be impacted by external contact with the hydrocarbon and absorption across cellular membranes potentially leading to additional impacts such as mortality, reduced reproductive output and reduced seed/propagule viability. Laboratory tests have illustrated the sensitivity of seagrasses to both surface oil and dissolved hydrocarbons (Hatcher & Larkum, 1982; Wilson & Ralph, 2017). Stress response has also been demonstrated for seagrass at low hydrocarbon concentrations similar to that expected to occur in oil spill situations (Thorhaug, 1987). A review of field studies conducted after spill events by Connell and Miller (1981) indicated a high degree of variability in level of impact, but in all instances the algae appeared to be able to recover rapidly from even very heavy oiling. The rapid recovery of algae was attributed to the fact that for most algae new growth is produced from near the base of the plant while the distal parts (which would be exposed to the hydrocarbon contamination) are continually lost. A heavy oiling of medium crude oil in Panama resulted in the loss of algae on coastal reefs. Within two months, algal cover had ‘recovered’ to a level in excess of the seasonal average, although species composition had changed (Cubit et al., 1987).

The spill modelling results show that floating or entrained MDO above moderate impact thresholds could contact shallow and intertidal areas supporting macroalgae and seagrass within and outside Darwin Harbour under modelled spill scenarios. Contact by dissolved MDO above impact thresholds is less likely.

Hard corals

Hard coral distribution is quite restricted within Darwin Harbour, with localised coral communities known to occur at Channel Island, Weed Reef, Northeast Wickham Point, South Shell Island and Mandorah (refer **Figure 9-6**). Coral communities occur within the intertidal zone and within shallow subtidal waters of less than 10m depth. Emergent corals are vulnerable to stranded hydrocarbons on shorelines that become remobilised due to periodic tidal and wave action exposure. Exposure of subtidal corals, such as those associated with the various reefs, shoals and banks outside of the harbour to entrained and dissolved fractions have the potential to result in lethal or sub-lethal toxic effects.

Experimental studies and field observations have found all species of corals to be sensitive to the effects of hydrocarbons, although there are considerable differences in the degree of tolerance between species (Jackson et al., 1989). The effect of oil on corals range from short or long-term sub-lethal effects to irreversible tissue necrosis and death. The timing of an oil spill event in relation to other environmental stresses, such as ambient temperature, or reproductive stage could also have significance in that corals are likely to be more sensitive to oil spill events at times of physiological stress.

The entrained and dissolved fractions of released hydrocarbons can produce lethal and sub-lethal effects in corals (Loya and Rinkevich, 1980); however documented effects such as increased mucous production, decreased growth rates, changes in feeding behaviours and expulsion of zooxanthellae (Peters et al., 1981; Knap et al., 1985) generally only occur at concentrations that are considerably higher than would occur in field situations.

Corals are reported as having a highly variable response after exposure to hydrocarbons. A study by Shafir et al. (2007) examined the effect of dissolved and entrained hydrocarbons on two species of corals at concentrations that would occur in event of heavy exposure. The effect of hydrocarbons on the corals tested did not indicate a high sensitivity and there was no effect on survivorship of corals.

Floating or entrained MDO above moderate impact thresholds could contact shallow and intertidal areas supporting hard corals within and outside Darwin Harbour under modelled spill scenarios. Contact by dissolved MDO above impact thresholds is less likely.

Filter feeders/octocorals

Filter feeder habitat is widespread both within and outside of Darwin Harbour (refer **Figure 9-6**). Filter feeders, including marine fauna, can be vulnerable to lethal and various sub-lethal effects from hydrocarbons in the water column. The latter include alteration in respiration rates, decreases in filter feeding activity, reduced growth rates, biochemical effects, increased predation, reproductive failure and mechanical destruction by waves due to inability to maintain hold on substrate (Connell and Miller, 1981; Ballou et al., 1989).

Floating or entrained MDO above moderate impact thresholds could contact shallow and intertidal areas supporting filter feeders within and outside Darwin Harbour under modelled spill scenarios. Contact by dissolved MDO above impact thresholds to shallow waters is less likely. Given MDO will remain on the water surface or entrain within the top 10 m of the water column, there is a low risk of filter feeders being exposed in water depths greater than 10m. Given exposure at the moderate threshold was limited to the first 10 m of the water column and restricted along the pipeline alignment, moving with the tidal flow, the majority of the filter feeder/octocoral habitat is in deeper water.

Intertidal areas

Intertidal areas within and outside of Darwin Harbour include sandy beaches, mud flats, rocky shores, mangroves (discussed above) and reefs (discussed above).

Intertidal sandy beaches and mud flats support burrowing fauna of crabs, burrowing bivalve molluscs, as well as a diverse community of benthic infauna comprising polychaetes, crustaceans and gastropods. In addition, the beaches at Casuarina and Cox Peninsula provide seasonal habitat for turtle nesting (albeit at very low densities), breeding seabirds and migratory wading birds. Shoreline loading and water movement may allow hydrocarbon residue to filter down into sediments, continue to biodegrade on the surface or remobilise into surf zone causing physical smothering. Toxicological impacts may also occur to biota and temporary declines in infauna and epifauna populations may have an indirect effect on feeding shorebirds and seabirds.

Epibiota that colonise intertidal rocky shorelines may be susceptible to impacts from a hydrocarbons spill (for example, filter feeders described above). Shoreline loading and attachment may result in thin and sporadic coating of hydrocarbon residues. Degree of oil coating is dependent upon the energy of the shoreline area, the type of the rock formation and continual biodegradation of the oil.

A worst case release of MDO as a result of a vessel collision could shoreline accumulation at or above impact thresholds along shorelines within Darwin Harbour and at the mouth of Darwin Harbour, with a peak volumes onshore ranging from 0.3 to 111.7 m^3 and maximum length of shoreline contacted ranging from 1 to 8 km (**Section 8.5.5**).

9.5.9.3 Primary Production

The effects of hydrocarbons on plankton, including phytoplankton and zooplankton have been well studied in controlled laboratory and field situations. Injury/mortality to planktonic species may occur due to a change in water quality following an unplanned hydrocarbon release from coming into contact with the spill source at the time of release may be impacted, and there is potential for localised mortality.

Given the characteristics of MDO (**Section 8.5.5**), expected rapid weathering and then degradation of the entrained component, and the relatively quick recovery times of plankton, significant impacts are not expected to plankton life cycle and spatial distribution. Impacts to benthic primary producer habitats of seagrass and macroalgae are discussed in **Section 9.5.9.2.**

9.5.9.4 Fish, sharks and rays

While fish, sharks and rays do not generally break the sea surface, individuals may feed at the surface. For diesel spills where a slick is expected to quickly disperse and evaporate, prolonged exposure to surface hydrocarbons by fish, shark and ray species is unlikely. Hydrocarbon droplets can physically affect fish, sharks and rays exposed for an extended duration (weeks to months). Smothering through coating of gills can lead to the lethal and sub-lethal effects of reduced oxygen exchange, and coating of body surfaces may lead to increased incidence of irritation and infection. Fish may also ingest hydrocarbon droplets or contaminated food leading to reduced growth. There is potential for localised mortality of fish eggs and larva due to reduced water quality and toxicity. Effects will be greatest in the upper 10 m of the water column and areas close to the spill source where hydrocarbon concentrations are likely to be highest.

Given MDO released from a vessel collision scenario will remain on the water's surface or within the top 10 m of the water column the greatest risk of impact to fish or sharks is for those in surface waters or occupying shallow coastal areas. There is a lesser risk of impact to demersal species that occupy depths greater than 10m.

9.5.9.5 Seabirds and shorebirds

Birds are particularly vulnerable to surface slicks. As most fish survive beneath floating slicks, they will continue to attract foraging seabirds, which typically do not exhibit avoidance behaviour. Smothering can lead to reduced water proofing of feathers and ingestion while preening. In addition, direct contact with hydrocarbons can affect feathers causing chemical damage to the feather structure that subsequently affects ability to thermoregulate and maintain buoyancy on water (O'Hara and Morandin, 2010). Shorebirds may be impacted by the presence of hydrocarbons accumulated on shorelines which may result in exposure to eggs and ingestion by foraging individuals. Shoreline hydrocarbons are expected to be less toxic than fresh hydrocarbons due to weathering processes such as photo oxidation and biodegradation reducing the levels of lighter chain hydrocarbons which are generally more toxic. Entrained hydrocarbons may be encountered while diving or foraging and lead to Lethal or sub-lethal physical and toxic effects such as irritation of eyes/mouth and potential illness. Darwin Harbour supports migratory shorebirds and seabirds, with areas such as beaches, rock reefs, intertidal sand and mud flats and East Arm Wharf all providing habitat for various migratory and threatened species, including the far eastern curlew, lesser sand plover, greater sand plover, terek sandpiper and sharp-tailed sandpiper.

9.5.9.6 Marine mammals

Darwin Harbour is a BIA (breeding) for three species of dolphin; the Australian snub-fin, Australian humpback and spotted bottlenose dolphin (**Section 9.4.5**). As well as these dolphin species, Darwin Harbour is also occasionally visited by small pods of false killer whales. The harbour is also home to a population of dugong (estimated to be between 180 to 300 individuals) that utilise the seagrass meadow habitat as foraging areas (**Section 9.4.5**). No BIAs for marine mammals are present outside the harbour within the moderate exposure zone.

Marine mammals (whales, dolphins and dugongs) come to the sea surface to breathe air. They are therefore theoretically vulnerable to exposure to hydrocarbons at the sea surface. Whales and dolphins are smooth-skinned, hairless mammals so hydrocarbons tend not to stick to their skin and since they do not rely on fur for insulation, they will not be as sensitive to the physical effects of oiling. Dugongs that come into contact with floating hydrocarbons as they come to the surface to breathe would be at risk from direct contact potentially causing skin lesions and irritation of mucous membranes (such as those in the nose, throat and eyes).

Small doses of hydrocarbons have been shown to cause acute fatal pneumonia in mammals when aspirated. Studies on effects of petroleum vapours on terrestrial mammals and seals showed (in cases of prolonged exposures and high concentrations) absorption of hydrocarbons in organs and other tissues, and damage to the brain and central nervous system.

Ingested hydrocarbons, particularly the lighter fractions of MDO, can be toxic to marine mammals. Ingested hydrocarbon can remain within the gastro-intestinal tract and be absorbed into the bloodstream and thus irritate and/or destroy epithelial cells in the stomach and intestine (Woodside Energy, 2022).

Dugongs that come into contact with floating hydrocarbons as they come to the surface to breathe would be at risk from direct contact potentially causing skin lesions and irritation of mucous membranes (such as those in the nose, throat and eyes).

Given volatile components of MDO will evaporate within the first 24 hours (**Section 8.5.5)** impacts to marine mammals would be expected to be more likely immediately following a MDO spill.

9.5.9.7 Marine reptiles

All six species of marine turtles occur in NT waters, however, only green, hawksbill and flatback turtles frequent Darwin Harbour regularly. Darwin Harbour is a BIA (inter-nesting) and critical habitat for flatback turtles, with peak inter-nesting activity occurring between May and October. Within and adjacent to Darwin Harbour, the closest nesting beaches for flatback turtles are Casuarina Beach, and beaches on Cox Peninsula however nesting effort is very low, and these are not considered significant sites on a regional basis (**Section 9.4.6**). Saltwater crocodiles are common within Darwin Harbour, however, breeding within the harbour is limited with the species preferring elevated, isolated freshwater swamps for breeding. Sea snakes are also common in the harbour and surrounding offshore waters, particularly in the open water and mangrove areas of the harbour.

Marine turtles are vulnerable to the effects of hydrocarbon spills at all life stages (eggs, post hatchlings, juveniles and adults) whilst in the water or onshore. Should turtles contact a spill, the impact is likely to include oiling of the body as well as irritations caused by contact with eyes, nasal and other body cavities and possibly ingestion or inhalation of toxic vapours (Jones, 1986).

Direct contact of marine turtles with hydrocarbons and exposure from hydrocarbons may lead to the following impacts:

+ Digestion/absorption of hydrocarbons through food contamination or direct physical contact, leading to damage to the digestive tract and other organs;
+ Irritation of mucous membranes (such as those in the nose, throat and eyes) leading to inflammation and infection;

+ Contamination of eggs leading to inhibition of development or developmental defects in hatchlings, either due to oil on the nesting beach or through transference from the adult turtles whilst laying the eggs; and
+ Hatchlings becoming oiled after emerging from the nests and making their way across the beach to the water.

Turtles nesting on beaches may be vulnerable if there is shoreline accumulation of oil. During the nesting season (May to October for flatback turtles), adult turtles will tend to aggregate in the inter-nesting areas adjacent to the nesting beaches, increasing the vulnerability of turtles in this area. Eggs may become directly exposed to hydrocarbons as a result of female turtles becoming oiled from surface hydrocarbon exposure or when crossing shorelines, resulting in the transfer of hydrocarbons to eggs during nest preparation and laying, which may in turn effect embryo development or lead to embryo mortality.

The sensitivity of sea snakes to hydrocarbon spills has been poorly studied. It is expected that susceptibility will be due to their need to surface in order to breathe. Sea snakes also have the ability to breathe through cutaneous respiration (Heatwole, 1999). Surface hydrocarbons may coat the skin, impairing respiration. Sea snakes may also be susceptible to toxic effects through ingestion of contaminated prey.

Similar to sea snakes, the sensitivity of crocodiles to marine hydrocarbon spills is not well known. Potential impacts are likely to be similar to those described for marine turtles and sea snakes.

There is the potential for shoreline accumulation of hydrocarbons at or above the moderate exposure thresholds at turtle nesting beaches of Casuarina Beach and on Cox Peninsula Beaches. Surface hydrocarbons at or above the moderate threshold would be limited to within 20 km of the release location. Given the nature of MDO, the volatile components are expected to evaporate readily when released to the sea surface (majority within the first 24 hrs), limiting the potential for toxicological impacts from inhalation after this time.

9.6 Environmental management

The controls to manage impacts and risks to the Marine Ecosystems are presented in **Table 12-1** and have been carried through to EMPs as relevant. Controls have been informed by referral commitments and subsequent feedback and consultation with government and the public and have been reviewed through ENVID workshops (refer **Section 7.4**) and during EMP development. The management table (**Table 12-1**) should be viewed as a consolidated list of measures to avoid or mitigate impacts of the DPD Project.

9.7 Conclusion of residual impacts and risks and predicted outcome

The assessment of residual impacts and risks to Marine Ecosystems from the Project is summarised in **Table 9-12**. The management and mitigation measures proposed in **Table 12-1** are considered effective and appropriate to reduce potential impacts and risks to Marine Ecosystems to a level that is considered acceptable. Impacts from planned events were assessed as having a Negligible or Minor impact to Marine Ecosystems while unplanned events were assessed as presenting a Low or Very Low risk to Marine Ecosystems.

Santos considers that the development of the Project will be consistent with the NT EPA's objectives for maintaining the environmental values for biodiversity, ecological integrity and ecological functioning.

Table 9-12 Residual impact and risk rating for Marine Ecosystems

Aspect	Potential impact	Residual impacts and risks rating
Planned events[1] (residual impact)		
Seabed disturbance	Disturbance of seabed pipeline installation activities, including trenching and spoil disposal, resulting in loss of habitat and associated impacts to marine fauna.	Minor
Underwater noise emissions	Increasing ambient underwater noise potentially reducing the quality of the environment and causing physiological and behavioural impacts to marine fauna.	Minor
Light emissions	Activity vessels will have external lighting to provide a safe working environment and to comply with relevant maritime navigation requirements at night. May cause behavioural impacts to marine fauna.	Minor
Contingency treated seawater discharge	Reduced water quality from contingency discharge of chemically treated seawater potentially impacting on marine fauna and habitats.	Negligible
Unplanned events[2] (risk rating)		
Dropped objects	Accidental dropping of objects from vessels may result in localised disturbance to benthic habitats. Consequence assessment: Minor Likelihood assessment: Occasional	Low
Invasive marine species	Introduction of IMS impact the environment by modifying existing habitats and decreasing biodiversity. Consequence assessment: Major Likelihood assessment: Unlikely	Low
Marine fauna interaction	Collisions with vessels may result in behavioural impacts, physical injury to, or the death of, the fauna involved. Consequence assessment: Minor Likelihood assessment: Possible	Low

Aspect	Potential impact	Residual impacts and risks rating
Hydrocarbon spill	Impact to Marine Environmental Quality including flora, fauna and habitats from loss of hydrocarbons (MDO/MGO) from: + A bunkering incident. Consequence assessment: Minor Likelihood assessment: Possible + A vessel collision. Consequence assessment: Moderate Likelihood assessment: Unlikely.	Low

1. All planned events have been rated as if they will occur, therefore only the activity's consequence (ranging from negligible to critical) has been considered for the risk assessment, refer to **Table 7-3**.

2. The assessment of the unplanned events considered both the likelihood (refer **Table 7-2**) and the consequence (refer **Table 7-3**) of an activity, and therefore the residual risk rating has been calculated using **Table 7-4**.

10 Atmospheric Processes

This section provides information on Atmospheric Processes, specifically greenhouse gas (GHG) emissions, created as a result of the DPD Project. This information has been provided to address additional information requirements requested by the NT EPA and submissions received on the referral from government departments and the public, using additional data as applicable, since the submission of the referral.

10.1 Environmental objective

Minimise greenhouse gas emissions so as to contribute to Santos' 2040 Scope 1 and 2 emissions Net Zero commitments and the NT Government's goal of achieving net zero greenhouse gas emissions by 2050.

10.2 Additional information required

As described in **Table 1-1**, the NT EPA requested additional information about Atmospheric Processes to further understand the magnitude of potential impacts and the effectiveness of environmental management and mitigation measures, specifically:

+ Provide details of proposed GHG emissions over the life of the DPD Project (from extraction from the reservoir through to completion of liquefaction);
+ Demonstrate how the DPD Project will be implemented to meet the NT EPA's objectives for the Atmospheric Processes environmental factor and the NT Government's goal of achieving net zero greenhouse gas emissions by 2050.
+ Provide an overarching long-term emissions target trajectory and proposed interim targets, and the measures and methods that will be used to meet the targets;
+ Application of the decision-making hierarchy, and that all reasonable and practicable measures would be applied to avoid and/or reduce emissions, including through best practice design, technology and management; and
+ Provide a description of any regulatory framework.

10.2.1 Proposed greenhouse gas emissions

The NT EPA requested Santos:

Provide details of the proposed greenhouse gas emissions over the life of the proposal (from extraction from the reservoir through to completion of liquefaction) including:

+ Estimates of annual and total Scope 1, Scope 2 and Scope 3 emissions over the life of the proposal;
+ A breakdown of Scope 1, Scope 2 and Scope 3 emissions according to the emission source locations within the NT and / or elsewhere in Australia and / or outside of Australia;
+ A breakdown of emissions by source, including but not limited to stationary energy, fugitives and transport; and

+ A comparison of estimated emissions from the proposal against the proponent's emissions across its entire business, and Northern Territory and Australian greenhouse gas emissions as reported in Australia's National Greenhouse Accounts.

10.2.1.1 Emission estimates and breakdowns

The Barossa Development and the DLNG Plant are shown in **Figure 10-1** below. In this development hydrocarbons are extracted from the reservoir through multiple subsea wells connected to a floating production, storage and offloading facility (FPSO). The FPSO processes the gas and then exports it to the DLNG Plant through a new gas export pipeline (GEP). This gas export pipeline (GEP) consists of two sections, termed the Barossa Offshore GEP and the DPD pipeline. The gas is then liquified at the DLNG Plant before being shipped to customers.

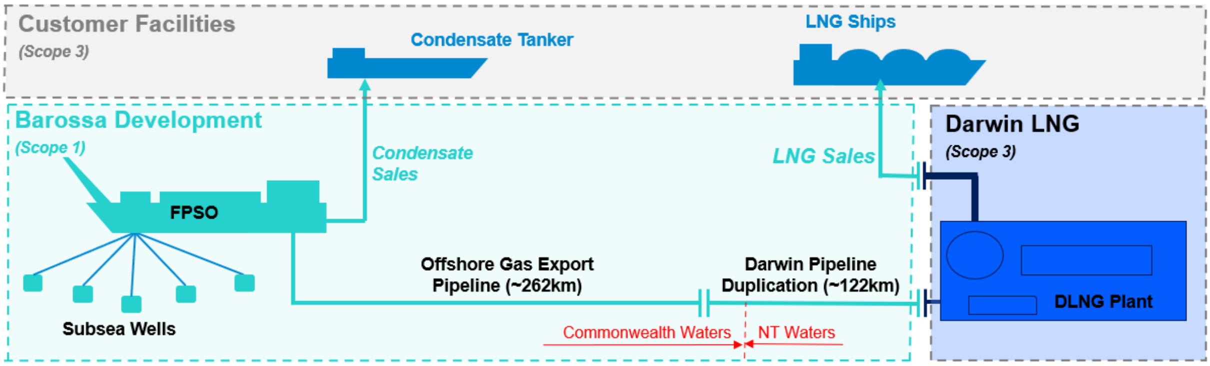


Figure 10-1 Barossa-DLNG schematic

This section discusses GHG emissions that result from the:

+ DPD Project;
+ Barossa Development, including the DPD Project;
+ DLNG Plant; and
+ Customer Facilities.

A GHG emissions study was conducted to determine the greenhouse gas emissions over the life of the proposal and wider Barossa Development. Scope 1 and 2 emissions have been calculated in accordance with NGER, and Scope 3 in accordance with the GHG Protocol. The assessment boundary is outlined in **Figure 10-2**.

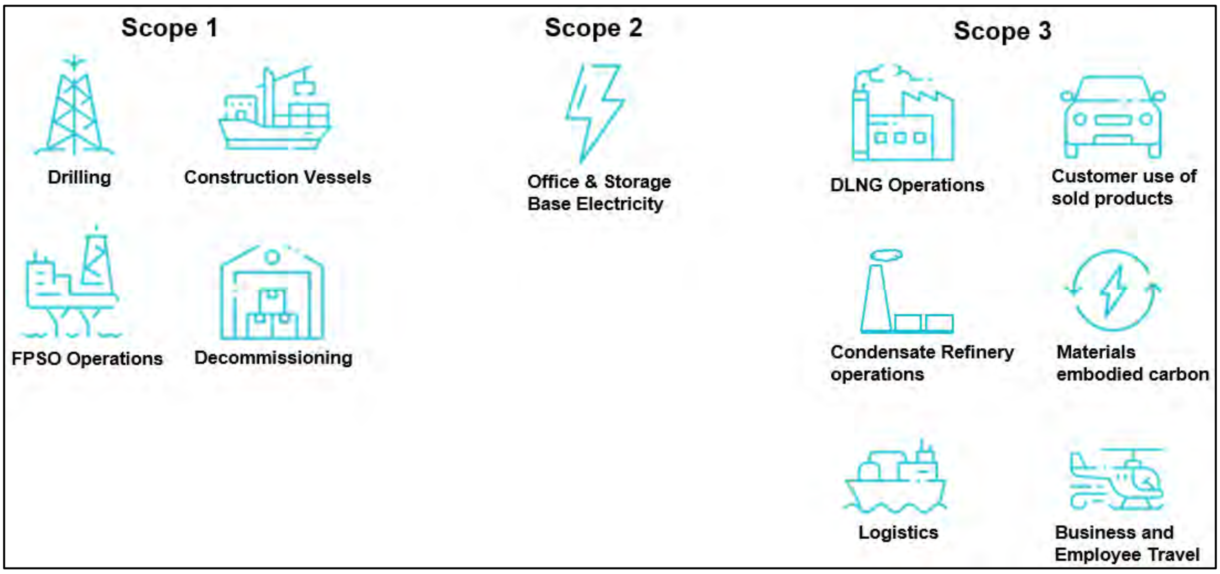


Figure 10-2 GHG inventory assessment boundary

The emissions sources in **Table 10-1** have been included in the GHG emissions inventory for design, construction, operations, use and decommissioning.

Table 10-1 GHG Emissions Source Inclusions

Activity	Aspect Emissions Source	GHG Emission Scope
Construction		
Personnel Travel	Flights	3
Drilling, Subsea, Pipeline & FPSO materials	Embodied carbon	3
Drilling	Flaring and Vessels	1
Offshore construction	Vessels	1
Operations		
Offices	Electricity Use	2
Personnel Travel	Flights	3
Operation at Barossa FPSO	Processing	1
Operation at Darwin LNG	Processing	3
Use of Sold Product		
Processing, transport & use of condensate	Transport & Combustion	3
Transport & use of LNG	Transport & Combustion	3
Decommissioning		
Decommissioning works	Vessels	1

The following definitions of emissions scope apply:

- Scope 1 GHG emissions are the emissions released to the atmosphere as a direct result of an activity, or series of activities at a facility level. Scope 1 emissions are sometimes referred to as direct emissions;
- Scope 2 GHG emissions are the emissions released to the atmosphere from the indirect consumption of an energy commodity; and
- Scope 3 GHG emissions are indirect GHG emissions other than Scope 2 emissions that are generated in the wider economy. They occur as a consequence of the activities of a facility, but from sources not owned or controlled by that facility's business.

An overview of the lifecycle Scope 1, 2 and 3 emissions is provided in **Table 10-2** below. These emissions are further broken down in the following sections.

Table 10-2 Emissions estimate for the 25-year lifecycle of the overall Barossa Development (including DPD) – Prior to any offsets

Broader Barossa Development *(including DPD)*	Lifecycle Emissions ($MtCO_2$-e)			
	Total (Barossa including DPD)	Emissions within the NT	Australian emissions (excluding NT)	Emissions Outside Australia
Scope 1	51.6	*0.08*	*51.5*	-
Scope 2	0.003	*0.003*	-	-
Scope 3	244.4	*32.3*	*0.1*	*212.0*

Scope 1 Estimate and Breakdown

The Scope 1 emissions estimates outlined in **Table 10-3** below relate to the Barossa Development, with the DPD Project (Scope 1 emissions of 0.08 Mt CO_2-e) being one part of the Barossa Development. These total lifecycle Barossa Development GHG emissions (51.6 Mt CO_2-e) are provided in this SER for completeness, however, they do not form part of the assessment of Scope 1 emissions of the DPD Project. These activities in Commonwealth waters and the resulting emissions were assessed under the Barossa Area OPP, which was accepted by the National Offshore Petroleum Safety and Environment Management Authority (NOPSEMA) on 13 March 2018.

Santos

Table 10-3 Scope 1 emissions estimate for the 25-year lifecycle of the overall Barossa Development (including DPD) – Prior to any offsets

Broader Barossa Development *(including DPD)*	Scope 1 Emissions ($MtCO_2$-e) [1]			
	Total (Barossa including DPD)	DPD (occur within the NT)	Barossa excluding DPD (occur in Australia outside the NT)	Emissions Outside Australia
Construction	**0.30**	**0.05**	**0.25**	**-**
Diesel	0.24	0.05	0.19	-
Flaring	0.06	-	0.06	-
Operation & Maintenance	**51.1**	**-**	**51.1**	**-**
Offshore Processing	17.4	-	17.4	-
Fuel gas	*15.9*	-	*15.9*	-
Flare	*0.9*	-	*0.9*	-
Fugitives	*0.6*	*0.03*	*0.6*	-
Diesel	*0.1*	-	*0.1*	-
Reservoir Emissions (vent)	33.7[2]	-	33.7[2]	-
Decom	**0.15**	**-**	**0.15**	**-**
Diesel	0.15	- [3]	0.15	-

[1] Estimate excludes the effect of any offsets that will be surrendered in compliance with the Safeguard Mechanism.

[2] The CCS projects aims to capture and store these reservoir emissions, with reservoir emissions receiving zero baseline under the Safeguard Mechanism (requiring them to be offset).

[3] DPD assumed to be left in-situ for GHG emissions estimate. Actual decommissioning philosophy will be determined in conjunction with NT Government closer to the end of field life (~25 years).

Within the context of the DPD Project, Scope 1 emissions within NT jurisdiction are emissions that result directly from the construction and operation of the DPD Project. This includes:

- Vessel-based construction activities (0.05 Mt CO_2-e); and
- Fugitive emissions (0.03 Mt CO_2-e)

These emissions comprise less than 0.2% of the total Scope 1 emissions associated with the Barossa Development.

Additional Scope 1 emissions from the Barossa Development that occur elsewhere in Australia and do not form part of the assessment of Scope 1 emissions of the DPD Project include:

- Construction of the wells, subsea infrastructure and FPSO (0.25 Mt CO_2-e);
- Operations & Maintenance of the FPSO (51.1 Mt CO_2-e); and
- Final decommissioning (0.15 Mt CO_2-e).

Scope 2 Estimate and Breakdown

Scope 2 emissions associated with the overall Barossa Development are limited to electricity purchased for office-based support and onshore supply base activities. These emissions are expected to occur with the NT jurisdiction with total lifecycle emissions of approximately 2.9 kt CO_2-e. The DPD project's contribution to these emissions is minor.

Scope 3 Estimate and Breakdown

The Scope 3 emissions estimates outlined in **Table 10-4** below relate to the overall Barossa Development including the DPD Project over the life of the proposal. As set out below, the Scope 3 emissions directly attributable to the DPD Project (206 kt CO_2-e) are a very minor contribution to the overall Scope 3 emissions of the Barossa Development The Barossa Scope 3 GHG emissions are provided in this SER for completeness, however it is worth noting that the Barossa Scope 3 emissions will be largely the same as a result of the DPD Project (i.e. they are largely the same whether the DPD Project or the option to tie-in to the Bayu-Undan to Darwin pipeline is pursued). The impact of the Bayu-Undan CCS project on Scope 3 emissions has not been included here, however, subject to all regulatory approvals, it offers the ability to significantly reduce the LNG processing emissions at Darwin LNG along with potential to capture customer end-use emissions.

Table 10-4 Barossa Development scope 3 emissions estimates

Barossa Development *(including DPD)*	**Scope 3 Emissions (kt CO2-e)**			
Subcategory	**Total**	**Within NT**	**Within Australia but outside the NT**	**Outside Australia**
DPD				
Capital goods	200	-	-	*200*
Business travel (vessels, helicopters)	6	*6*	-	-
Processing of sold products (LNG)	*Refer to Barossa*			
Transport & Use of product (LNG)	*Refer to Barossa*			
Processing, transport & use of Condensate	*Refer to Barossa*			
Barossa				
Capital goods	800	-	-	*800*
Business travel (vessels, helicopters)	154	*44*	*110*	-
Processing of sold products (LNG)	32,300	*32,300*	-	-
Transport & Use of product (LNG)[1]	191,200[2][3]	-	-	*191,200*
Processing, transport & use of Condensate[1]	19,800	-	-	*19,800*
TOTAL	**244,400**	*32,300*	*110*	*212,000*

[1] A conservative approach has been taken, with products assumed to be combusted (as opposed to non-fuel products such as plastics)

[2] This includes ~6,000kt CO_{2-e} of emissions associated with shipping. Barossa's shipping related emissions are expected to be far smaller than most LNG suppliers (particularly USA) due to Darwin's proximity to Asian customers.

[3] In Santos' key international markets, coal represents 30-64 per cent of power generation, providing significant scope for coal to gas switching over time (Santos, 2022). According to (IEA, 2019), in 2018, gas on average resulted in 33% fewer emissions than coal per unit of heat used in industry and buildings, and 50% fewer emissions than coal per unit of electricity generated."

Scope 3 emissions include the operation of the DLNG plant and the consumption of Barossa products by customers. The emissions from the DLNG facility are considered Scope 3 for the purpose of this assessment as the DLNG facility is outside of the Barossa Development boundary with DLNG being owned by a different joint venture[3] to the Barossa Development.

The DLNG facility was assessed under an Environmental Impact Statement (EIS) by the NT EPA under the *Environmental Assessment Act 1982* and approved in February 1998. A revised proposal was submitted in March 2002 for expansion to a max 10 Mtpa facility. This allowed gas to be sourced from several offshore fields (including Barossa reservoirs). The expansion was considered under the Commonwealth *Environment Protection (Impact of Proposals) Act 1974* and not the EPBC Act in line with transitional arrangements under the *Environmental Reform (Consequential Provisions) Act 1999* and a direction (dated 20 September 2001) from the Commonwealth Minister for the Environment.

Ongoing regulatory oversight and management of emissions from the DLNG facility is covered by DLNG's Environmental Protection Licence (EPL217-03) and an Operations Environmental Management Plan (EMP).

Within the context of the DPD Project, Scope 3 emissions include:

+ Capital goods for DPD construction - outside of the NT (200 kt CO_2-e); and
+ Third party vessel-based inspection, maintenance and repair (IMR) activities (6 kt CO_2-e)

Within the context of the Barossa Development (excluding DPD), Scope 3 emissions includes:

+ Capital goods (800 kt CO_2-e);
+ Business travel (150 kt CO_2-e);
+ Processing of LNG (32,300 kt CO_2-e);
+ Transport & Use of LNG (191,200 kt CO_2-e); and
+ Processing, transport & use of Condensate (19,800 kt CO_2-e).

10.2.1.2 Emissions comparison

The NT EPA requested Santos:

Provide a comparison of estimated emissions from the proposal against the proponent's emissions across its entire business, and Northern Territory and Australian greenhouse gas emissions as reported in Australia's National Greenhouse Accounts.

DPD Scope 1 Comparison

The DPD Project's Scope 1 emissions are anticipated to be approximately 80,000 t CO_2-e. Santos' equity Scope 1 GHG emissions for the 2021-2022 period was 4.75 MT CO_2-e, as shown in **Table 10-5** (Santos, 2023). Australia's total GHG emissions in 2022 are estimated at 486.9 Mt CO_2-e (DCCEEW, 2022a),

[3]Barossa joint venture: Santos (50%), SK E&S (37.5%) and Jera (12.5%). DLNG shareholders: Santos (43.4%), SK E&S (25%), INPEX (11.4%), Eni (11.0%), JERA (6.1%), Tokyo Gas (3.1%).

whilst the NT emissions in 2020 were 17.3 Mt CO_2-e (DCCEEW, 2022b). As a percentage, the DPD Project emissions represent:

- 1.68% of Santos' Corporate equity annual Scope 1 GHG emissions (2021-2022);
- 0.02% of Australia's annual GHG emissions (2022); and
- 0.46% of NT annual GHG emissions (2020).

Therefore, these emissions represent a very minor contribution to Santos', Australia's and the NT's GHG emissions.

Table 10-5 Santos 2021 -2022 scope 1 emissions, based on equity share

Scope 1 Emissions by Location (Santos Equity Share)	Mt CO_2-e
Australia	3.79
Timor-Leste	0.19
PNG	0.77

Barossa Development Comparison

Whilst not within the scope of this SER, for completeness the estimated annual CO_2-e emissions associated with the Barossa Development are presented in **Table 10-6**. In contextualising the contribution of the emissions nationally in Australia and globally, the following peer-reviewed, published GHG emissions have been used:

- 2022 Australian Emissions: Emissions for the year to June 2022 are estimated to be 486.9 Mt CO_2-e (DCCEEW, 2022a)
- 2021 Global Energy Related Emissions: Global CO2 emissions from energy combustion and industrial processes was estimated by IEA to have reached 36.3 gigatonnes (Gt) in 2021 (IEA, 2022).
- 2030 predictions of world energy-related CO2-e emissions estimated by the International Energy Agency:
  - 2022 World Energy Outlook (STEPS): 36,211 Mt CO_2-e (The Stated Policies Scenario (STEPS) is one scenario reflective of today's announced policy intentions and targets)
  - 2021 World Energy Outlook (SDS): 28,487 Mt CO_2-e (The Sustainable Development Scenario (SDS) delivers sustainable development in line with the Paris Agreement while limiting global temperature increase to 1.65 degrees Celsius)
  - 2022 World Energy Outlook (NZE): 22,846 Mt CO_2-e (The Net Zero by 2050 scenario achieves net zero emissions from the global energy sector in 2050 while limiting global temperature increase to 1.5 degrees Celsius)

Table 10-6 Barossa GHG emissions in context

Stage	Estimated Average[1] Annual CO_2-e Emissions (Mtpa)	Barossa Contribution (%)				
		2022 Australian Emissions	2021 Global Emissions	2030 STEPS Global CO_2-e Emissions	2030 SDS Global CO_2-e Emissions	2030 NZE Global CO_2-e Emissions
Scope 1:						
Operations & Maintenance	2.5	0.51%	0.007%	0.007%	0.009%	0.011%
Scope 3:						
Onshore Processing [3]	1.7	0.35%	0.005%	0.005%	0.006%	0.007%
Product End Use	11.0	- [2]	0.030%	0.030%	0.039%	0.048%
Totals	15.2	0.86%	0.042%	0.042%	0.053%	0.067%

[1] Average taken over initial plateau production period, with emissions decreasing once off plateau.

[2] End-user combustion will occur outside Australia.

[3] Onshore processing estimate conservatively taken from highest year of emissions reported under NGER (2016-17).

In a national context, the total annual average Australian CO_2-e emissions associated with Barossa Development inclusive of onshore processing at the DLNG Plant (Scope 1 and 3) would equate to ~0.86% of the 2022 Australian emissions.

In a global context, the estimated emissions total from the Barossa Development (Scope 1 and 3) equates to 0.042% of the 2021 global emissions; and 0.042%, 0.053% or 0.072% of the predicted 2030 global CO_2-e emissions under the IEA STEPS, the IEA SDS and the IEA NZE by 2050 scenario respectively.

10.2.2 Demonstration of meeting Atmospheric Processes objectives and NT net zero goal

The NT EPA requested Santos:

Demonstrate how the proposal will be implemented to meet the NT EPA's objectives for the Atmospheric Processes environmental factor and the NT Government's goal of achieving net zero greenhouse gas emissions by 2050.

Refer to **Section 10.7** for a demonstration of how the DPD Project will be implemented to meet the NT EPA's objectives for the Atmospheric Processes environmental factor and the NT Government's goal of achieving net zero greenhouse gas emissions by 2050.

10.2.3 Long-term and interim emissions targets

The NT EPA requested Santos:

Provide an overarching long-term emissions target trajectory and proposed interim trajectory targets, and the measures and methods that will be used to meet the targets.

10.2.3.1 DPD Project emissions targets

The Scope 1 GHG emissions from the Barossa Development, including the DPD Project, are regulated by the Safeguard Mechanism. The Safeguard Mechanism establishes a Scope 1 GHG emission baseline, which in turn establishes the net emissions targets for the Barossa Development to comply with. Baseline exceedance is required to be offset through the purchase of carbon credits, with the cost of the carbon credits providing a market stimulus to abate emissions consistent with the baseline. Under proposed Safeguard Mechanism reforms, the emissions baseline will gradually decline to limit Scope 1 emissions and achieve net zero by 2050. The decline rate is proposed to be an average of 4.9% each year to 2030, with post 2030 decline rates to be set in predictable five-year blocks thereafter.

10.2.3.2 Emissions Abatement to meet targets

Compliance with the requirements of the Safeguard Mechanism in connection with the Barossa Development will be supported by carbon abatement, with emissions mitigation based on the hierarchy of avoidance first, followed by reduction and offsetting:

+ Avoid: Transformation of the energy business to supply critical fuels more sustainably, with lower emissions intensity and better environmental outcomes
+ Reduce: Implementing energy efficiency and other low-emission technology to reduce the emissions footprint of our activities and products
+ Offset: Invest in high-quality carbon sequestration projects to address any residual emissions and support our transition to net-zero emissions

Measures to avoid and/or reduce emissions for the DPD Project are outlined in Section 10.2.4. Detailed measures to avoid, reduce or offset emissions for the Barossa Development will be incorporated in the Barossa Operations Environment Plan that will be submitted to NOPSEMA, including:

+ Designing the facilities to reduce Barossa fuel, flare and vent (FFV) emissions, including the ability to send the full reservoir CO_2 stream to Darwin (enabling CCS);
+ Embedding fugitive emissions surveillance and management into facilities operations and maintenance;
+ Undertaking optimisation of energy efficiency through periodic opportunity identification workshops or studies, evaluation and implementation;
+ Reporting on GHG emissions as required per the National Greenhouse and Energy Reporting (NGER) Scheme;
+ Implementing a GHG management plan and energy management program that incorporates an adaptive management approach that facilitates a continuous cycle of monitoring, evaluating, and implementing improvements to minimise GHG emission to ALARP and acceptable levels over the life of field operations; and
+ Complying with the requirements of the Safeguard Mechanism, including surrendering of carbon credit units for any emissions above the baseline for the year.

10.2.3.3 Santos emissions targets and abatement

In addition to the Barossa-DPD emissions baselines set by the Safeguard Mechanism's, Santos has industry leading emissions targets across its portfolio which include:

+ Net-zero Scope 1 and 2 emissions by 2040;
+ A 30% reduction in absolute Scope 1 and 2 emissions by 2030;
+ A 40% reduction in Scope 1 and 2 emissions intensity by 2030; and
+ Reducing customer emissions (Santos Scope 3) by 1.5 MT CO_2-e per annum.

These Scope 1 and 2 targets aim to be achieved through both CCS and a broad range of operational efficiency initiatives (including fuel, flare and vent reduction and renewable integration). The Scope 3 targets aim to be achieved through generation of carbon offsets for customers along with the supply of clean fuels. Santos has also made a commitment to only sell products to customers from countries that have a net-zero commitment or that are signatories to the Paris Agreement.

The Santos Climate Change Transition Plan is shown in **Figure 10-3.**

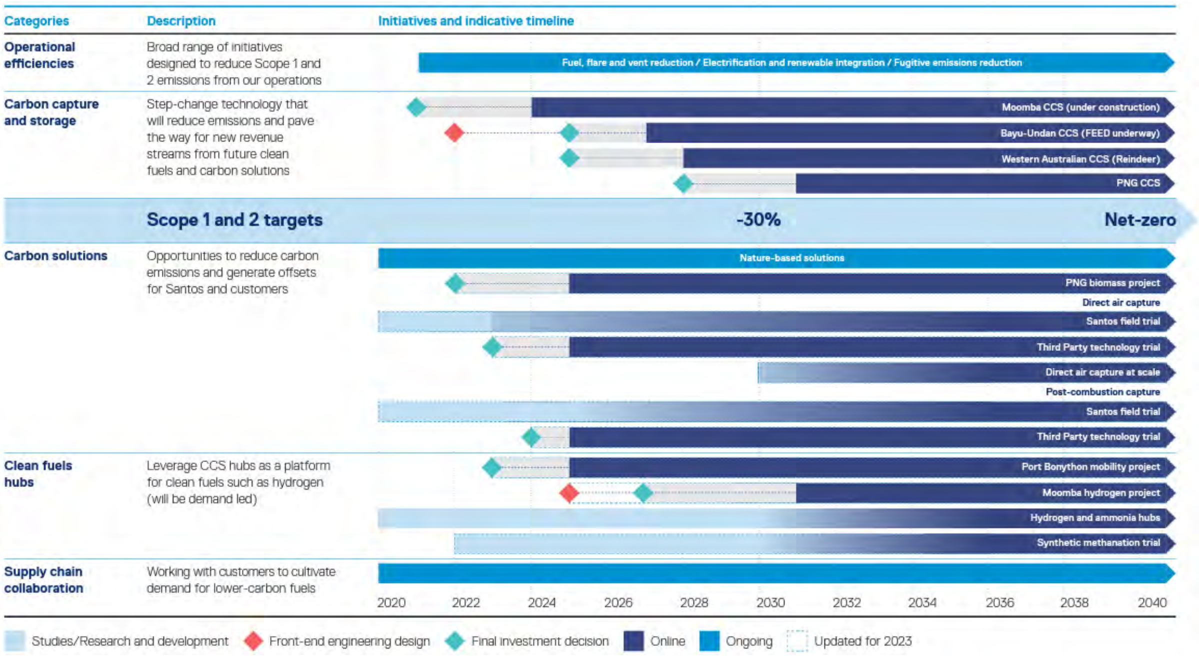


Figure 10-3 Climate transition action plan

10.2.4 Reasonable and practicable measures to avoid or reduce emissions

The NT EPA requested Santos to

Demonstrate application of the decision-making hierarchy (part 2 of the EP Act), and that all reasonable and practicable measures would be applied to avoid and/or reduce emissions, including through best practice design, technology and management.

The DPD Project includes the construction and operation of part of the pipeline connecting the Barossa FPSO to the DLNG Plant, where it will be processed into a saleable product. During the operations phase, inspection, maintenance and repair (IMR) activities will be undertaken along the pipeline to ensure its integrity is retained and the pipeline remains safe to operate.

Santos has a carbon emissions hierarchy of controls that consists of avoidance first, followed by reduction and offsetting.

10.2.4.1 Construction phase

During the construction phase, fossil fuel powered vessels and equipment will be commissioned to install an approximately 123 km section of pipeline (the DPD Project pipeline).

Due to the lack of alternatives to the use of fossil fuel powered vessels to complete these works, it is not possible to avoid vessel emissions during this stage of the project.

Emissions reductions from vessels during the pipelines construction and operation phases will be accomplished by requirements for vessel maintenance to be undertaken by appropriately qualified personnel in accordance with a planned maintenance regime to ensure vessel performance remains optimised. In addition, vessels employed during the construction of the pipeline, as well as those utilised to undertake IMR activities, will comply with the requirements of the *Navigation Act 2012* (Cth) (as applicable for vessel size, type and class). This includes implementing Marine Order 97 (Marine Pollution Prevention - Air Pollution) including (as required by vessel class) ensuring that vessels maintain a Ship Energy Efficiency Management Plan (SEEMP).

There were no available alternatives to fossil fuel powered vessels provided through the contractor selection process for undertaking specialist activities required for the DPD Project's construction.

The exclusive use of vessels with engines and incinerators that achieved higher efficiency was also considered and found to be neither practicable nor reasonable. This is due to the potential difficulty procuring such vessels in time to meet construction schedules and the subsequent impact on construction timeframes.

10.2.4.2 Operations Phase

The primary emission source during the operations phase of the DPD Project is IMR activities. Santos will implement a risk-based inspection (RBI) schedule, in accordance with industry standards to ensure the safe operation and integrity of the pipeline. IMR activities are critical to ensure the pipeline retains its integrity and is safe to operate. The RBI schedule ensures only inspections required for integrity and safety purposes are undertaken, thereby optimising the number of vessel inspections required and minimising associated GHG emissions.

Inspections of the pipeline will generally involve fossil fuel-powered vessels travelling along the route of the pipeline using towed acoustic instruments or may involve using a remote operated vehicle (ROVs) connected to the vessel via an umbilical. Alternatively, autonomous underwater vehicles (AUVs) may also be used to undertake IMR activities.

Maintenance and repair activities will be performed on the pipeline on an 'as needed basis' to ensure faults are identified in a timely manner and prevented from compromising the structural integrity of the pipeline. Events such as cyclones and known dropped or dragged objects that could affect pipeline integrity may also trigger IMR inspections.

Given the short-term and periodic nature of IMR activities, emissions from these activities are not forecast to create material GHG emissions.

Emissions from these activities cannot be avoided due to the need to use fossil fuel powered vessels to undertake these activities, however inspection frequencies will be set to minimise activities. Emissions from these vessel-based activities will be reduced using measures consistent with those proposed for vessels to support the construction phase of the DPD Project. New technologies like AUV inspections will also be considered to both reduce inspection times and vessel size. IMR activities will also lower the likelihood a loss of pipeline integrity will occur, which would increase GHG emissions from the pipeline.

Note: The operation of the FPSO and DLNG and the resultant emissions are not within the scope of the DPD Project and so are not assessed in this section. The operation of the FPSO and the resultant emissions will be assessed by NOPSEMA in the Barossa Operations EP, which is currently under development. The operation of DLNG is permitted under the existing Environmental Protection Licence (EPL217-03) and the DLNG Operations Environmental Management Plan.

10.2.5 Regulatory frameworks

The NT EPA requested Santos:

Provide a description of any regulatory frameworks, including any licences, approvals or permits required, for greenhouse gas emissions within the NT, elsewhere in Australia or outside of Australia.

10.2.5.1 International GHG Framework

Sustainable Development Goals

The 2030 Agenda has 17 sustainable development goals (SDG), which were adopted by the United Nations (UN) in 2015 (United Nations, 2022). The SDGs were a progression of the Millennium Development Goals (MDGs) which were adopted in 1990 and were in effect until 2015 when that framework expired.

Agenda 2030 has an overarching goal to create a sustainable world and provides a guide curating to a more sustainable approach with details of strategies for ending extreme poverty, helping the environment and diminishing inequality. To accomplish this plan, nations will need to take extreme actions. The 2030 Agenda rests on state and non-state actions both in state defined contributions to the agreements as well as in the efforts initiated by UN organizations to orchestrate actions to reach the goals of the agreements. Their implementation is based on countries identifying, and subsequently acting and reporting on their own priorities. Non-state actors are formally expected to participate in overseeing and facilitating the implementation.

Paris Agreement

The Paris Agreement was adopted by 196 parties at COP21 in December 2015 and came into effect in November 2016. The Paris Agreement currently includes 192 participating parties, with its primary purpose to strengthen the global response toward climate change. Specifically, the Agreement seeks to substantially reduce GHG emissions to limit the global temperature increase in this century to 2°C, while pursuing efforts to limit the increase even further to 1.5°C. The Paris Agreement has not been ratified by four nations: Eritrea, the Islamic Republic of Iran, Libya and Yemen. These nations are not key Australian trading partners and Santos Climate Policy contains a commitment to sell the products it generates only to customers from countries that have a net-zero commitment or are signatories to the Paris Agreement.

The Paris Agreement is legally binding, and signatories are reviewed every five years with the submission of an updated national climate action plan, known as Nationally Determined Contributions (NDCs). Where the Kyoto Protocol had legally binding emissions targets for the 37 developed emitting nations, the Paris Agreement has legally bound NDCs for all signatories regardless of their status of economic development. While the Paris Agreement is legally binding, there are no penalties for countries declaring unambitious NDCs, lack of financial aid to other nations, or failing to meet a pledge once it has been made. Due to this, the success of the agreement is ultimately dependent on the leadership of the largest emitting countries.

Australia has ratified the Paris Agreement and has adopted NDCs that can be monitored and reported on as part of the 5-year stocktake. At the Paris conference in 2016, Australia announced its first NDC to reduce GHG emissions by 26-28% below 2005 levels by 2030. This commitment was reaffirmed in 2020 after the 5-year review and further commitments were made in 2021 to reach net-zero emissions by 2050 and inscribe low emissions technology stretch goals.

In May 2022, the elected Labor Government made a goal of reducing Australia's GHG emissions by 43% below 2005 levels by 2030 and reaffirmed Australia's commitment to net zero emissions by 2050. This was lodged with the United Nations Framework Convention on Climate Change (UNFCCC) as an updated NDC as part of Australia's obligations under the Paris Agreement. NDCs under the Paris Agreement are legally binding, and Australia mainly focuses on Article 10 with a low-emissions technology led approach. Australia's NDCs are implemented through schemes such as the Safeguard Mechanism and the Emissions Reduction Fund, in addition to continuous monitoring and focusing on alternatives to lower overall emissions.

International Convention for the Prevention of Pollution from Ships (MARPOL)

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

The MARPOL Convention was adopted on 2 November 1973 at the International Marine Organisation. The Protocol of 1978 was adopted in response to tanker accidents in 1976-1977. As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument entered into force on 2 October 1983. In 1997, a Protocol was adopted to amend the Convention and a new Annex VI was added which entered into force on 19 May 2005. MARPOL has been updated by amendments through the years.

The MARPOL Convention includes regulations aimed at preventing and minimizing both accidental pollution from ships and that from routine operations and currently includes six technical Annexes. Special areas with strict controls on operational discharges are included in most Annexes. Annex VI, the Prevention of Air Pollution from Ships, entered into force on the 19th of May 2005. The Energy Efficiency Design Index (EEDI) was made mandatory for new ships and the SEEMP for all ships with the adoption of amendments to MARPOL Annex VI (resolution MEPC.203(62)), by Parties to MARPOL Annex VI.

10.2.5.2 National GHG Framework

Australia has a well-established legislative framework under which the Barossa Development is regulated. This includes:

+ GHG reporting under the National Greenhouse and Energy Reporting Act 2007 (NGER Act) (Cth);
+ The purchasing of the Australian carbon credit units through the Emissions Reduction Fund; and
+ Safeguard Mechanism to maintain emissions (or purchasing offsets) to keep net emissions below an established baseline.

NGER Act

The NGER Act is a single national framework for reporting and disseminating company information about GHG emissions, energy production, energy consumption, and other information otherwise specified under the legislation (Department of Industry, Science and Resources, 2020). The objectives of the NGER Act are to:

+ Inform government policy;
+ Inform the Australian public;
+ Help meet Australia's international reporting obligations;
+ Assist Commonwealth, State, and Territory government programmes and activities; and
+ Avoid duplication of similar reporting requirements in the states and territories.

Scope 1 and 2 emissions are reported under the NGER Act. However, Scope 3 emissions are not required to be reported.

The Clean Energy Regulator administers the NGER Act, its legislative instruments, and related policies and processes. The Clean Energy Regulator administers the scheme by:

+ Registering and deregistering corporations for reporting;
+ Receiving reports;
+ Monitoring and enforcing compliance;
+ Applying the audit framework; and
+ Publishing reported data.

Emissions Reduction Fund

The purpose of the *Carbon Farming Initiative Amendment Act 2014* (Cth) was to amend the *Carbon Credits (Carbon Farming Initiative) Act 2011* (Cth) to include and establish the Emissions Reduction Fund. The Emissions Reduction Fund is a voluntary scheme that aims to provide incentives for a range of organisations and individuals to adopt new practices and technologies to reduce their emissions. Through the Emissions Reduction Fund, the Australian Government will purchase the lowest cost abatement (in the form of ACCUs) through several sources whilst providing incentives to businesses, households, and landowners to reduce their overall emissions (Clean Energy Regulator, 2022). Several activities are eligible under the scheme and participants can earn ACCUs for emissions reductions, including CCS.

Safeguard Mechanism

The Safeguard Mechanism was established as part of the Emissions Reduction Fund. The Emissions Reduction Fund provides an incentive for activities that count towards meeting Australia's international climate commitments. The safeguard mechanism applies to facilities with Scope 1 emissions of more than 100,000 tonnes of CO_2-e per year.

The Safeguard Mechanism requires Australia's largest GHG emitters to keep their net emissions (actual emissions minus any surrendered carbon credits) below an emissions baseline.

The Australian Parliament has legislated to:

+ Gradually reduce baselines to help Australia reach net zero emissions by 2050;
+ Introduce credits for facilities that emit less than their baseline; and

- Provide tailored treatment to emissions-intensive, trade-exposed facilities so businesses are not disadvantaged compared to international competitors and emissions do not increase overseas (Clean Energy Regulator, 2023).

Together with the reporting obligations under the NGER Act, the Safeguard Mechanism provides a framework for Safeguarded facilities to measure, report and manage their emissions. It does this by requiring facilities, whose net emissions exceed the safeguard threshold, to keep their emissions at or below emissions baselines set by the Clean Energy Regulator.

Navigation Act 2012

The Navigation Act 2012 (Cth) is legislation that governs international ship and seafarer safety and protects the marine environment where it relates to shipping and the actions of seafarers in Australian waters and implements MARPOL. The *Navigation Act 2012* (Cth) requires energy efficiency pollution certificates.

Protection of the Sea (Prevention of Pollution from Ships) Act 1983

The Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Cth) also implements MARPOL. The Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Cth) includes the requirement for a SEEMP to improve the energy efficiency of a ship.

Climate Change Act 2022

The *Climate Change Act 2022* (Cth) enshrines into law Australia's emissions reduction target of 43% from 2005 levels by 2030 and net zero emissions by 2050. In addition, this Act ensures accountability through an annual update to Parliament by the Climate Change Minister on the progress made towards the target and empowers the Climate Change Authority to provide advice to government on future target.

10.2.5.3 Relevant NT Legislation

EP Act

The NT has legislation currently in place under which the Barossa Development is regulated due to DPD Project activities occurring within Northern Territory jurisdiction. The key legislative instrument is the EP Act. The objective of the EP Act are:

- To protect the environment of the Territory;
- To promote ecologically sustainable development so that the wellbeing of the people of the Territory is maintained or improved without adverse impact on the environment of the Territory;
- To recognise the role of environmental impact assessment and environmental approval in promoting the protection and management of the environment of the Territory;
- To provide for broad community involvement during the process of environmental impact assessment and environmental approval; and
- To recognise the role that Aboriginal people have as stewards of their country as conferred under their traditions and recognised in law, and the importance of participation by Aboriginal people and communities in environmental decision-making processes.

Policy documents prepared by the NT EPA have also informed the assessment of the DPD Project through the SER process, specifically:

- The NT EPA Environmental Factors and Objectives: Environmental impact assessment general technical guidance;
- Environmental Impact Assessment Guidance for Proponents: Preparing a Supplementary Environmental Report; and
- Draft Environmental Factor Guideline: Atmospheric Processes.

Greenhouse Gas Emissions Management for New and Expanding Large Emitters' Policy

The primary guideline that establishes the minimum requirements for the management of GHG emissions from new or expanding industrial projects is the Greenhouse Gas Emissions Management for New and Expanding Large Emitters' Policy (the 'Large Emitters Policy'). The 'Large Emitters Policy' applies to industrial projects with an estimated Scope 1 emissions of greater than 100 000 t CO_2-e in any financial year over the lifecycle of a project. NB: as the GHG emissions from the DPD Project are not expected to exceed 100 000 t CO_2-e in any financial year over the life cycle of a project, the Large Emitters Policy does not apply to the DPD Project.

Northern Territory Climate Change Response: Towards 2050

The NT's climate change policy, 'Northern Territory Climate Change Response: Towards 2050', aligns with the Territory's plan for reaching net zero by 2050. The Territory's climate policy is supported by a 'Climate Response Policy Framework'. This Policy applies to all new projects and expanding existing projects likely to be large emitters that occur after commencement of this policy, and which are required to obtain an environmental authorisation under Territory legislation to proceed and will be reviewed in 2025. The Framework is focussed on the following objectives:

- Net Zero Emissions By 2050;
- A Resilient Territory;
- Opportunities from a low carbon future; and
- Inform and involve all Territorians.

Greenhouse Gas Emissions Offset Policy (Draft)

The Offset Principles make clear that there is an expectation the mitigation hierarchy must be rigorously applied; and that offsets will not always be available or appropriate. The determination about whether residual emissions are significant and the amount of residual emissions that need to be offset will be based on the following:

- The estimated emissions produced by the project, either annually or for a single event;
- The projected emissions profile over the life of the project; and
- The target for emissions offsets.

The overall impact on the NT's emissions profile and trajectory towards the target of net zero emissions by 2050, based on:

- The emissions produced by the project;
- The cumulative emissions produced across a proponent's enterprises in the Territory;

- The emissions associated with the relevant industry;
- The capacity of the project, proponent and industry to avoid, mitigate or offset emissions;
- The advice of any assessing agencies for the project (for example, the NT EPA for projects assessed under the EP Act); and
- National and international emissions reduction targets, strategies and obligations.

10.2.5.4 Licences, approvals or permits required

Santos and the previous titleholder of the Barossa Gas Field has obtained a range of environmental approvals in support of the Barossa Development.

Offshore Petroleum and Greenhouse Gas Storage Act 2006 (Cth)

The primary environmental approval was provided in the Barossa Area Development OPP was accepted by NOPSEMA on 13 March 2018. An OPP is the document submitted by a proponent to NOPSEMA when seeking acceptance for an offshore project, under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (the OPGGS Act) and the EPBC Act. A decision to accept an OPP means that NOPSEMA is reasonably satisfied that the OPP meets the acceptance criteria set out the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 and the EPBC Act. An OPP acceptance decision indicates that the proponent has demonstrated, with a sufficient evidence base, that the offshore project can meet an acceptable level of environmental performance and that comments during the public comment period have been adequately addressed. Following the acceptance of an OPP, subsequent environment plans will need to be submitted and accepted before any activities covered under the OPP can be undertaken.

The DPD Project will interface with the activities described in the Barossa Area Development Offshore Project Proposal. The DPD Project will also interface with the activities described in the Barossa Gas Export Pipeline Installation Environment Plan which was accepted by NOPSEMA on 9 March 2020 and which authorises construction of a new 262 km gas export pipeline (GEP) in Commonwealth waters.

The DPD Project activities in Commonwealth waters were not included in the Barossa OPP, and therefore are not authorised pursuant to the Commonwealth Minister's 'class approval' decision dated 27 February 2014. All petroleum activities undertaken in Commonwealth waters for the Barossa Development, (and included within the Barossa OPP), and the DPD Project, (included in this referral), will also require Environment Plans (EPs) to be assessed and accepted by NOPSEMA. Current EPs associated with the Barossa Development are:

- Barossa Gas Export Pipeline Installation EP (BAA-100 0329) – NOPSEMA accepted 9 March 2020;
- Barossa Subsea Infrastructure and FPSO Moorings Installation and Pre-commissioning EP (BAA-200 0636) – submission to NOPSEMA scheduled Q4 2022; and
- Barossa Production Operations EP (BAA-200 0637) – submission to NOPSEMA scheduled Q1 2023.

For completeness, it is noted that NOPSEMA's decision to accept the Barossa Development Drilling and Completions EP (BAD-200 0003) on 14 March 2022 was set aside by the Federal Court on 21 September 2022. The EP is currently being revised for resubmission to NOPSEMA.

An EP for the DPD Project pipeline installation activity in Commonwealth waters will be submitted to NOPSEMA for assessment following a decision on the DPD Project EPBC Act referral and Preliminary Documentation (refer below).

Environment Protection and Biodiversity Conservation Act 1999 (Cth)

The EPBC Act is the Australian Government's key piece of environmental legislation which commenced on 16 July 2000. The EPBC Act enables the Australian Government to provide a national scheme of environment and heritage protection and biodiversity conservation, alongside the States and Territories. The EPBC Act focuses Australian Government interests on the protection of matters of national environmental significance, with the states and territories having responsibility for matters of state and local significance.

On 8 November 2022, Santos referred the DPD Project (the proposed action) to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) for assessment under the EPBC Act. On 6 December the proposed action was determined to be a controlled action under Section 75 of the EPBC Act, requiring further assessment by preliminary documentation under Section 87 of the EPBC Act. Santos is currently progressing preliminary documentation for submission.

Waste Management and Pollution Control Act 1998 (NT)

The DLNG Plant currently operates under an Environmental Protection Licence (EPL217-03) which was issued under Section 34 of the *Waste Management and Pollution Control Act 1998* on 19 September 2022, expiring on 18 September 2025. This licence, among other conditions, requires the licensee to implement an auditable Operational Environmental Management Plan, which includes environmental management strategies for managing greenhouse gas emissions.

10.3 Legislation, policy and guidance

The legislative requirements, policy and guidance relevant to the DPD project are outlined in **Section 10.2.5**.

10.4 Environmental values

Climate change impacts cannot be directly attributed to any one activity, as they are the result of global GHG emissions, minus global carbon sinks, that have accumulated since the onset of the industrial revolution. However, both species and ecosystems are increasingly vulnerable to impacts arising from increasing atmospheric CO_2 concentrations. In Australia, the vulnerability of species and ecosystems to the impacts of climate change is due to climate change exacerbating the impact of existing pressures on species and ecosystems (Commonwealth of Australia, 2021). A report by Australia's Biodiversity and Climate Change Advisory Group (Steffen et al., 2009) and the 2021 State of the Environment Report (Commonwealth of Australia, 2021) provide a summary of the current state of species and ecosystems across Australia, including in the NT.

10.4.1 Existing vulnerabilities to species within the NT

10.4.1.1 Terrestrial mammals

Terrestrial mammals across Australia have experienced high rates of extinction, with 10% of endemic species becoming extinct over the past 200 years (Commonwealth of Australia, 2021). Mammals are subject to ongoing population declines and increasing numbers of species are becoming threatened (Commonwealth of Australia, 2021). Approximately 21% of terrestrial mammal species are now assessed as threatened (Woinarski et al., 2015, 2019). Most mammal extinctions in Australia to date have resulted from predation by introduced species, particularly the European red fox and the feral cat. Extinction rates are particularly high in arid and semi-arid regions of Australia. Northern Australia is overrepresented when examining the location of mammal species most at risk from extinction over the next 20 years (Geyle et al., 2018).

10.4.1.2 Birds

Numerous Australian bird species are experiencing population declines and are currently at risk of extinction, with significant declines in the abundance of threatened birds for which monitoring data is available (Commonwealth of Australia, 2021). It has also been documented that the relative abundance of threatened birds decreased by an average of 60% between 1985 and 2018 (Commonwealth of Australia, 2021).

10.4.1.3 Reptiles

Many of Australia's reptile species are currently declining, with the past decade defined by the first Australian reptile extinctions in the wild (Commonwealth of Australia, 2021). The numbers of Critically Endangered reptile species are increasing nationally. By 2040, up to 11 species of snake and lizards currently threatened by invasive plants and animals and with restricted ranges could become extinct (Geyle et al., 2020). About half of the 25 species of Australian freshwater turtles are experiencing significant population decline and are listed as Vulnerable, Endangered or Critically Endangered (Commonwealth of Australia, 2021). All six Australian species of marine turtle are also listed under the EPBC Act, half of which are Endangered. Sea snake populations have experienced recent dramatic reductions in the spatial distributions of some species and populations of these species are considered to be poor and declining (Commonwealth of Australia, 2021).

10.4.1.4 Frogs

A recent assessment of Australian frog species against the International Union for Conservation of Nature (IUCN) Red List criteria found 18.5% as either extinct or threatened (Commonwealth of Australia, 2021). Most threatened species of amphibians are restricted to a comparatively small geographic range within Australia, which includes the wet tropics (Commonwealth of Australia, 2021). Disease is a persistent pressure on amphibians, with both drought and fire comprising increasing sources of pressure on these species.

10.4.1.5 Fish

Currently, 62 Australian fish species are listed under the EPBC Act, including 38 freshwater fish species (Commonwealth of Australia, 2021). A recent analysis also shows that 20 freshwater fish species have more than a 50% risk of extinction in the next 20 years, but only 3 are currently listed (Commonwealth of Australia, 2021). Since 2016, several major fish deaths occurred in Australian waterways. Major bushfires also impact water quality and aquatic species (Commonwealth of Australia, 2021).

10.4.1.6 Invertebrates

Australia is estimated to have up to 320,465 invertebrate species, of which approximately 35% have been described. A total of 285 invertebrate species are listed as threatened under various state and territory conservation Acts, the EPBC Act and the IUCN Red List (Taylor et al., 2018). This is considered an underestimate of the number of endangered invertebrate species because the vast number are undescribed and limited knowledge of their distributions is available (Commonwealth of Australia, 2021). Major threats to invertebrate biodiversity come from habitat loss through native vegetation clearing, habitat fragmentation, weed invasion, loss of natural corridors and inappropriate fire regimes (Braby, 2019). Other threats to invertebrate populations include the disturbance of plant communities on hilltops, creek embankments and in water courses along with exposure to pesticides, trampling and grazing by stock and feral animals and predation by non-native predators (Sands, 2018). Changes in temperature and rainfall potentially affect invertebrate distribution, development and reproduction (Sands, 2018).

10.4.1.7 Plants

Australian plant species are increasingly vulnerable to the impacts of human disturbance, with more plant than animal species are listed as threatened under national, state and territory legislation (Commonwealth of Australia, 2021). The major pressure causing population declines in threatened plant species is habitat destruction, with declining species concentrated in highly modified agricultural and urban landscapes (Commonwealth of Australia, 2021). Inappropriate fire regimes and changes in fire regimes are also a significant pressure for many plant species (Commonwealth of Australia, 2021).

10.4.2 Existing vulnerabilities to NT ecosystems

10.4.2.1 Climate and weather

The NT's climate is shaped by a number of weather systems and large-scale drivers that operate over a range of time scales (Northern Territory Government, 2020). Monsoons are responsible for much of the wet season rainfall in the north of the NT.

The El Niño Southern Oscillation (ENSO) influences rainfall, temperatures and tropical cyclones and during the El Niño phase there is reduced cloud cover leading to cooler minimum temperatures, reduced rainfall in the monsoon build-up and fewer tropical cyclones. El Niño years tend to have a later monsoon onset and lower rainfall totals overall. Dry season temperatures in the following year are generally higher (Northern Territory Government, 2020). During the La Niña phase, higher sea surface temperatures lead to higher minimum temperatures in near coastal areas and increased rainfall in the build-up months. Dry season temperatures the following year are generally lower.

A changing climate will cause these large-scale processes to change, although the outcomes of these changes are currently unclear. However, El Nino events are predicted to become both more frequent and severe in the future (Northern Territory Government, 2020). Extreme La Nina events are also likely to become more frequent (Northern Territory Government, 2020). These changes will affect rainfall, drought and extreme climate events in the NT.

10.4.2.2 Tropical cyclones

The NT is situated within Australia's Northern tropical cyclone region (Northern Territory Government, 2020). Tropical cyclones can occur in the Northern Territory between November and April, with an average of three tropical cyclones each season in this region (Northern Territory Government, 2020).

10.4.2.3 Rainfall

The Territory's Top End receives 600–1800 mm of rain in the wet season, but only 100–400 mm in the dry season (Northern Territory Government, 2020). Rain falls all year around in the central and southern parts of the NT, but winter is the driest season with an average 50–100 mm rainfall in the central part of the NT and 100–200 mm in the south. In summer, average rainfall in the central region is 400–900 mm and 200–400 mm in the south. Rainfall can vary a great deal from year to year due to the normal variability of the climate system (Northern Territory Government, 2020)

10.4.2.4 Average temperature

In the north of the NT, average daily temperatures range between 15 to 33°C in the dry season (May to October) and 21 to 36°C in the wet season (November to April). In the central and southern region of the NT average daily summer temperatures range from 18 to 39°C, while winter is 3 to 27°C. Since the middle of last century there has been a clear warming trend in the NT, with many hotter than-average than cooler-than-average years (Northern Territory Government, 2020). Extreme temperature events are becoming more common in the NT.

10.4.2.5 Drought

The NT has experienced a number of periods of extended, unusually dry conditions from the Federation Drought at the turn of the 20th century through to the recent 2017–2020 drought (Northern Territory Government, 2020). Drought conditions are capable of occurring all over the NT; however, the south is typically more prone to drought than the north (Northern Territory Government, 2020). The Impacts of drought are likely to be more severe in the future due to increasing temperatures.

10.4.2.6 Fire weather

The occurrence of bushfires relies on an ignition source, fuel availability, fuel dryness and suitable fire weather (hot, dry, windy). Within the NT, fuel availability is a major limiting factor and is dependant largely on rainfall (Northern Territory Government, 2020). In the central and southern regions of the NT, conditions are most conducive to bushfires in spring (September–November). In the north, the most dangerous fire weather conditions occur in the dry season due to the drier conditions and increased fuel availability following the wet season. Over the past 30 years, the number of days with severe fire weather has increased during the dry season (winter and spring) (Northern Territory Government, 2020).

10.4.2.7 Oceanic processes

While oceanic marine areas are generally in good condition, nearshore reefs are in poor condition and many coastal habitats and communities are highly impacted due to multiple pressures which combine to overwhelm ecosystem health and function (Commonwealth of Australia, 2021). Climate change continues to warm and acidify the ocean and the occurrence of a number of major marine heatwaves during the past five years has resulted in an overall deteriorating trend (Commonwealth of Australia, 2021).

Global warming is causing sea levels to rise through both thermal expansion where the volume of water increases at it warms and the remainder is from melting ice sheets and glaciers (Northern Territory Government, 2020). To date, about a third of sea-level rise has come from thermal expansion (Northern

Santos

Territory Government, 2020). Sea surface temperature have also risen significantly across the globe over recent decades, with sea surface temperature around the NT having warmed by at least 0.5°C since 1950 (Northern Territory Government, 2020).

Globally, marine heatwaves are becoming more frequent and longer in duration (Northern Territory Government, 2020). Between 1925–1954 and 1987–2016 the number of marine heatwave days averaged across all the oceans increased by 50%. These events are also becoming more intense (Northern Territory Government, 2020). The 2015/16 northern Australian marine heatwave persisted for 224 days – the longest in the region on the satellite record – with the temperature rising to 1.6°C above average (Northern Territory Government, 2020).

Around one-third of the carbon dioxide which has been emitted into the atmosphere by humans since the industrial revolution has been absorbed by the oceans (Northern Territory Government, 2020). This in turn has led to a 0.1 pH fall in the ocean's surface water pH (a 26% rise in acidity) (Northern Territory Government, 2020).

10.4.2.8 Coral reefs

Coral reefs, due to their role as spawning and nursery grounds for many fish species are valuable Marine Ecosystems, while also acting as buffer zones against high tides, rising sea levels and storms for coastal areas and communities (Commonwealth of Australia, 2021). Coral reef ecosystems are generally in poor condition and deteriorating (Commonwealth of Australia, 2021). Marine heatwaves in 2016, 2017 and 2020 which were unprecedented in nature resulted in the first ever consecutive years of coral bleaching and widespread coral losses (Commonwealth of Australia, 2021). Most offshore (oceanic) reef systems are in good condition, with fewer signs of human impacts than inshore reef systems but may become threatened by warmer waters (Edgar et al., 2014).

10.4.2.9 Terrestrial vegetation communities

The clearing and degradation of onshore native vegetation has been undertaken to facilitate other land uses with native vegetation replaced by urban, productive and extractive land uses (Commonwealth of Australia, 2021). Almost half of Australia's major vegetation types have lost at least 20% of their original extent (Commonwealth of Australia, 2021). Woodlands in particular have been extensively cleared and extensive areas of sparse woody and nonwoody vegetation have been cleared and converted to other uses, principally pastures, although the full extent of this conversion is not well documented (Commonwealth of Australia, 2021). The most intensively used areas of Australia have the most fragmented native vegetation, including major agricultural areas, and the urban and peri urban areas of Australia's major cities and towns. Significant areas of native vegetation have also been extensively impacted by the grazing activities of sheep and cattle, as well as the destructive activities of introduced species such as pigs, goats, camels, buffalo, horses and donkeys (Commonwealth of Australia, 2021).

Arid and semi-arid areas are vulnerable to pressures of land use change which have materially impacted woody vegetation gains and losses (Commonwealth of Australia, 2021). In terms of vegetative loss in areas in other than forest, the NT lost 28% of its sparse woody vegetation between 2014 and 2019 (Commonwealth of Australia, 2021). These changes in sparse woody vegetation abundance related to a variety of causes, including the 'natural' reduction from changes in rainfall patterns, as well as land use such as grazing of native vegetation, and fire. Within the NT, 55% of all lost sparse woody vegetation was found to coincide with fire events (Commonwealth of Australia, 2021). Other pressures on these areas include the spread of invasive species and the high extinction of native mammal species in arid and semi-arid areas from predation by introduced species (Commonwealth of Australia, 2021).

10.4.2.10 Coastal ecosystems

Coastal ecosystems are also under increasing pressure due to increasing pressure from human habitation (Commonwealth of Australia, 2021). Coastal dune vegetation is increasingly under threat due to bushfires, land clearing and reduced rainfall and coastal vegetation in northern Australia is documented as ranging in condition from poor to good condition (Commonwealth of Australia, 2021). The transformation of native systems to monocultures of introduced species has occurred and has become extensive in some areas, along with the loss of significant zones of vegetation across tropical Australia due to the unseasonably dry 'wet season' in 2019–20 that left coastal dunes exposed to erosion from high winds and cyclonic activity (Babcock et al., 2019; Duke et al., 2020).

10.4.2.11 Freshwater ecosystems

Freshwater ecosystems in northern Australia are generally considered to be in good condition (Commonwealth of Australia, 2021). These ecosystems are expected to be at least able to maintain their minimum expected function. However, the reduced functioning of these ecosystems, or even persistent transformation, has been noted in some localised areas (Commonwealth of Australia, 2021). Wetlands provide important environmental, social, cultural and economic services and are often significantly affected by changes in agricultural and urban landscapes (Commonwealth of Australia, 2021). Noted pressures on wetland communities include extensive clearing, the introduction of non-native species, alteration to flows and concentrated grazing pressure. Drought conditions, in conjunction with increased consumptive water use, have resulted in a decrease in flows into wetlands and resulted in a reduction in the inundation of these communities (Commonwealth of Australia, 2021). In addition, grazing, pests and weeds are also having a significant impact on wetland health (Commonwealth of Australia, 2021). Wetlands and billabongs in some areas of central and northern Australia are particularly threatened by invasive feral hoofed animals (Commonwealth of Australia, 2021). Indigenous knowledge has noted the loss of wetland plant species since the introduction of hard-hoofed ungulates and their subsequent proliferation and spread with some billabongs suspected to have passed an ecocultural threshold and shifting towards turbid, sediment dominated system driven by feral animals (Ens et al., 2016; Russell et al., 2021).

10.5 Potential significant impacts

In the past decade, climate change has emerged as a new driver for habitat change and species loss as a result of more severe drought events, extreme weather events, fires and habitat modification (Commonwealth of Australia, 2021). Species adaptation does not occur quickly and many species cannot keep up with the pace of ecosystem change (IPCC, 2021). Changes in climate recorded across the Australian landmass are associated with a range of biodiversity responses, including decreases in some species and increases in others (Commonwealth of Australia, 2021). Some species may cope with the impacts of climate change by moving or extending their range to find more favourable conditions (Commonwealth of Australia, 2021). Range shifts and extensions on land can be very complicated and different species have markedly different abilities to shift their location and range to cope (Commonwealth of Australia, 2021). Due to the clearing of native vegetation many terrestrial species are unable to shift their distribution because of the loss of connecting habitats (Commonwealth of

Australia, 2021). Climate change has also been identified as impacting the natural cycles within ecosystems.

In 2020 the Commonwealth Scientific and Industrial Research Organisation (CSIRO) released their biennial “State of the Climate” report in conjunction with the Bureau of Meteorology (BOM). This report draws on the latest climate research and allows CSIRO to draw detailed conclusions on the long-term changes that will impact Australia and Australia’s climate. The CSIRO concluded that climate change has already physically impacted Australia and will continue to do so in the coming years. In northern Australia, rainfall and streamflow was found to have increased. There have been elevated increases in severe fire weather and the ocean acidification around Australia is continuing to worsen (CSIRO, 2020). The physical impacts of climate change are already being seen in Australia and the estimated impacts that will be felt in Northern Australia are:

+ Decreased rainfall on the land surface, with droughts occurring more frequently with prolonged and frequent dry/hot days;
+ Increased surface and ocean temperatures, Increased risk of marine heatwaves, increasing ocean acidification and coral bleaching;
+ Sea level rise contributing to coastal and beach habitat erosion; and
+ Increased risk of tropical cyclones varying in intensity occurring in the north of Australia, with at risk cities including Darwin (CSIRO 2020).

10.5.1 Potential impacts to species within the NT from climate change

A report by Australia’s Biodiversity and Climate Change Advisory Group (Steffen et al., 2009) gives a summary of potential impacts to marine and terrestrial species, habitats and ecosystems across Australia from climate change. This report found mammals are susceptible to rapid climate change, including potential changes in competition between grazing macropods in tropical savannas due to changing fire regimes and water availability, along with the decreasing nutrition quality of foliage due to CO_2 fertilisation (Steffen et al., 2009).

10.5.1.1 Birds

Australia’s bird species are vulnerable to climate change induced impacts, which include changes in the phenology of migration and egg laying, increased competition, reductions in waterbird breeding and changes in food availability (Steffen et al., 2009). In addition, rising sea levels will potentially impact birds which nest within coastal and near-shore environments and saltwater intrusion into freshwater wetlands would further degrade water bird breeding habitats.

10.5.1.2 Reptiles

Warming temperatures may potentially alter the sex ratios of reptile species with environmental sex determination, such as marine turtle species (Steffen et al., 2009). Whereas amphibians may experience altered interactions between pathogens, predators and fires (Steffen et al., 2009). Frogs may be the most at risk terrestrial taxa from the impacts of climate change.

10.5.1.3 Fish

Freshwater fish species will be potentially vulnerable to reductions in water flows and water quality and there is anticipated to be limited capacity for freshwater species to migrate to new waterways

(Steffen et al., 2009). All fish species are susceptible to the flow-on effects of global warming on the phytoplankton base of food webs.

10.5.1.4 Invertebrates

Invertebrates are expected to be more responsive than vertebrates due to their short generation times, high reproductive rate and sensitivity to climatic variables (Steffen et al., 2009).

10.5.1.5 Plants

Climate change may impact the functional dynamics of plant species due to increasing atmospheric CO_2 concentrations, increased fire frequency and changes in plant phenology and characteristics in response to changing climatic conditions (Steffen et al., 2009).

10.5.2 Potential impacts to ecosystems within the NT from climate change

Alongside the impacts to individual taxa, both marine and terrestrial ecosystems found in the NT are also expected to be adversely impacted through the effects of climate change (Steffen et al., 2009).

10.5.2.1 Temperature

Since the middle of 20th century there has been a clear warming trend in the NT (Northern Territory Government, 2020). In the 'Top End' of the NT, the near future (2030) will see warming of around 0.5 to 1.4°C compared to the average for the period 1986–2005. By mid-century (2050), warming will range from 0.7 to 1.6°C to 1.4 to 2.4°C, depending on global GHG concentrations (Northern Territory Government, 2020). At the end of the century (2090) warming will range from 0.6 to 1.8°C to 2.8 to 5.1°C under differing emissions scenarios (Northern Territory Government, 2020). Near future warming in the Northern Territories central and southern regions is similar to the Top End at around 0.6 to 1.5°C. Mid-century warming ranges from 0.7 to 1.6°C to 1.4 to 2.4°C (Northern Territory Government, 2020). By the end of the century, the central and southern part of the NT may experience warming of 3.1 to 5.6°C (Northern Territory Government, 2020).

By the middle of the century, the number of days a year over 35°C will at least double in many places across the NT (Northern Territory Government, 2020). The number of days over 40°C will also increase considerably (Northern Territory Government, 2020). Frost risk days will decrease over time and the number of frost risk days in Alice Springs could be halved by the middle of the century, depending on atmospheric GHG concentrations (Northern Territory Government, 2020).

10.5.2.2 Rainfall

Over the past century, annual total rainfall in the NT has increased, except for a small region in south-east Arnhem Land and more recently drying in this region and further north on the coast has increased (Northern Territory Government, 2020). Seasonal rainfall characteristics have also changed with wet season rainfall increasing over the 'Top End', with Darwin recording a seasonal average of 1732 mm per annum for the period 1989–2018 compared to 1586 mm for the period 1959–1988 (Northern Territory Government, 2020). Tennant Creek has recorded an average of 459 mm and 343 mm per annum for the same periods, respectively (Northern Territory Government, 2020). The annual average amount of rainfall at Alice Springs remained relatively unchanged over these periods, although the seasonal distribution has changed, with more summer rainfall and less in March and the winter months (Northern Territory Government, 2020).

In the near future, natural variability will cause greater year-to-year changes in rainfall than the effects of climate change (Northern Territory Government, 2020). In the 'Top End', near-future projections for the dry season range from 35% drier to 29% wetter than the 1986–2005 average and projected wet season changes for the same period range from 8% wetter to 7% drier, depending on atmospheric GHG concentrations. In the central and southern NT, annual rainfall change projections range from 12% drier to 8% wetter. Towards the end of the century, the projected dry season change in the Top End ranges from 45% drier to 44% wetter, depending on atmospheric GHG concentrations (Northern Territory Government, 2020). For the wet season, the range is 23% drier to 19% wetter. In the central and southern parts of the NT, projected annual rainfall change ranges from 31% drier to 19% wetter, depending on atmospheric GHG concentrations (Northern Territory Government, 2020).

10.5.2.3 Drought

While it is anticipated that increasing temperatures will lead to more severe drought conditions, the changes in NT drought conditions are unclear in climate models, given the relationship to rainfall (Northern Territory Government, 2020). There is currently low confidence in projecting how the frequency and duration of extreme meteorological drought may change, although under a high emissions pathway the time spent in drought will increase by 2090 in the central and southern regions of the NT (Northern Territory Government, 2020).

10.5.2.4 Tropical cyclones

Tropical cyclones in the NT are projected to become less frequent but more intense due to the increased energy in the climate system from warming (Northern Territory Government, 2020). There is some potential that tropical cyclones may also reach slightly further inland under a warmer climate due to the impact of warmer oceans and changing large-scale wind patterns (Northern Territory Government, 2020). However, there is currently relatively low confidence in the regional aspects of these projections due to challenges associated with modelling tropical cyclones, including their frequency, intensity, formation and tracks (Northern Territory Government, 2020).

The rainfall produced by tropical cyclones is also expected to increase, particularly the intensity of extreme rainfall events which could increase by about 10% or more per degree of global warming (noting that about one degree of warming has already occurred) (Northern Territory Government, 2020). This is due to a warmer atmosphere holding more moisture, as well as increasing the energy available for cyclones ((Northern Territory Government, 2020)). When this increased rainfall intensity is combined with higher sea levels, it is anticipated flooding will increase in frequency and magnitude in the future for many coastal and estuarine regions (Northern Territory Government, 2020).

10.5.2.5 Fire weather

In the Top End of the NT, where abundant rainfall and bushfires are common, there is projected to be little change to the frequency of bushfires (Northern Territory Government, 2020). Whereas within the southern and central parts of the NT, changes in fire frequency depend on rainfall changes (Northern Territory Government, 2020). With the combination of higher temperatures and lower rainfall, climate change is anticipated to result in a harsher fire-weather climate in the future where the occurrence of bushfires is accompanied by more extreme fire behaviour (Northern Territory Government, 2020).

10.5.2.6 Oceanic processes

The sea level around the NT has risen at a higher rate than much of Australia due to the combination of natural climate variability and climate change (Northern Territory Government, 2020). In the near future, the projected increase is 0.06 to 0.17 m above the 1986–2005 sea level. At the end of the century, sea level rise is anticipated to be between 0.28 to 0.85 m, depending on atmospheric GHG concentrations (Northern Territory Government, 2020). It is anticipated that rising sea levels will exacerbate the impacts of storm surges and other extreme sea-level events (Northern Territory Government, 2020). The number of marine heatwave days per year and the intensity of marine heatwaves is projected to increase across the 21st century, with the degree dependent on atmospheric GHG concentrations. Under a high emissions pathway, the intensity of marine heatwaves could be double that of under a medium emissions pathway (Northern Territory Government, 2020).

The pH of oceans is projected to fall by an additional 0.07 units in the NT's coastal waters In the near future (Northern Territory Government, 2020). At the end of the century, decreases of between 0.14 units and 0.3 units are projected, representing a 40% and 100% increase in acidity respectively (Northern Territory Government, 2020).

10.5.2.7 Coral reefs

Coral Reefs may be undermined by increasing ocean acidity and the increasing of frequency bleaching events (Steffen et al., 2009). Climate change may also suppress ocean upwelling in some locations while increasing it in other locations, shifting the location and extent of ocean productivity zones (Steffen et al., 2009). Increasing ocean acidity is also causing an accompanying decrease in the availability of carbonate ions which are an important building block of seashells and coral skeletons, while impacts on phytoplankton will affect secondary production in benthic communities (Steffen et al., 2009).

10.5.2.8 Terrestrial vegetation communities

Mangrove ecosystems in Australia will face higher temperatures, increased evaporation rates and warmer oceans (McInnes, 2015) as well as an associated sea-level rise (Hoegh-Guldberg et al., 2018). Modelling indicates an increased likelihood of future severe and extended droughts across parts of Northern Australia (Dai, 2013). Consequently, mangrove ecosystems may increase their southern range because of warmer temperatures. However, higher temperatures and evaporation rates and extended droughts could lead to die-offs in northern Australia and a change in mangrove distribution and abundance (Duke et al., 2017). Mangrove systems should cope with rising sea-level by accumulating more peat or mud which will give them the opportunity to adjust to a rising sea level (Field, 1995).

Within tropical rain forests, savannas and grasslands, there are expected to be competitive shifts between plant species due to differential responses to elevated atmospheric CO_2 concentrations and altered fire regimes creating more intense fire events (Steffen et al., 2009). Climate change may also result in altered patterns of flowering, fruiting and leaf flush which will affect the food resources available for animals within tropical rain forests (Steffen et al., 2009). Within these areas potential increases in productivity could occur where rainfall is not limiting, however reduced forest cover will likely lead to soil drying (Steffen et al., 2009).

Reduced river flows and changes in the seasonality of flows may affect eutrophication levels, leading to the incidence of blue-green algal outbreaks (Steffen et al., 2009). Saltwater intrusion could also occur into low lying floodplains, freshwater swamps and groundwater reservoirs, leading to the degradation of freshwater sources and the replacement of riparian vegetation by mangroves.

In arid and semi-arid regions primary production is likely to be impacted by changing rainfall patterns while, enhanced runoff redistribution will be expected to intensify vegetation patterning and erosion in degraded areas (Steffen et al., 2009). Changes in rainfall variability and amount are also expected to impact fire frequency and the incidence of dryland salinity (Steffen et al., 2009). Changes in fire regimes could also cause the vegetation structure to shift towards the landscape-wide dominance of fire tolerant species.

10.6 Environmental management and mitigation

10.6.1 DPD Project emissions management and mitigation

Refer to **Section 12** for the measures which were implemented to reduce and mitigate atmospheric emissions from the DPD project.

10.6.2 DLNG GHG emissions management and mitigation measures

The operation of DLNG complies with the requirements of the Australian Government's Safeguard Mechanism. This includes surrendering carbon credit units for any of DLNG's Scope 1 emissions above the approved baseline.

The DLNG facility currently operates under an Environmental Protection Licence (EPL217-03) which was issued under Section 34 of the *Waste Management and Pollution Control Act 1998* on 19 September 2017, expiring on 18 September 2025 and its associated environmental management plan.

10.7 Conclusion of residual impacts and risks and predicted outcome

As outlined in **Section 10.2.4**, reasonable and practicable GHG management measures are being employed to avoid and reduce emissions from the DPD Project. The reduction of vessel-based GHG emissions during construction and IMR activities will be achieved through vessel maintenance and adherence to the *Navigation Act 2012* (Cth) the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cth) and the MARPOL requirements.

A Risk Based Inspection schedule will be implemented for operational inspection, maintenance and repair (IMR) activities. This will ensure Santos will only mobilise vessel surveys (with associated GHG emissions) when needed to assure pipeline integrity and safety.

The operation of the pipeline itself is anticipated to be low emission in nature due to its primary function of conveying hydrocarbon gas from the Barossa FPSO to DLNG for processing into a saleable product. The RBI IMR activities will also reduce emissions during the operations phase of the DPD Project by ensuring inspect activities are reduced to appropriate levels whilst ensuring the pipeline retains its integrity and faults are readily identified so repairs can be affected in a timely fashion.

The Barossa Development represents 0.86% of Australia's 2022 GHG emissions and 0.042% of 2021 global GHG emissions. The DPD Project is one part of the Barossa Development, representing ~0.02% of Australia's 2022 GHG emissions. Therefore, the GHG emissions resulting from the DPD Project are not anticipated to represent a significant contribution to atmospheric GHG concentrations and are unlikely to alter the pace of climate change.

In addition, Santos has established a target of net-zero Scope 1 and 2 emissions by 2040, including the DPD Project, and DLNG.

Santos has determined that the development of the DPD Project will be consistent with the NT EPA's objectives for Atmospheric Processes.

11 Other Environmental Factors

This section reviews the other environmental factors that were not specifically identified as having the potential for significant impact from the DPD Project by the NT EPA in their Notice of Decision and Statement of Reasons on the referral, or their Direction to Provide Additional Information in the SER, but have been raised through the stakeholder submissions process.

Santos has undertaken further assessment of impacts to these factors to address the concerns raised through public and NT Government submissions on the referral, however, they are considered of lesser significance than impacts associated with Marine Environmental Quality, Marine Ecosystem and Atmospheric Processes factors. Nonetheless they will be managed and mitigated through implementation of DPD Project environmental management measures.

11.1 Coastal Processes

11.1.1 Environmental objective

The NT EPA environmental objective for Coastal Processes is to protect the geophysical and hydrological processes that shape coastal morphology so that the environmental values of the coast are maintained.

11.1.2 Legislation, policy and guidance

The following Commonwealth and NT legislation and other policies and guidance documentation apply to the Project.

Northern Territory

+ *Ports Management Act 2015*

Other Relevant Policies and Guidelines

+ The Coastal and Marine Management Strategy 2019-2029
+ Darwin Harbour Regional Plan of Management
+ NT EPA Environmental Factors and objectives: Environmental impact assessment general technical guidance (NT EPA, 2021c);
+ Anthropogenic Pressures on Darwin Harbour: An IMMRP Monitoring Plan (Version 1). Technical Report No. 11/2020 (Radke and Fortune, 2020);
+ Guidelines for the environmental assessment of marine dredging in the Northern Territory (NT EPA, 2013);
+ Darwin Harbour Strategy (DHAC, 2020); and
+ Darwin Harbour Water Quality Protection Plan (DLRM, 2014).

11.1.3 Environmental values

The Darwin Coastal Bioregion is generally flat, low-lying country, drained by several large rivers. Based on local Darwin topography maps, the shore crossing area ranges in level from about relative level (RL) 3 m Australian Height Datum (AHD) to approximately RL 9 m AHD. The majority of the Project area is mapped as having a slope less than 2%. The littoral land system has negligible relief and slope and is subject to tidal inundation, with mangroves and salt flats lying over muddy soils formed by sedimentary progradation (Acer Vaughan, 1993).

Coastal Processes provide an important source of sediment input and dispersion for Darwin Harbour and are an important part of the natural environment as they can provide protection from storms and flooding and help to protect marine fauna habitats and ecosystems. The Coastal Processes within Darwin Harbour include:

+ Wave action: This is dominant along the foreshore of Darwin Harbour and is responsible for the erosion and deposition of sediment along the shoreline;
+ Tidal action: These produce strong currents in the harbour that can cause erosion and sedimentation;
+ Longshore drift: This occurs when waves approach the shore at an angle and transport sediment in a parallel direction to the shore;
+ Hurricanes and cyclones: Darwin Harbour is exposed to tropical cyclones, which can cause significant shoreline erosion and sedimentation;
+ Surface water drainage: Run off from upstream creeks and estuarine systems can increase sediment loading and nutrients; and
+ Sea level rise: Sea level rise is an ongoing process that is causing the shoreline of Darwin Harbour to retreat as the sea level rises.

Darwin Harbour supports a strong and variable tidal regime with currents caused by strong tides creating a heavily flushed system (Northern Territory Government, 2022).

11.1.4 Potential significant impacts

11.1.4.1 Physical presence

Based on the current design, for the majority of the pipeline route, the top of the 26/34 inch pipeline is laid without protection and is close to the natural seabed level. Where rock protection is required, the length of protected pipeline is laid in a trench such that there is minimal change to natural seabed level with the rock protection (**Figure 2-2** and **Figure 2-3**). Consequently, the proposed changes to seafloor topography are negligible or small, particularly relative to the water depths along the pipeline route, which will result in very small, immeasurable changes to the seafloor currents and in turn insignificant changes to sediment transport, deposition and erosion (RPS, 2022e).

There is one section of the proposed pipeline route from KP121.37 to KP122.48 (~110 m in length), where the top of the proposed berm design will be up to 1.5 m above the natural seabed level in some small lengths over the section. This section of the pipeline is within the shore-crossing area in the intertidal zone, spanning from a level of 3 m above to 10 m above LAT. Approximately 50 m of this section of the proposed pipeline is within the footprint of an existing rock groyne structure which was constructed as part of the original DLNG facility construction (construction period 2003-2006) and is already above the natural seabed level.

Based on Digital Earth Australia Coastlines shoreline movement analysis (Geoscience Australia, 2020) the coastline in the shore crossing area has remained net stable (no significant trend of growth or retreat of shoreline material) between 1988 and 2020, suggesting that no significant changes in Coastal Processes have been observed as a result of the construction of either the Bayu-

Undan to Darwin pipeline or Ichthys pipelines and shore crossing works, including the presence of the existing rock groyne. Therefore, neither the presence of the pipeline, nor the proposed small sections where the top of the rock protection berm is above the natural seabed level in the shore crossing area, are expected to result in significant changes to hydrodynamics, nor in turn, changes in Coastal Processes (including sedimentation).

As discussed in **Section 2.3.4**, two temporary causeways are proposed to be constructed to assist with the shore crossing and near shores works. The temporary causeways are unlikely to have any significant adverse impacts to the coastal process of the area, due to them being short-term, temporary structures, with a relatively small footprint, i.e., they have combined area of 200 m by 25 m, with an average height not exceeding ~2 m. Consequently, the temporary causeways are not expected to significantly change the flow of the current near the shoreline, nor impact Coastal Processes.

11.1.4.2 Seabed disturbance

Changes to seabed morphology through the trenching process and the sediment mounding formed by the spoil disposal at the offshore spoil disposal ground has the potential to change the local hydrological and geophysical processes. Excavation of material for the construction of the trenches will temporarily modify the currents along the shoreline, however this is not expected to have a significant impact due to the short duration of the construction in this area.

As presented above, the coastline in the shore crossing area has remained net stable (no significant trend of growth or retreat of shoreline material) between 1988 and 2020, suggesting that no significant changes in Coastal Processes have been observed as a result of the construction of either the Bayu-Undan to Darwin pipeline or Ichthys pipelines and shore crossing works. Consequently, given the extent and method of seabed disturbance associated with the DPD Project compared to those previous projects, impact to Coastal Processes is not expected.

11.1.4.3 Ground disturbance (onshore)

Ground disturbance associated with the onshore construction activities, including trenching and onshore site facility installation, will all occur in the areas previously disturbed during construction of the Bayu-Undan to Darwin pipeline and the DLNG facility.

The construction of the trench at the shore crossing has the potential to increase erosion and runoff into the harbour in the event of heavy rains (e.g. Radke et al, 2019). However, this would only be a temporary impact as the trench will be filled in again after pipeline installation.

Trenching and onshore site construction also has the potential to disturb ASS and the potential to interact with groundwater that may be acidic. ASS and groundwater investigation has been conducted to inform the development of a Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) (refer **Appendix 12**). Given similar management experiences with DLNG construction the issue is considered readily manageable. Consequently, ground disturbance is not expected to have significant impacts on Coastal Processes.

11.1.5 Environmental management

The controls to manage impacts and risks to Coastal Processes are presented in **Table 12-1** and have been carried through to EMPs as relevant. Controls have been informed by referral commitments and subsequent feedback and consultation with the government and the public and have been reviewed through ENVID workshops (refer **Section 7.4**) and during EMP development. The management table (**Table 12-1**) should be viewed as a consolidated list of mitigation measures to avoid or mitigate impacts of the DPD Project.

11.1.6 Conclusion of residual impacts and risks and predicted outcome

The assessment of residual impacts to Coastal Processes from the DPD Project is summarised in **Table 11-1**. The management measures proposed in **Table 12-1** are considered effective and appropriate to reduce potential impacts to Coastal Processes to a level that is considered acceptable. Impacts from planned events were assessed as having Negligible or Minor impact.

The evaluation of how DPD Project activities will change the seabed and topography has determined it would result in very small, immeasurable changes to the seafloor currents and in turn insignificant changes to the current hydrodynamics, sediment transport (such as deposition and erosion) and Coastal Processes.

Santos considers that the development of the DPD Project will be consistent with the NT EPA's objectives for coastal morphology.

Table 11-1 Residual impact rating for Coastal Processes

Aspect	Potential impact	Residual impacts and risks rating
Planned events[1] (residual impact)		
Physical presence	Construction and presence of Project infrastructure, including the pipeline, associated rock protection and temporary causeways has the potential to change local geophysical and hydrological processes.	Negligible
Seabed disturbance	Changes to seabed topography from trenching and spoil disposal activities has the potential to affect local geophysical/hydrological processes	Minor
Ground disturbance (onshore)	Onshore disturbance, including site preparation and trenching for pipelay has the potential to temporarily influence local and hydrological processes, including surface water drainage and potential exposure of groundwater.	Minor

[1] All planned events have been rated as if they will occur, therefore only the activity's consequence (ranging from negligible to critical) has been considered for the risk assessment, refer to **Table 7-3**.

11.2 Community and Economy

11.2.1 Environmental objective

The NT EPA environmental objective for Community and Economy is to enhance communities and the economy for the welfare, amenity and benefit of current and future generations of Territorians.

11.2.2 Legislation, policy and guidance

The following Commonwealth and NT legislation and other policies and guidance documentation apply to the Project.

Commonwealth

Section 3A of EPBC Act – short and long term economic and social and equitable considerations, intergenerational equity, intragenerational equity.

Northern Territory

+ *Marine Act 1981*
+ *Control of Roads Act 1953*
+ *Traffic Act 1987*
+ *Ports Management Act 2015.*

Other Relevant Policies and Guidelines

+ Environmental Impact Assessment and Environmental Approval in the Northern Territory: Environmental Impact Assessment Guidance (NT EPA, 2021e);
+ Darwin Harbour Advisory Committee (DHAC) (2020). Darwin Harbour Strategy 2020-2025, Darwin Harbour Advisory Committee, Darwin.
+ Guidelines for the preparation of an economic and social impact assessment (NT EPA, 2013a);
+ Consultation Framework (IAP2, 2015); and
+ Remote Engagement and Coordination Strategy 2015 (NTG, 2015).

11.2.3 Environmental values

This section provides additional information on environmental values to Community and Economy within the region of the Project area which were not included in Section 7.4 of the NT referral.

11.2.3.1 Recreation and lifestyle

Lifestyle in the Northern Territory is often described as ‘laid-back’ or ‘relaxed’ and are characterised by outdoor-based activities.

One popular pastime is to visit the Mindil Beach Sunset Market; a traditional market located along the foreshore of Mindil Beach, Darwin Harbour. The market started in 1987 and has become the largest market in Darwin. The market operates during the dry season and hundreds of locals and visitor are attracted to the market which became Darwin’s number one, most visited attraction, winning numerous awards for tourism, multiculturalism and was officially accorded national icon status by the National Trust in 2000.

Mindil Beach is located approximately 9 km north of the closest onshore infrastructure of the DPD Project and approximately 3 km east of where the pipeline will be laid through Darwin Harbour. The nearest sensitive residential, tourist and/or commercial area to the onshore infrastructure of the DPD Project is located approximately 6 north (Stokes Hill Wharf) and 6 km east (East Arm).

Darwin Harbour, its waterways and surrounds are also key parts of the NT lifestyle and support number of recreational activities include fishing, diving, sailing, water-skiing, swimming, camping and off-road driving.

11.2.3.2 Recreational fishing and charter boat operators

The NT has the largest number of fishing-club members in Australia and the National Recreational Fishing Survey undertaken in 2000 indicated that around 540 000 hours were spent fishing in the Darwin region during the survey year. Half of this time was by local residents and the other half by visitors to that area. The Darwin Harbour presented approximately one-third of the fishing effort from that survey, which demonstrates the significant importance of the Darwin Harbour for recreational fishing in the region (Coleman, 2004). According to the report - *A Survey of Recreational Fishing in the Greater Darwin Area 2015* (Northern Territory Government, 2015), a national recreational fishing survey undertaken in 2000-01 recognised the NT as having 32% of resident fishers which is the highest resident participation rate of any state or territory in Australia. The NT also has the highest proportion of interstate visiting anglers. The Darwin Harbour plays an important role in the total recreational fishing effort in the NT, accounting for 37% of the total NT recreational fishing (Cardno 2013). Recreational fishing is estimated to generate approximately $35 million in revenue per annum in the NT by locals and visitors, excluding the tour operators.

A number of tour operators run fishing charters and other tourism activities including wildlife and harbour cruises which contributes to local jobs and the local economy.

Santos has continuously engaged with tourism stakeholders to discuss issues raised during the referral public consultation period (refer **Section 4**, **Appendix 13**). Santos has engaged with Tourism NT to discuss the DPD referral and the stakeholder consultation undertaken to date with other users of Darwin Harbour and surrounds. Tourism NT assisted Santos with further identification of stakeholders, including Tourism Top End which represents charter boat operators along with the NT Guided Fishing Industry Association. Tourism NT advised that communication prior to and during the activities was critical and offered to assist by passing on communication via its monthly newsletter. Following this, Santos engaged with Sea Darwin to discuss the referral and other stakeholder consultations undertaken to date. The business owner/operator reiterated the importance of communication and need to liaise with Tourism NT and Top End Tourism. Santos has engaged with the Darwin Dive Shop/Academy to discuss the DPD Project. Santos was requested to ensure it mitigates any impact causing turbidity near to any identified dive wreck sites and keep stakeholders informed prior to and during the proposed activities. A meeting with the Top End Tourism (representing charter boat operators) was also held with Santos to discuss the DPD Project. Top End Tourism advised that it would be happy for Santos to present to their board of management on the DPD Project.

11.2.3.3 Commercial fishing and aquaculture

As discussed in Section 7.4.3 of the DPD Project referral, the Northern Prawn Fishery is the only active Commonwealth managed fishery that operates within the Project area. Based on the map of fishing intensity (ABARES, 2022; refer **Figure 11-2**) little fishing effort (not even categorised as low) overlaps the DPD Project area. Section 7.4.3.2 of the referral also provides a description of the NT managed fisheries. Those commercial fisheries that may be active within the broader area of the Project include the NT Aquarium fishery, Darwin Aquaculture Centre (DAC), Paspaley Pearls, the

Offshore Net and Line Fishery, the Spanish Mackerel Fishery and the Coastal Line Fishery. There is a low potential for fishing in the NT Demersal Fishery to occur in the Project area.

Santos has provided a presentation to the DITT-Fisheries Division, and their stakeholders, in relation to the proposed activities and the indicative schedules, with targeted discussion on the outcomes of the sediment dispersion modelling for the planned trenching in closest proximity to Channel Island. DITT-Fisheries Division has expressed concern on the potential for trenching to mobilise and transport contaminants (e.g. heavy metals) to the DAC and the potential for these to impact aquaculture species through the DAC seawater pump intake. Santos considers the potential for impacts from heavy metals in trenched sediments (refer to **Section 8.5.1.6**). Monitoring at DAC is being included within the environmental monitoring program proposed for trenching and spoil disposal (Refer to TSDMMP **Appendix 4**).

Santos has already had discussions with Paspaley Pearls around Project vessel activities in the vicinity of pearl lease areas and has instructed contractor vessel to avoid these areas when transiting to the Project area (e.g. supply vessels transferring pipe to pipelay vessels).

Santos will continue to engage with these industry groups, as outline in **Section 4**, throughout all phases of the Project.

11.2.3.4 Ports and commercial shipping

Section 7.4.1 of the DPD Project referral provides a description of current commercial shipping traffic intersecting the DPD Project with further detail of vessel activity presented in **Section 9.4.8** above. The Port of Darwin recorded 1,510 vessel visits in 2021-22 with traffic in the Port typically influenced by a number of the well-established industrial and commercial facilities that receive a wide range of maritime traffic (i.e., cargo, livestock vessels, LNG tankers and cruise ships).

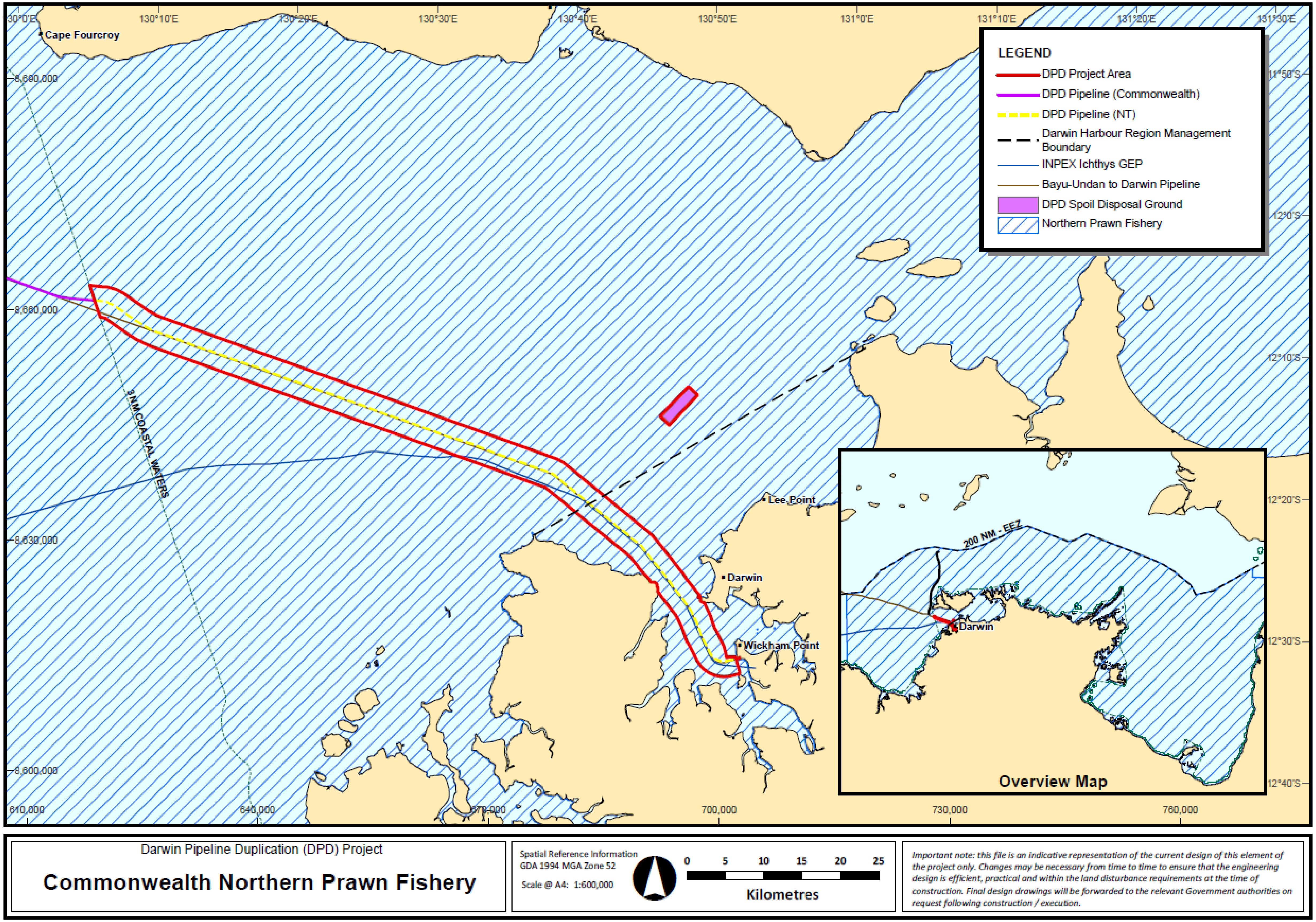


Figure 11-1 Commonwealth northern prawn fishery

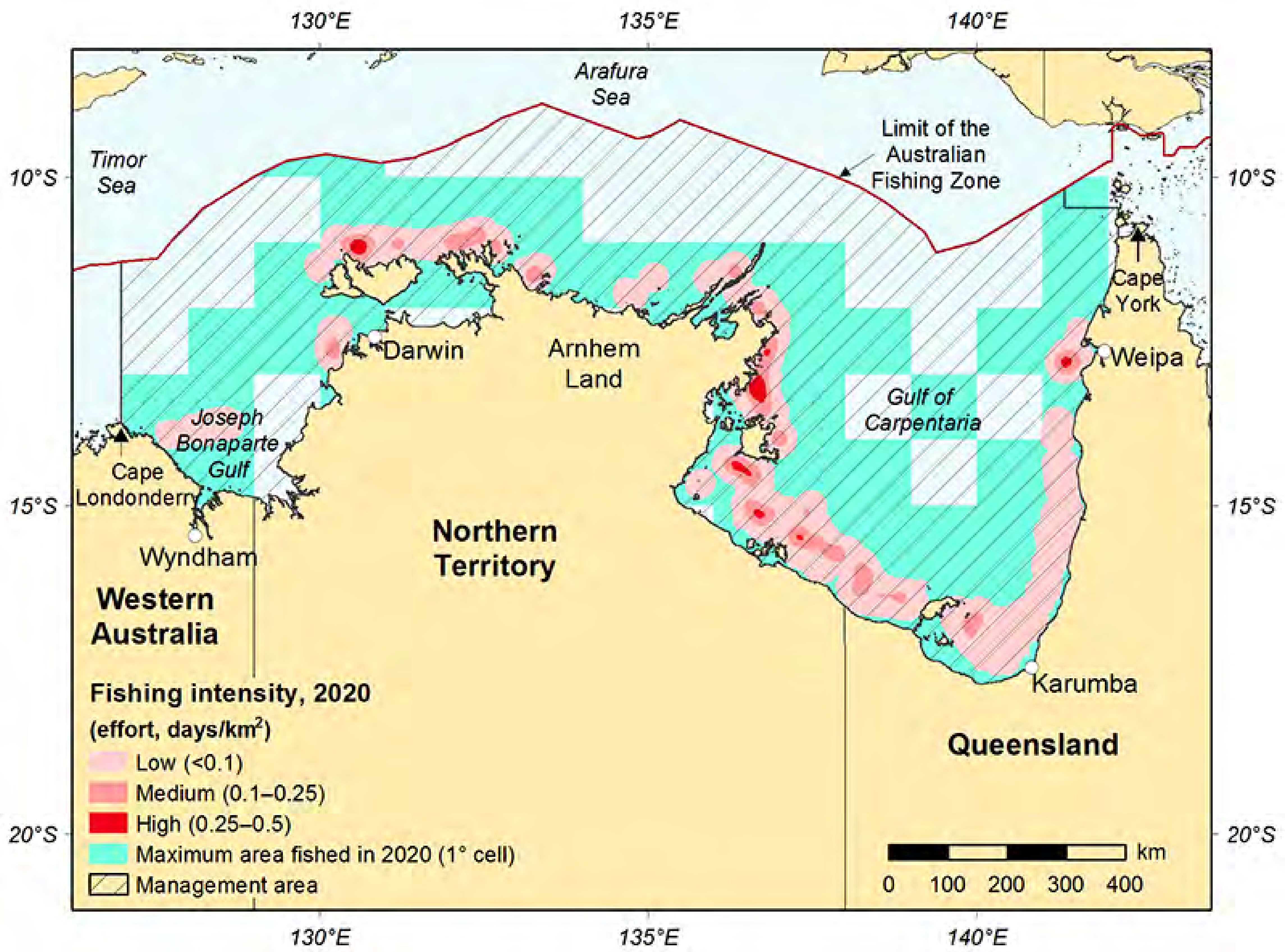


Figure 11-2 Fishing intensity in the northern prawn fishery, 2020 (ABARES, 2022)

11.2.4 Economic benefits

11.2.4.1 Overview

The DPD Project is part of the Barossa Development, one of the largest investments in the LNG sector in Australia for almost a decade and signifies Santos' ongoing commitment to development of the Northern Territory.

The Barossa Development is an important gas project for the nation, enhancing jobs, exports and relationships with investors and gas customers in Asia who have depended on Australia for their energy security for decades.

The potential for the Barossa Development to stimulate economic activity in the Northern Territory is also significant, including providing the opportunity for the NT to host one of the first major common user CCS projects in Australia.

Santos is the leading Australian oil and gas exploration and production company in the NT, with a significant presence both onshore and offshore. The company's partnership with the NT stretches back many years, having been the major supplier of gas to the local market and as the only Australian company in Darwin LNG.

The Barossa Development and Darwin Pipeline Duplication will enable continued Darwin LNG operations for another 20 years and allow for repurposing of the existing Bayu-Undan to Darwin pipeline to facilitate CCS options.

Subject to all regulatory approvals, Bayu-Undan CCS can become a low-cost, large-scale, commercial project storing CO_2 from future NT and Australian developments as well as an enabler for future zero emissions clean fuels projects.

11.2.4.2 Darwin Pipeline Duplication

In August 2022 Santos, as operator of the Barossa joint venture, announced a final investment decision (FID) to proceed with Darwin Pipeline Duplication, enabling the dedicated Barossa GEP to be extended all the way to Darwin LNG.

The works will occur in both Commonwealth and NT Waters and are scheduled to commence in 2024, subject to regulatory approvals. A major Engineering, Procurement, Construction and Installation (EPCI) contract has been awarded.

During the execution phase, the overwhelming majority of several hundred personnel working on the Project will be accommodated on two large offshore vessels, avoiding the need for development of major support infrastructure in Darwin or significant pressure on existing facilities.

The majority of opportunities for NT-based companies will occur within the Project's logistics chain and the offshore and onshore movement of personnel and equipment by air and sea and all associated activities such as fuel and water supply, catering and the supply and movement of equipment and materials.

Opportunities for the provision of goods and services by Australian and NT companies through sub-contracting are identified and promoted in conjunction with the Industry Capability Network of the NT under the Barossa Australian Industry Participation Plan. Information on this Commonwealth Government process is provided in **Section 11.2.4.4.**

Santos' supply base for all its NT offshore activities is located in Darwin. The project will involve an increased number of personnel needing to transit through Darwin, particularly during the offshore installation phase.

It is anticipated this increased demand would be for short-term accommodation only and could be met through existing and planned future facilities. Onshore accommodation requirements will be planned well in advance in consultation with local facilities.

The logistical arrangements for transiting workers would be focused on using existing capacity; and existing industrial areas would be used for locating logistics support, including vessels and helicopters, in Darwin.

At a regional scale, cumulative socio-economic impacts may arise as higher levels of vessel and small aircraft movements between Darwin and offshore and higher passenger levels at Darwin airport. In view of the number of vessel and passenger movements involved, the cumulative impact is anticipated to be minor.

Overall, the socio-economic effects associated with the Project are anticipated to be positive. Any negative socio-economic effects are unlikely and of short-term, low magnitude.

11.2.4.3 Associated Projects

Combined, the Barossa Development, Darwin Pipeline Duplication, DLNG Life Extension and Bayu-Undan CCS will, subject to all regulatory approvals, promote sustainable economic development and employment growth in the NT and Timor-Leste, while building momentum for a whole-of-region carbon reduction solution.

11.2.4.3.1 Barossa Development

The Barossa Development is predominantly an offshore project with most activities occurring in Commonwealth Waters, including the provision and installation of massive, specialised and complex infrastructure.

The Floating Production, Storage and Offtake vessel (FPSO), GEP and network of subsea equipment can only be provided by a small number of international companies with the necessary capacity, capability and economies of scale.

The Barossa Development is now almost 50 percent complete and continues to be on budget and schedule for production start in the first half of 2025. Construction activities are continuing across a range of international locations.

The majority of opportunities for NT-based suppliers will occur during the installation, hook-up and commissioning phases of the Project. The extent of these opportunities has been increased through the additional work required in NT Waters for Darwin Pipeline Duplication which will also use the Santos' supply base in Darwin.

The Barossa Development will extend the life of the Darwin LNG facility which has been a significant employer and user of goods and services in northern Australia for the past decade. It will also generate significant returns to government in the form of company and income taxation payments.

Combined with life extension works required at DLNG, Santos estimates the creation of 600 construction jobs, 350 long-term operational jobs and about A$2.5 billion to be spent locally. Indirect jobs can also be expected to be created for every direct job involved in the project as well as positive impacts on the broader economy.

As an indicator of the operational phase which would last for approximately 20 years, the existing Bayu-Undan and Darwin LNG operations has supported over 1,300 jobs across Australia and Timor-Leste.

On average about 150 personnel work on the Bayu-Undan offshore facility located in Timor-Leste waters. Santos' commitment to Darwin's ongoing development will include the requirement that the Barossa FPSO operational workforce will be based in the NT.

Opportunities for the provision of goods and services by Australian and NT companies through sub-contracting are identified in the Barossa Australian Industry Participation Plan and promoted in conjunction with the Industry Capability Network of the NT. Information on this Commonwealth Government process is provided in **Section 11.2.4.4**.

11.2.4.3.2 DLNG Life Extension

The Darwin Life Extension project is required to facilitate the Barossa Development as the new source of gas for the facility from 2025 and will re-life the facility for decades to come.

During 2022 work is progressing on the pre-shutdown scopes, undertaking key planning, engineering and procurement activities to ensure the facility is ready to start up in 2025 when Barossa comes online.

Site works to date have included civil, electrical and minor mechanical works in preparation for major site works starting in 2023. The increase in site personnel for these works is planned to increase by over 200 people in the first half of 2023.

DLNG operations currently support around 250 direct jobs and generate approximately $100 million annually in supply and service opportunities. In addition to regular operations, DLNG also undertakes a major maintenance program every two years that employs around 600 extra workers and injects up to $50 million into the local economy.

Santos understands the importance of conducting business in a manner that promotes economic growth in the communities and regions in which we operate. In the past year alone, Santos has invested significantly in procurement for its projects in the NT across 74 different suppliers. This commitment to invest in the Territory will continue as DLNG life extension works progress.

Santos is committed to helping build local capacity in the supply chain and service sector. Local businesses have grown in size and expertise to produce world-class work servicing DLNG and supporting Bayu-Undan.

11.2.4.3.3 Bayu-Undan CCS

Santos' Bayu-Undan CCS project entered into front-end engineering and design (FEED) phase earlier in 2022. The FID on the project is targeted for 2025.

The Bayu-Undan CCS project has the capacity to capture and store up to 10 million tonnes of carbon dioxide per annum, equivalent to about 2 per cent of Australia's carbon emissions each year (or four times the Barossa Development's estimated annual Scope 1 emissions), from other projects, customers and other hard to abate industries and, subject to all regulatory approvals, has the potential to be one of the largest CCS project in the world.

The Bayu-Undan CCS project will require further additions and modifications to the DLNG facility, which is proposed as the foundation for a CO_2 processing hub, as well as the repurposing of the Bayu-Undan to Darwin GEP, the offshore processing facility and the facility wells for reinjection of the processed CO_2.

In September 2022, Santos was awarded two permits to undertake evaluation and appraisal work for the potential storage of carbon dioxide in offshore Northern Australia. One of the permits is located in the Bonaparte Basin in proximity to the Bayu-Undan CCS project. The permits build on Santos' CCS strategy and have the potential to yield additional CCS opportunities.

The Bayu-Undan CCS project will be subject to a range of regulatory processes including assessment of the relevant NT activities through a referral to the NT-EPA. A required Australian Industry Participation (AIP) Plan is also in place for the Project and the summary is available at www.industry.gov.au.

11.2.4.4 Procurement Approach

Santos is providing full, fair and reasonable opportunity for Australian industry to compete for the supply goods and services for Barossa, including Darwin Pipeline Duplication, through an AIP Plan under the *Australian Jobs Act 2013* (Cth).

The Barossa AIP Plan was approved by the Commonwealth Government prior to the project moving into the detailed engineering and design phase (FEED). It states how Santos and its major Barossa contractors provide "full, fair and reasonable opportunity" to Australian industry to supply goods and services to the project and includes an indicative list of these opportunities.

The procurement approach for the major scopes such as the FPSO, subsea, export pipeline, drilling and pre-operations has been through a combination of EPC/I, leasing or direct contracting and procurement.

Santos has partnered with the Industry Capability Network NT to assist with Australian vendor identification and raise awareness of the project. Barossa has established a presence on the Gateway website operated by ICNNT where Project information and work opportunities are available. Further details on the Project and associated opportunities can be found at: BarossaOffshore.icn.org.au.

AIP requirements are embedded into the tendering activities across all packages and confirm bidders are given equal timeframe. Further information on AIP requirements and a summary of the Barossa AIP Plan are available at www.industry.gov.au.

Additional to the Barossa AIP Plan, Santos generally places a high priority on purchasing goods and services locally and providing local suppliers with the opportunity to participate in projects through a competitive bid process.

As the Operator of DLNG, Santos is committed to training and employing a residential workforce with numerous programs to develop local skills, including early career traineeships, graduate programs and operations pathways. A residential workforce policy requires DLNG staff to live in Darwin, injecting local jobs and global expertise into the region.

This is supported by our Darwin Operations Trainee Academy (DOCTA) program, which trains NT residents with skills in related trades to be LNG plant operators. To be eligible for DOCTA, candidates must have lived in the NT for several years. This program has proved to be a successful long-term investment with local recruits tending to prefer to stay in the local area and having longer term employment.

Santos aspires to positively contribute to Indigenous communities in which we operate so everyone can share in the benefits throughout the lifecycle of project developments.

Santos has long-standing relationships with many Indigenous communities, engaging and working in partnership with Traditional Owner Groups, Land Councils and statutory bodies for the life cycle of our operations on matters relating to Native Title, informed consent and cultural heritage.

In addition, we support economic opportunities including employment, training, education and enterprise opportunities. Santos is committed to building and maintaining mutually beneficial relationships with Indigenous communities, as reflected in our Local Industry, Community and Indigenous Participation Policy.

The Santos Indigenous Participation framework affords all traditional owner groups, associated communities and statutory representative bodies across its operations access to the framework.

The purpose of the framework is to ensure Indigenous Communities are engaged, informed and have access to economic opportunities for the lifecycle of operations. Santos is committed to identifying Indigenous Participation and Community Partnership opportunities throughout a project lifecycle.

11.2.5 Potential significant impacts

11.2.5.1 Vessel, trenching and pipelay activities

The increased vessel movements and the presence of trenching and pipelay vessels within the Darwin Harbour during the construction of the DPD Project has the potential to temporarily change the visual amenity of the harbour during construction and may also impact the visual amenity of the surrounding areas, as was raised during the referral consultation process, especially in relation to the popular Mindil Beach Sunset Market. While the DPD Project activities are expected to increase vessel traffic by 3-5% (refer **Section 2.8**) it is not expected to significantly change the visual amenity of the harbour given the current volume and range of commercial vessels already present. The proposed vessels are similar in size to cargo vessels that already frequent the harbour. The use of dredgers is an existing activity in the Darwin Harbour used for other projects. The installation of linear infrastructure like this pipeline, has been undertaken for other operations (Bayu-Undan and Ichthys projects), and the vessels that Santos is proposing are smaller in scale that what have previously been used.

Santos has conducted a quantitative risk assessment (INTECSEA, 2021) which included assessment of current marine traffic, with an addendum to cover future traffic growth based on the DIPL proposed port expansion. Engagement has been undertaken with DIPL to describe the potential impacts of the DPD Project's vessels on other port users, and Santos will continue to liaise with other infrastructure users and proponents to create opportunities to share resources and minimise potential impacts to port users. Santos and all contractors for the DPD Project have robust systems in place to risk assess and manage the proposed construction activities and vessels. These are described in **Table 12-1**.

The presence of the vessels and the safety exclusion zones around the vessels may temporarily displace other users of the harbour from the areas they prefer to visit and use. This impact is unavoidable, and the pipeline route and spoil disposal location has been determined based on the engineering requirements to construct a stable and protected pipeline (informed by geophysical and geotechnical studies), and with consideration of other users, including engagement with the Harbourmaster.

Project vessels will move slowly along the pipeline route during construction so displacement of other users from any one area would be temporary and localised to only where the vessels were working on the pipeline route and at the spoil disposal grounds at any particular time. This is not considered to present a significant impact.

The movements of DPD Project vessels are not considered to significantly add to the annual movements of vessels in and out of the harbour or within the harbour (refer **Figure 2-9**). Any increase to the annual average of vessel movements within the harbour will be limited to a short-term project construction phase. Moreover, whilst interactions between vessels engaged for other Santos Project activities are unlikely, a simultaneous operations (SIMOPS) procedure will be implemented to control and manage any concurrent SIMOPS activities.

During planning for the INPEX Ichthys LNG project, a Recreational Fishing and Fish Health Monitoring Program (RFFHMP) was undertaken to detect potential changes in patterns of recreational fishing and catch rates, as well as reports of ill-health in key recreationally targeted fish species. The study aimed to investigate whether any changes were observed as a result of dredging and construction activities associated with the Ichthys project (Cardno, 2013). The RFFHMP involved seasonal fishery-dependent recreational fishing surveys (Access Point Surveys (APS)) as well as fishery-independent fish sampling and fish health assessments at two locations potentially affected by construction: Darwin Harbour Inner (DI), Darwin Outer (DO), and two control locations (Bynoe Harbour (BH) and Adelaide River (AR)).

As part of the RFFHMP, recreational fishing sampling was undertaken during the Access Point Surveys Monitoring Program (APSMP) prior to the commencement of dredging, periodically throughout the dredging and post dredging. Data collected during the dredging phase and post-dredging phase sampling seasons were compared against data collected pre-dredging to detect potential changes in recreational fishing parameters investigated. Access Point Surveys conducted during multiple sampling seasons have facilitated temporal and spatial comparisons of standardised recreational fisher parameters.

This assessment identified that most fishing effort reported by parties returning to boat ramps occurred at fishing sites within the location into which they launched, indicated by grids as shown in **Figure 11-3** (Cardno, 2013).

According to the *Recreational Fishing Monitoring Program Post-dredging Report* (Cardno, 2015a), the majority of the fishers interviewed during the APSMP reported that their catch averages had either remained the same or increased over the past 12 months or few years. Similarly, during the post-dredging and dredging phase sampling seasons no evidence was recorded to indicate any influence of Project dredging or construction activities on fisher targeting behaviour, catches or catch rates, fish health, besides the usual changes in fisher targeting due to climatic conditions and seasonality (Cardno, 2015a).

As discussed in **Section 4.4**, Santos has been continuing to engage with stakeholders, following submission of the referral, to discuss topics raised during the public consultation period, including AFANT and NT DITT – Fisheries (refer to **Section 5**). Prior to the referral submission, Santos engaged with AFANT where concerns were raised about the impact of planned activities on recreational fishing in the harbour which is already subject to many pressures as a result of varied and similar conflicting uses. AFANT also advised that Santos needs to explain how the scale of its project will be different to INPEX Ichthys Project. Santos had a meeting with AFANT to update on the referral submission and to further discuss issues and concerns raised by AFANT at the previous meeting. AFANT agreed that the DPD Project was a significantly smaller and different project to the Ichthys project and was pleased that trenching would not be occurring in the Charles Point RFPA and spoil disposal would not occur within the INPEX spoil disposal area, which had now become a recreational fishing site. A subsequent meeting was held to provide an update regarding submission of the NT-EPA referral and outcomes of discussions held with NT DITT-Fisheries.

The NT Seafood Council (NTSC), which represents commercial fishing licence-holders, confirmed that commercial fishers do not operate within the harbour, however, there are some fishing activities within other NT waters jurisdictions. NTSC's two main requests were for Santos to not disturb the jewfish aggregation area within the Charles Point RFPA and to mitigate against fishing gear being snagged around the pipeline.

Santos has held meetings with NT DITT – Fisheries to provide updates on the referral submission and to further discuss the Department's views on range of environmental factors addressed in the referral documentation. The department requested that the route not pass over a jewfish aggregation area within the Charles Point RFPA, that artificial reef areas are not impacted, and Santos consult with the Amateur Fisherman's Association of the NT to gain recreational fishing sector views. The department's view was that the pipeline installation's local impact was unlikely to have any broader consequences for fisheries and was unlikely to pose an issue for mud crab migration. Santos has undertaken follow-up consultation with the department, providing assurance that the pipeline route will not pass over the jewfish aggregation area within the Charles Point RFPA (it is located over 2.5 km away) and providing seabed footage of the pipeline route within the Charles Point Wide RFPA collected during benthic habitat surveys.

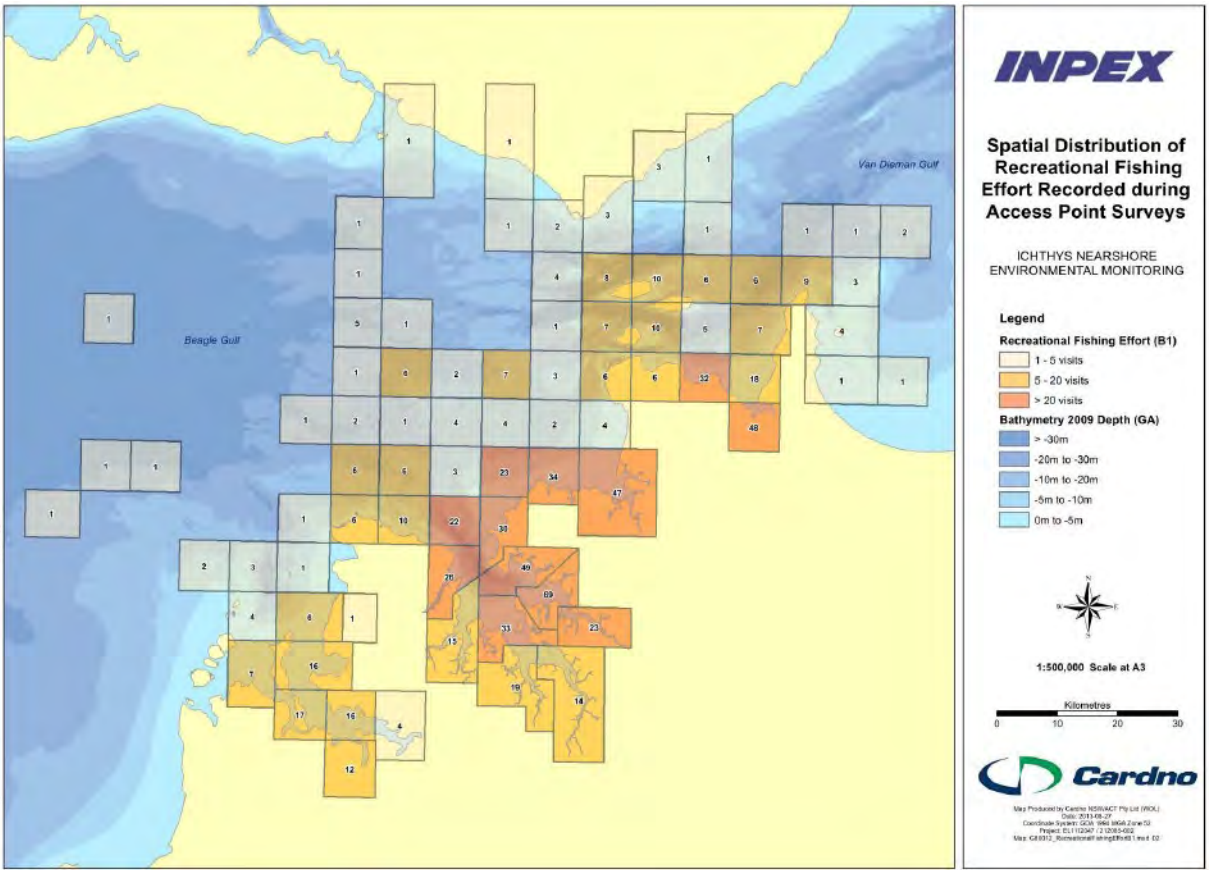


Figure 11-3 Frequency of reported visits by APS interviewees to fish area grids (from Cardno, 2013)

The presence of activity vessels has the potential to cause temporary disruption to commercial shipping. However, given all shipping vessels and activity vessels are required to comply with the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) and associated Marine Orders, it is expected navigational and communicative aids are sufficient to preventing any negative interactions beyond basic avoidance during DPD Project construction phase.

Anchoring operations with the Darwin Harbour navigation channel shall be managed in consultation with the Darwin Port, the Darwin Harbourmaster and other key stakeholders. The frequency and extent of anchoring will be less than what was undertaken on the previous Darwin Harbour pipelay campaigns due to the shallow water pipelay barge being smaller than what was used for the Bayu-Undan and Ichthys pipeline projects. Preliminary assessments indicate that approximately 1150 anchor movements will be undertaken during the DPD pipelay campaign, with only half of these being located towards the navigation channel. The proposed anchor pattern for the shallow water pipelay barge is smaller than that for previous projects', and the anchor suspension catenaries are typically 100-200 m from the vessel.

Marine notices shall be in pace for the duration of the works, and Darwin Port and DIPL will be consulted throughout the relevant DPD Project construction risk assessments.

11.2.5.2 Project infrastructure

The installation and ongoing presence of the pipeline and other project infrastructure (such as stabilisation structures and rock backfill) is not considered likely to significantly impact other users in the area. A detailed quantitative risk assessment (INTECSEA, 2021) has been performed to assess the risk of damage to the DPD pipeline by third parties. Data from the Marine Traffic website (marinetraffic.com) was used to examine vessel movement and behaviour along the proposed DPD pipeline route. The impact frequencies were calculated and assessed for the typical shipping impact scenarios such as vessel sinking and anchor drop and drag (refer **Section 11.2.5.1.7**). It was determined that pleasure craft, such as sailing vessels and yachts, were unlikely to rupture or cause any major damage to the pipeline.

The quantitative risk assessment concluded that three zones were at risk from third party activities, and the design of the DPD pipeline has incorporated additional protection where the pipeline wall thickness and concrete weight coating alone is not sufficient to maintain its integrity. The proposed pipeline and armour rock installation will provide new habitat for marine species which could potentially positively impact fish populations and thus tourism and recreation activities within the area. Similarly, while DPD Project activities at the spoil disposal ground may temporarily displace fishing activities, the deposition of spoil may increase seabed structure and fish abundance at the spoil disposal grounds.

Potential impacts to traffic associated with the transport of personnel, equipment and materials to the Project area (including rock from Mt Bundey East Arm Wharf and the DLNG facility) has been assessed within a Traffic Impact Assessment provided in **Appendix 10.** The Traffic Impact Assessment has been presented to the Transport and Civil Services Division of DIPL, who have advised that it meets their requirements as raised in their submission on the DPD Project referral (**Table 5-1**).

In developing the Traffic Impact Assessment, existing transport conditions were reviewed, informed via a combination of desktop reviews, site visit, crash/traffic data analysis and review of relevant policies and legislation.

Traffic associated with Project was assessed as accounting for a very minor proportion of traffic on the local road network. The modelling results indicate additional traffic movements generated by the construction of the Project in 2024 would result in negligible impacts on intersection capacity and performance and no road upgrades are anticipated to be required to accommodate Project-related traffic.

11.2.5.3 Seabed disturbance

The trenching activities will result in temporarily increased suspended sediment which may result in a visible plume that could impact visual amenity and dissuade the use of the area in the harbour and at the spoil disposal ground. Given that there will be restricted access near the trenching vessel and given the suspended sediment concentrations above SSC and sedimentation thresholds will remain largely within the trenching footprint, the impact to visual amenity from trenching activities is not expected to be significant.

The analysis of sediments from the Project area (**Section 8.4.2**) identified that metals and metalloid concentrations in the sediment were below NAGD screening levels, with the exception of arsenic, which is considered to be naturally occurring within Darwin Harbour. There is a potential risk that the disturbance of the sediments may mobilise contaminants within the benthic material and be redistributed to the wider area or become dissolved in the water column. This has been assessed in **Section 8.5.1.6**), and it is considered to be a low likelihood that this will occur. Santos has outlined water quality monitoring sites and methodologies within the TSDMMP (**Appendix 4**).

In terms of the potential for trenching activities to impact fish and therefore fishing activities, the Recreational Fishing and Fish Health Monitoring Program (RFFHMP) did not find any evidence of fish health issues prior to, during and post INPEX Ichthys LNG project dredging activities. Field based observations and extensive laboratory examination of finfish and crab species during the RFFHMP did not reveal any areas of particular concern regarding the types of externally visible abnormalities or health problems associated with the prevalence and intensity of parasitic and histopathological infections (Cardno, 2015a). For finfish frequently examined within the laboratory, particularly golden snapper, barramundi and gold-spotted rock cod, the prevalence and intensity of infections were generally similar between the post-dredging, dredging and pre-dredging sampling seasons and among locations. Variability in the prevalence and intensity of infection was evident for some parasites, however there was no indication that the health parameters monitored during the RFFHMP substantially changed in the short, medium, and long term since the completion of Ichthys LNG project dredging activities compared to the pre-dredge data. Rather, infections recorded within finfish species were within 'natural' occurrences through habitat, food sources and dietary preferences, and there was no evidence to suggest changes in finfish and crab characteristics and health parameters were related to Project dredging or construction activities.

Indirect impacts to fish and therefore fishing and recreational activities have also been considered. **Section 9.5.1** details the impact assessment undertaken on how seabed disturbance could impact benthic habitats and marine fauna, and also considers the importance of the habitats for fish.

Based on that assessment, impacts to marine fauna as a result of seabed disturbance and disturbance to benthic habitats is not considered to be significant. The presence of the pipeline; stretches of rock backfill; and increased topographic complexity at the spoil disposal ground, is expected to increase topographic complexity of the seabed and provide additional habitat to fish and other marine fauna. Subsequently, this may result in greater fish abundance and diversity, particularly in areas of low topographic complexity (e.g. flat sand habitats), as has been found when fish assemblages on and off of the Bayu-Undan to Darwin pipeline have been compared (McLean et al., 2020).

11.2.5.4 Noise emissions

As there are a number of tour operators whose businesses are dependent on the presence of wildlife in Darwin Harbour, any significant impact to marine fauna could indirectly impact the Community and Economy factor.

Section 9.5.2 presents the impact assessment for potential impacts to marine fauna from underwater noise emissions as a result of DPD Project activities. The management actions that will be implemented to avoid and mitigate noise impacts are presented in **Table 12-1**.

Given DPD Project underwater noise is expected to have a minor impact on marine fauna, it is considered unlikely that Community and Economy could be significantly impacted.

The potential for noise impacts to other users of Darwin Harbour and residential areas was assessed using the formula that calculates the sound attenuation over distance for a point source (this is the

Inverse Square Law[4]). Noise levels generated from construction activities (using a backhoe dredger and a cutter suction dredger as examples) are expected to be below the NT EPA nuisance thresholds of 35 dB (NT EPA, 2018), within ~320 m of the construction vessels (**Figure 11-4**). The nearest residential area is approximately 1.5 km from Project construction activities. It is anticipated that the noise levels on the decks of the construction vessels will result in negligible impacts to residential communities. Additionally, major vessels that will be used for the DPD Project will have exclusion zones imposed (expected to be 500 m).

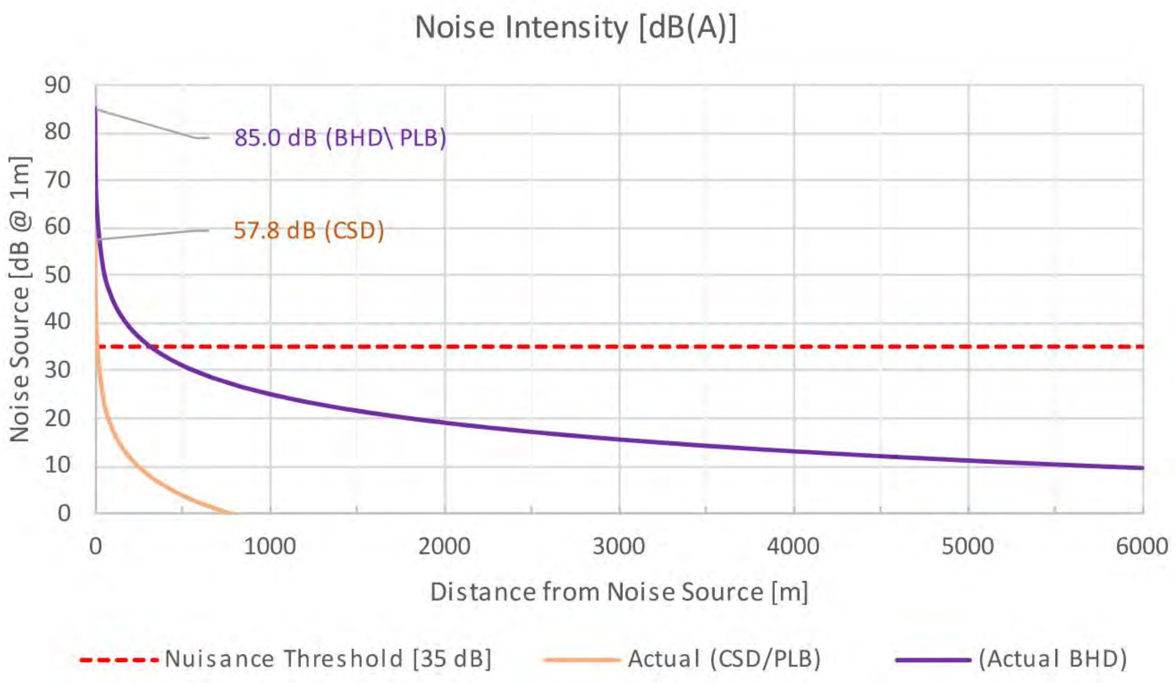


Figure 11-4 Noise attenuation from construction vessels

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[4] Lp(R2) = Lp(R1) - 20·Log10(R2/R1)

Where:

Lp(R1) = Known sound pressure level at the first location (typically measured data or equipment vendor data)

Lp(R2) = Unknown sound pressure level at the second location

R1 = Distance from the noise source to location of known sound pressure level

R2 = Distance from noise source to the second location

11.2.5.5 Treated seawater discharge

As presented in **Sections 8.5.2** and **Section 9.5.4**, should treated seawater need to be used to preserve the pipeline and then be discharged to the environment as a contingency action following an unlikely wet buckle event, no exceedance of the NOEC 99% species protection levels are predicted over a 48-hour period and consequently, no significant impact to either the Marine Environmental Quality, nor Marine Ecosystems is expected from this dewatering activity. The only impact related to the contingency discharge of treated seawater may be through temporary visual amenity (if a dye is used as part of the seawater treatment chemical package) and temporary exclusion of the area during the discharge.

11.2.5.6 Ground disturbance (onshore)

Ground disturbance associated with the onshore construction activities, including trenching for the shore pull and onshore site facilities will be earthworks undertaken in the area previously disturbed during construction of the Bayu-Undan to Darwin pipeline and the DLNG facility, and will be located within the DLNG facility disturbance footprint. The nearest sensitive residential, tourist and/or commercial area to the onshore infrastructure of the DPD Project is located approximately 6 km north (Stokes Hill Wharf) and 6 km east (East Arm). No residential and commercial receptors are present near the onshore site. Negligible impact to Community and Economy is predicted from onshore construction activities within the DLNG disturbance footprint.

11.2.5.7 Dropped objects dry gas release

The only credible scenario where a dropped object event has the potential to have a significant impact on Community and Economy is if a dropped object ruptured the Santos Bayu-Undan to Darwin pipeline or the INPEX Ichthys pipeline, or the DPD Project pipeline (once in operation) resulting in the release of dry gas. During the quantitative risk assessment (INTECSEA, 2021), the DPD pipeline between KP 104 and KP 106 was identified as requiring additional protection from a 21.5 tonne anchor drag event. The rock protection in this area has been designed to ensure the anchor fluke cannot penetrate through to the pipeline.

Two other areas were identified to pose a risk to the DPD pipeline from vessel anchors. These areas are located between KP 106 and KP 108 and between KP 112 and KP 115. It was determined that these areas of the DPD pipeline may be susceptible to damage from a 5-6 tonne anchor drag event from smaller vessels. The analysis determined that the inherent strength and protection of the pipeline was sufficient to prevent an anchor penetrating the pipeline in these areas.

In terms of a dropped object from DPD Project construction activities rupturing an existing pipeline, a number of controls will be in place to prevent dropped object from occurring (**Table 12-1**). Furthermore, other users will be restricted from the area where any lifting activity would occur by way of vessel exclusion zones and consequently the risk to other marine users from such an event is considered low.

11.2.5.8 Invasive marine species

As presented in **Section 8.5.4** vessels are the most common vector for the translocation of IMS in the marine environment and the introduction of IMS could impact the marine environment with subsequent impact to the Community and Economy. Impacts could include decreasing biodiversity (from the reduction or loss of native marine species) and loss of fishing resources and IMS have resulted in direct impacts to ports and shipping activities in other parts of the world. IMS has previously been found in Darwin Harbour, e.g. the black-striped false mussel which resulted in the closure and quarantine of all Port of Darwin marinas before it was successfully eradicated.

Darwin Harbour is a commercial port where large commercial vessels, such as cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels enter, exit and move around the harbour on a regular basis. DPD Project activities are not considered to have any higher risk of introducing IMS into the area than regular activities within the harbour and the proposed controls are considered effective and appropriate to reduce the risk of introducing IMS and no significant impact to the Community and Economy are expected.

11.2.5.9 Marine fauna interaction

As there are a number of tour operators whose businesses are dependent on the presence of marine fauna in Darwin Harbour, any significant impact to marine fauna populations could indirectly impact the Community and Economy factor.

Section 9.5.7 presents the impact assessment for marine fauna interactions as a result of DPD Project activities and the management actions that will be implemented to reduce the risk of interactions and impacts are presented in **Table 12-1**.

Based on the assessment that the potential for the DPD Project activities to impact marine fauna is considered low, it is considered unlikely that Community and Economy factor could be significantly impacted.

11.2.5.10 Hydrocarbon spill – marine diesel oil

The release of MDO from a Project vessel is considered an unlikely event as it is for commercial vessels that move in, out and within Darwin Harbour on a daily basis. Historical records show that vessel collisions are infrequent events and collisions resulting in rupture and release of fuels even more infrequent. With controls in place as per **Section 12**, including those dictating Darwin Port operations, vessel collisions will be prevented.

Recreational fishing and tourism

Darwin Harbour supports a range of commercial and recreational maritime uses, including fishing, tourism and recreational shipping/boating activities.

Any impacts to receptors that support nature-based recreational tourism (e.g. popular target recreational fishing species such as barramundi or black jewfish) may cause a subsequent negative impact to recreation and tourism activities. There is the potential for temporary closure of all recreational activities due to the risk to public health and safety following a fuel spill. Similar impacts arising from the shoreline accumulation of hydrocarbons will add a visual impact and potentially restricted access to shorelines. There is also potential for impacts to the wider service industry (hotels, restaurants and their supply chain) and local communities in terms of economic loss as a result of spill impacts to tourism.

Commercial fishing

Within the area that may potentially be impacted by spills of MDO (i.e., moderate exposure zones) the Commonwealth managed Northern Prawn Fishery and the NT Managed Aquarium, Offshore Net and Line, Spanish Mackerel and Coastal Line Fisheries are likely to be active (refer to **Section 11.2.3**).

There is the potential for hydrocarbons to temporarily disrupt fishing activities if surface or entrained hydrocarbons moves through fishing areas. It is possible that there could be accumulation of oil in fish tissues to the extent that could result in hydrocarbon tainting of fish flesh and potential temporary closure of fisheries to protect the public health and safety. Connell and Miller (1981) compiled a summary of studies listing the exposure value concentrations at which tainting occurred for hydrocarbons. The results contained in their review indicate that tainting of fish occurs when fish are exposed to ambient concentrations of 4 to 300 ppm (4,000 to 300,000 ppb) of hydrocarbons in the water, for durations of 24 hours or more, with response to phenols and naphthenic acids being the strongest. Given the volume of MDO that could potentially be released, it is possible impacts could be detected to fisheries on a stock level, although natural variation in fish abundance may be on a greater scale than any impacts attributable to a hydrocarbon spill. This would most likely be the case for fisheries species that utilise surface waters in close proximity to the spill and could also occur through direct impacts to fisheries species from damage to nursery habitats (for example, seagrass, coral reef, mangrove habitats).

Shipping and ports

At the approach to Darwin Harbour, and within the harbour itself, several notable shipping traffic lanes converge to create a high-density shipping traffic area where hydrocarbons from an unplanned release of MDO may spread.

In the event of a large spill of MDO (e.g. Scenario 1: 700 m^3 outside the harbour or Scenario 4, 300 m^2 inside the harbour, refer **Section 8.5.5**), an exclusion zone may be established around the spill affected area. This could result in exclusion of other users such as shipping vessels. Any exclusion zone established would be limited to the immediate vicinity of the release point, and due to the rapid weathering of marine diesel would only be in place for a short time following a spill.

11.2.6 Environmental management

The controls to manage impacts and risks to Community and Economy are presented in **Table 12-1** and have been carried through to EMPs as relevant. Controls have been informed by referral commitments and subsequent feedback and consultation with the government and the public and have been reviewed through ENVID workshops (refer **Section 7.4**) and during EMP development. The management table (**Table 12-1**) should be viewed as a consolidated list of mitigation measures to avoid or mitigate impacts of the DPD Project.

11.2.7 Conclusion of residual impacts and risks and predicted outcome

The assessment of residual impacts and risks to Community and Economy from the DPD Project is summarised in **Table 11-2**. The management measures proposed in **Table 12-1** are considered effective and appropriate to reduce potential impacts to Community and Economy to a level that is considered acceptable. Impacts from planned events were assessed as having Negligible or Minor impact, while unplanned events were assessed as presenting a Low or Very Low risk to Community and Economy.

Santos considers that the development of the DPD Project will be consistent with the NT EPA's objectives for social, economic and cultural values.

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Table 11-2 Residual impact risk rating for Community and Economy

Aspect	Potential impact	Residual impacts and risks rating
Planned events[1]		
Physical presence (impacts to other users)	Physical presence of the pipeline and work vessels during the construction phase could potentially result in temporary visual impact to local residents and visitors, impact on commercial and recreational tourism and fishing and also impact commercial shipping due to increased number of vessels and associated exclusion zones.	Minor
Seabed disturbance	Disturbance of seabed during trenching and spoil disposal activities resulting in temporarily increased suspended sediment. This may result in a visible plume that could impact visual amenity and dissuade the use of the area in the harbour and at the spoil disposal ground.	Minor
Noise emissions	Underwater noise impacts to key marine species that support commercial and recreation activities has the potential to impact these activities. Airborne noise from Project vessels has the potential to pose a nuisance to other users of Darwin Harbour and its shorelines.	Minor
Contingency treated seawater discharge	Contingency dewatering (e.g. a wet buckle event) to the marine environment from planned treated seawater may present an aesthetic impact to other users within the harbour, if a dye were to be used.	Minor
Ground disturbance (onshore)	A trench is required to be dug to allow the shore pull of the pipeline from offshore to onshore. This will be undertaken in a previously disturbed area and within the DLNG footprint.	Negligible
Unplanned events[2]		
Dropped objects – dry gas release	A dropped object has the potential to rupture the existing Bayu-Undan to Darwin pipeline during DPD Project construction or the DPD pipeline (once operating) and result in dry gas release. This has the potential to impact other users in the harbour. Consequence assessment: Minor Likelihood assessment: Unlikely	Very Low

Aspect	Potential impact	Residual impacts and risks rating
Invasive marine species	The introduction of IMS could decrease biodiversity (from the reduction or loss of native marine species) and loss of fishing resources which could impact the Community and Economy. Consequence assessment: Major Likelihood assessment: Unlikely	Low
Marine fauna interaction	Vessel interactions with marine fauna (e.g. vessel disturbance or interaction with trenching equipment) may result in behavioural impacts, physical injury to, or the death of the fauna involved. There is the potential that this could have flow on impacts to the community and economic activities (e.g. tourism). Consequence assessment: Minor Likelihood assessment: Possible	Very Low
Hydrocarbon spill – marine diesel oil	Hydrocarbon spills have the potential to cause an adverse impact to recreational and commercial fishing and other tourism activities as a result of temporary closure of fishing and tourism areas as well as contamination of fish and damage to habitats and wildlife. The worst case MDO spill associated with the activity was determined to be from vessel collision and fuel tank rupture. Consequence assessment: Moderate Likelihood assessment: Unlikely	Low

[1] All planned events have been rated as if they will occur, therefore only the activity's consequence (ranging from negligible to critical) has been considered for the risk assessment, refer to **Table 7-3**.

[2] The assessment of the unplanned events considered both the likelihood (refer **Table 7-2**) and the consequence (refer **Table 7-3**) of an activity, and therefore the residual risk rating has been calculated using **Table 7-4**.

11.3 Culture and Heritage

11.3.1 Environmental objective

The NT EPA environmental objective for Culture and Heritage is to protect sacred sites, culture and heritage.

11.3.2 Legislation, policy and guidance

The following Commonwealth and NT legislation and other policies and guidance documentation apply to the Project.

Commonwealth

+ *Aboriginal and Torres Strait Islander Heritage Protection Act 1984;*
+ *Aboriginal Land Rights (Northern Territory) Act 1976;*
+ *Environment Protection and Biodiversity Conservation Act 1999; and*
+ *Underwater Cultural Heritage Act 2018.*

Northern Territory

+ *Aboriginal Land Act 1978;*
+ *Heritage Act 2011; and*
+ *Northern Territory Aboriginal Sacred Sites Act 1989.*

Other Relevant Policies and Guidelines

+ ***United States of America Sunken Military Craft Act 2004*** – *The Sunken Military Craft Act 2004* provides for the protection of sunken US military vessels and aircraft and the remains of their crews from unauthorized disturbance, salvage, or recovery. The Act applies to sunken US military ships and aircraft wherever located around the world and preserves the sovereign status of sunken US military vessels and aircraft by codifying both their protected sovereign status and permanent US ownership, regardless of the passage of time.
+ **UNESCO 2001 *Convention on the Protection of Underwater Cultural Heritage*** – The United Nations Educational, Scientific and Cultural Organization (UNESCO) 2001 *Convention on the Protection of the Underwater Cultural Heritage* is an international treaty that was developed to provide a common framework for States Parties on how to better identify, research, and protect underwater heritage whilst ensuring its preservation and sustainability.

11.3.3 Cultural connections to Darwin Harbour and adjacent coastal waters

Santos recognises the cultural connections that traditional owners and other members of the Darwin community have with Darwin Harbour and adjacent coastal waters (including Beagle Gulf). Santos additionally recognises the importance of the ongoing health of Darwin Harbour and adjacent coastal waters for recreational fishing and other community activities. Darwin Harbour and adjacent coastal waters also hold significant maritime and World War II heritage values including numerous wreck sites. The value of Darwin Harbour for community recreational activities is included in **Section 11.2.3**. Maritime and World War II heritage is included in **Section 11.3.4** and Indigenous heritage is included in **Section 11.3.5**.

11.3.4 Maritime and World War II heritage values

British exploration and surveying began in the early 1800's which led to an increase in vessel transport within the Darwin Harbour from cargo and passenger vessels, industry, trade and recreation (Cosmos Archaeology, 2022). In the 1870's and 1880's, three subsea telegraph cables were laid (Cosmos Archaeology, 2022).

The Darwin Harbour and surrounds saw significant military action during World War II, including air and sea combat between Allied and Japanese forces which resulted in the sinking of numerous ships and aircraft within Beagle Gulf and Darwin Harbour (Cosmos Archaeology, 2022). Areas near and adjacent to the proposed DPD pipeline route have been designated as live-fire ranges, and the proposed pipeline route enters a gazetted air-to-air range, though it is unknown if live fire exercises have been undertaken.

Santos engaged Cosmos Archaeology to undertake a maritime archaeological heritage assessment (MAHA) (**Appendix 16**), with results of the assessment presented herein. An Archaeological Scope of Works prepared by the Heritage Branch of the NT Department of Territory Families, Housing and Communities, in November 2021, informed the Cosmos Archaeology assessment. The MAHA study area consisted of a pipeline corridor along the entire route and a wider anchoring corridor (900 m either side of the pipeline route) along the pipeline route within which anchoring by the shallow water pipelay vessel is proposed to occur. This was to ensure that the seabed disturbing activities of pipelay, trenching and temporary anchoring were covered.

Following finalisation of the DPD pipeline route (refer **Section 3.3**), Cosmos Archaeology reviewed the MAHA and found that the revised route did not result in any changed recommendations in the original report, other than that one site (Target MA_007; refer **Table 11-6**) no longer required further impact assessment due to it being sufficiently far enough away from the revised route to be avoided (Cosmos Archaeology, 2023; **Appendix 16**).

Shipwrecks and aircraft

Cosmos Archaeology identified 17 known shipwrecks within the MAHA study area. These are shown in **Table 11-3** and **Figure 11-5**. The closest shipwreck to the DPD Project pipeline route is the USAT Mauna Loa.

Table 11-3 Known shipwrecks in the MAHA study area

Name	Type	Year	Wreck event	Location	Approx. distance of DPD pipeline to Exclusion Zone	Statutory heritage protection
USAT Mauna Loa	Steel single screw steamship, former passenger cargo vessel commissioned as a United States Army transport during World War II. 5436 tons, 125 m in length	1942	Sunk by enemy action during first Japanese air raid on Darwin Harbour on 19 February 1942	12° 29' 49.344'' S 130° 49' 9.696'' E	15 m	*Underwater Cultural Heritage Act 2018; Heritage Act 2011* – 100 m radius (under *Heritage Act 2011*); and *United States of America Sunken Military Craft Act 2004*
I-124	Steel Imperial Japanese Navy I-121 Class minelaying submarine – 1470 tons, 85.2 m in length	1942	Sunk during counterattack by Allied forces on 20 January 1942.	12° 29' 24.3276'' S 130° 6' 23.6196'' E	100 m	*Underwater Cultural Heritage Act 2018* – 800 m radius (under *Underwater Cultural Heritage Act 2018*)
USAT Meigs	Steel single screw steamship, former cargo vessel commissioned as a United States Army transport during World War II. 12568 tons, 131.3 m in length	1942	Sunk by enemy action during first Japanese air raid on Darwin Harbour on 19 February 1942	12° 29' 4.74'' S 130° 49' 6.168'' E	270 m	*Underwater Cultural Heritage Act 2018; Heritage Act 2011* – 100 m radius (under *Heritage Act 2011*); and *United States of America Sunken Military Craft Act 2004*
Mandorah Queen	Steel and aluminium motor vessel passenger ferry – 22 m in length	1974	Wrecked in Cyclone Tracy	12° 26' 33.7992'' S 130° 46' 41.9016'' E	690 m	N/A
NR Diemen	Motor vessel prawn trawler – 124 tons, 20.4 m in length	1974	Wrecked in Cyclone Tracy	12° 25' 35.76'' S 130° 46' 6.888'' E	700 m	N/A
Yu Han 22	Timber Taiwanese fishing motor vessel – 25 m in length	1975	Partially burned and scuttled	12° 31' 3'' S 130° 49' 17.976'' E	730 m	N/A
Song Saigon	Steel Vietnamese refugee motor vessel – 200 tons, 38 m in length	1982	Scuttled to form an artificial reef	12° 28' 28.9992'' S 130° 48' 4.6008'' E	755 m	N/A
Medkhanun 3	Steel Thai fishing motor vessel – 25 m in length	2007	Scuttled to form an artificial reef	12° 28' 43.32'' S 130° 48' 8.496'' E	850 m	N/A
John Holland Barge	Steel work barge – 18 m long by 12 m wide	1982	Scuttled to form an artificial reef	12° 28' 27.0012'' S 130° 47' 57.0012'' E	930 m	N/A
Ham Luong	Steel Vietnamese refugee motor vessel – 15 m in length	1983	Scuttled to form an artificial reef	12° 28' 36.0012'' S 130° 47' 53.9988'' E	1,140 m	N/A
Darwin Princess	Steel motor vessel passenger ferry – 22.8 m in length	1974	Wrecked in Cyclone Tracy	12° 23' 53.34'' S 130° 45' 55.26'' E	1,300 m	N/A
Buffalo Amphibian	Steel LVT Buffalo amphibious tracked landing craft – 16.5 tons, 7.95 m in length	1960s	Foundered whilst being used as support vessel for Mandorah Ferry	12° 26' 16.656'' S 130° 47' 53.268'' E	1,380 m	N/A
Barge - Unknown No. 1	Steel barge; likely WWII era	Not known	Not known	12° 26' 54.348'' S 130° 48' 36.576'' E	1,700 m	N/A

Name	Type	Year	Wreck event	Location	Approx. distance of DPD pipeline to Exclusion Zone	Statutory heritage protection
Darwin Harbour Unidentified Wreck 2	Timber hulled vessel – 30 m in length, carrying 10 tons of steel cargo	Not known	Not known	12° 28' 59.988'' S 130° 49' 59.988'' E	2,000 m	N/A
Mandorah Unidentified Wreck 1	Timber hull motor vessel	Not known	Not known	12° 26' 47.976'' S 130° 46' 1.02'' E	2,000 m	N/A
Mandorah Unidentified Wreck 2	Timber hull motor vessel	Not known	Not known	12° 26' 53.16'' S 130° 45' 57.96'' E	2,000 m	N/A
USS Peary	Steel twin screw steamship, United States Navy Clemson Class destroyer – 1190 tons, 95.8 m in length	1942	Sunk by enemy action during first Japanese air raid on Darwin Harbour on 19 February 1942	12° 28' 31.1988'' S 130° 49' 47.352'' E	2,000 m	*Underwater Cultural Heritage Act 2018 Heritage Act 2011* – 100 m radius (*under Heritage Act 2011*); and *United States of America Sunken Military Craft Act 2004*

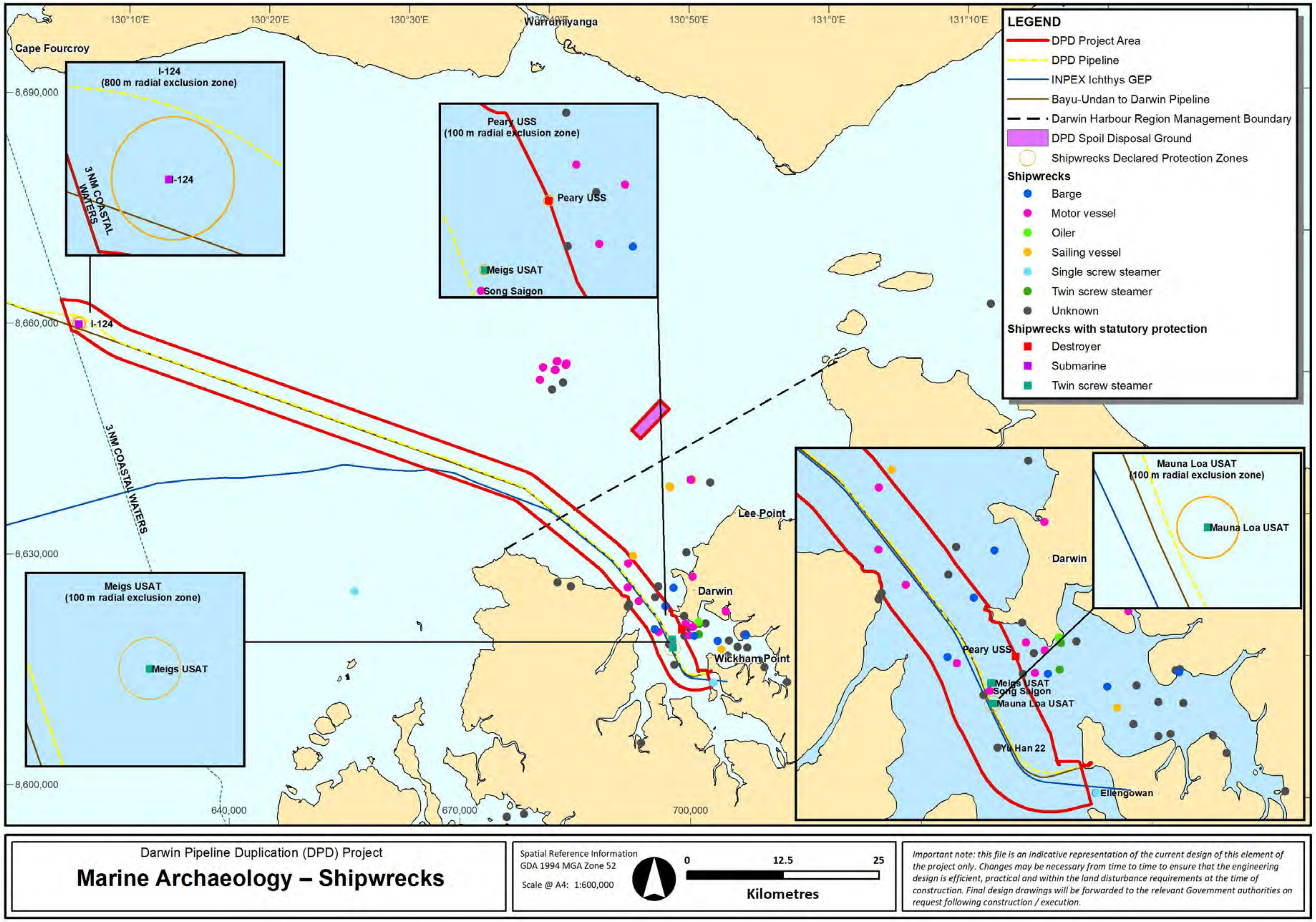

Figure 11-5 Location of known shipwrecks in study area.

Cosmos Archaeology noted 29 known but unlocated shipwrecks, and 25 known but unlocated aircraft wrecks were recorded to have sunk within the vicinity of the MAHA study area and could potentially occur within the Project area (**Appendix 16**). This is based on historical accounts and general indication of where the wreck may be located. The location data for these wrecks provided by heritage inventories and historical records are not always accurate, due to movement on the seabed, or how the data was captured at the time.

11.3.4.1 Maritime Infrastructure and UXO

In addition to the wreckage of vessels, six records of maritime infrastructure, and five records of unexploded ordnance (UXO) are known to be within the MAHA study area (**Appendix 16**), however, there are many more sites that are thought to contain maritime archaeological finds which are yet to be located.

Six historical maritime infrastructure installations are known to occur within parts of the MAHA study area, including three subsea telegraph cables from the 1800's, a World War II anti-submarine boom net installation, and potential remnants of two groups of World War II indicator loops that have been lifted and removed (**Figure 11-6**).

Four of the known UXOs are located at shipwrecks situated in the MAHA study area (**Table 11-4**). These are associated with World War II military vessels and are protected under the *Underwater Cultural Heritage Act 2018* and the *United States of America Sunken Military Craft Act 2004*. Additionally, one location of dumped UXOs was recorded. This consists of a collection of dumped mechanical time fuses and fuse cones located near KP105, approximately 175 m from the proposed DPD pipeline route. The occurrence of these UXOs have no statutory protection, nor heritage protection radius.

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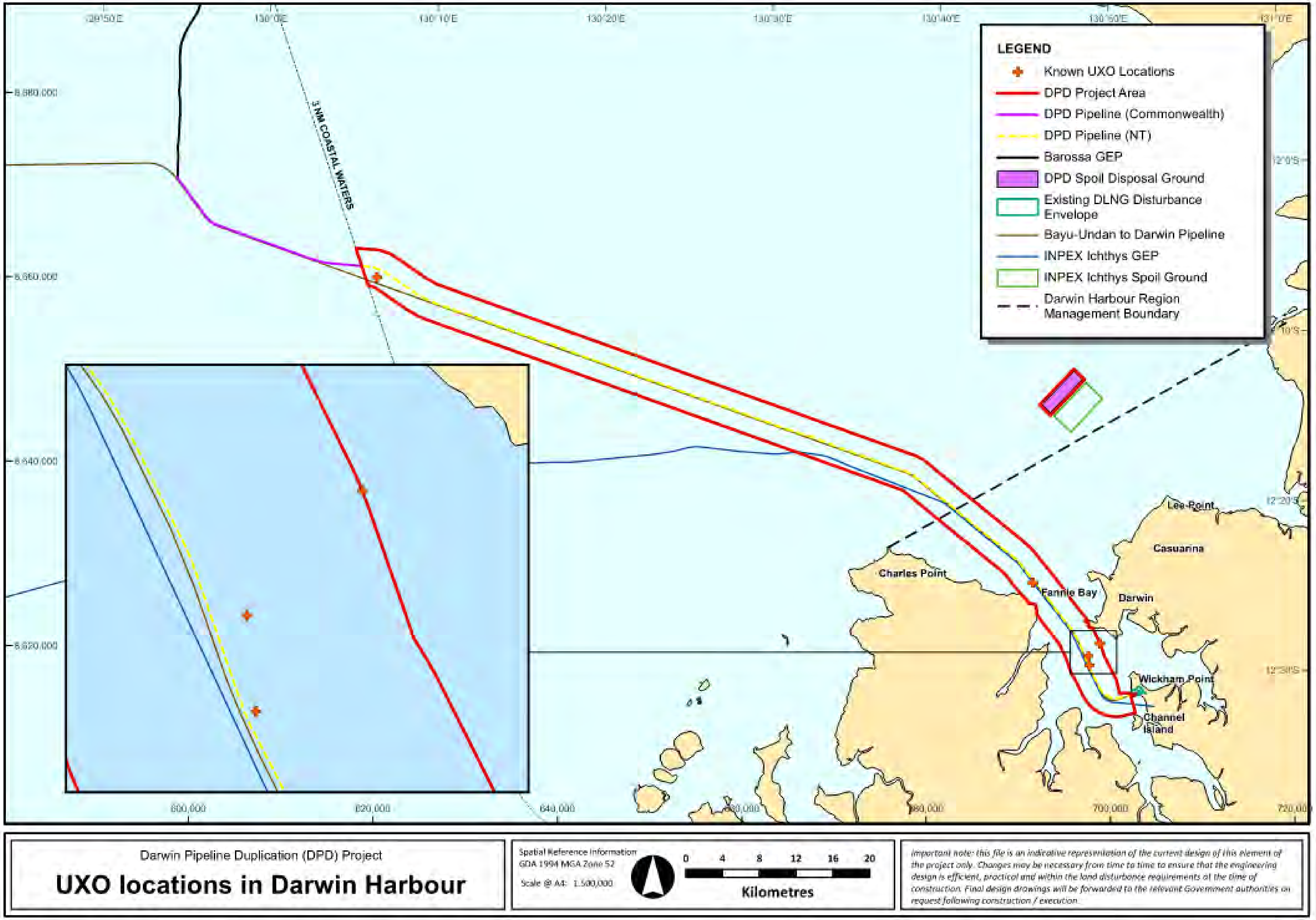

Figure 11-6 UXO locations in Darwin Harbour

Table 11-4   Known UXO within the MAHA study area

Shipwreck	UXO Type	Location	Approx. distance of DPD pipeline to Exclusion Zone	Statutory Heritage Protection
USAT Mauna Loa	.303 calibre and .45 calibre ammunition and 3” mortar	12° 29' 49.344'' S 130° 49' 9.696'' E	15 m	*Underwater Cultural Heritage Act 2018* and *Heritage Act 2011* – 100 m radius (under *Heritage Act 2011*)
I-124	5.5” artillery shells and 21” torpedos	12° 29' 24.3276'' S 130° 6' 23.6196'' E	100 m	*Underwater Cultural Heritage Act 2018* – 800 m radius
USAT Meigs	.303 calibre ammunition and possible depth charges or land mines	12° 29' 4.74'' S 130° 49' 6.168'' E	270 m	*Underwater Cultural Heritage Act 2018* and *Heritage Act 2011* – 100 m radius (under *Heritage Act 2011*)
USS Peary	3” and 4” artillery shells	12° 28' 31.1988'' S 130° 49' 47.352'' E	2000 m	*Underwater Cultural Heritage Act 2018* and *Heritage Act 2011* – 100 m radius (under *Heritage Act 2011*)
Other				
Dumping	Mechanical time fuses and fuse cones	12° 24' 58.2114'' 130° 45' 45.7194''	175 m	No statutory protection, no heritage protection radius.

MAHA study area anomalies

Santos provided Cosmos Archaeology with geophysical data to conduct an assessment to identify geophysical anomalies that could be representative of underwater cultural heritage artefacts along the DPD pipeline route. This assessment primarily used a side scan sonar (SSS) data. Additionally, MBES and magnetometer data were used as a second and third data source to support the selection of targets/anomalies from SSS.

From the geophysical data provided, 42 anomalies were identified by Cosmos Archaeology, including three magnetic anomalies with no SSS or MBES presence (**Appendix 16**). The distribution of anomalies increases with the approach into Darwin Harbour, with the highest concentration between KP101 and KP116 (refer to Figure 43 of **Appendix 16**).

Sixteen of these targets were located within 50 m of the DPD pipeline route and were shortlisted for visual survey to confirm their identity and significance (**Figure 11-8**). In addition to the assessment of the 16 targets, three transects were planned solely for heritage purposes in the location of known World War II anti-submarine netting. Cosmos Archaeology carried out a visual assessment of ROV from surveys conducted between 6-8 June 2022.

The ROV surveys investigated all 16 shortlisted targets and detected the remains of historic maritime infrastructure (refer to Figure 71 of **Appendix 16**) and the remains of World War II anti-submarine boom net moorings (known as 'trots') were clearly identified by all the three heritage transects.

In addition to the geophysical targets identified from the pipeline corridor geophysical data provided by Santos, an additional 135 targets were identified from publicly available MBES data from Geosciences Australia within the gap between the geophysical survey corridor and the anchoring corridor. It was found that 90 of these targets are between KP107 and KP108, which is known to be the location of the World War II anti-submarine boom net moorings. It is believed that these are large cement mooring blocks. The remaining 45 targets have been identified as most likely debris. These targets are scattered along the length of the anchoring corridor.

One of the ROV survey transects (Heritage Transect 1) identified submarine boom net mooring chains that cross the route of the DPD pipeline. However, it should be noted that a gap exists between sections of the chain, particularly southeast of anomaly ID 246, which could not be located. Heritage Transect 2 and Heritage Transect 3 did not cross the proposed DPD pipeline route.

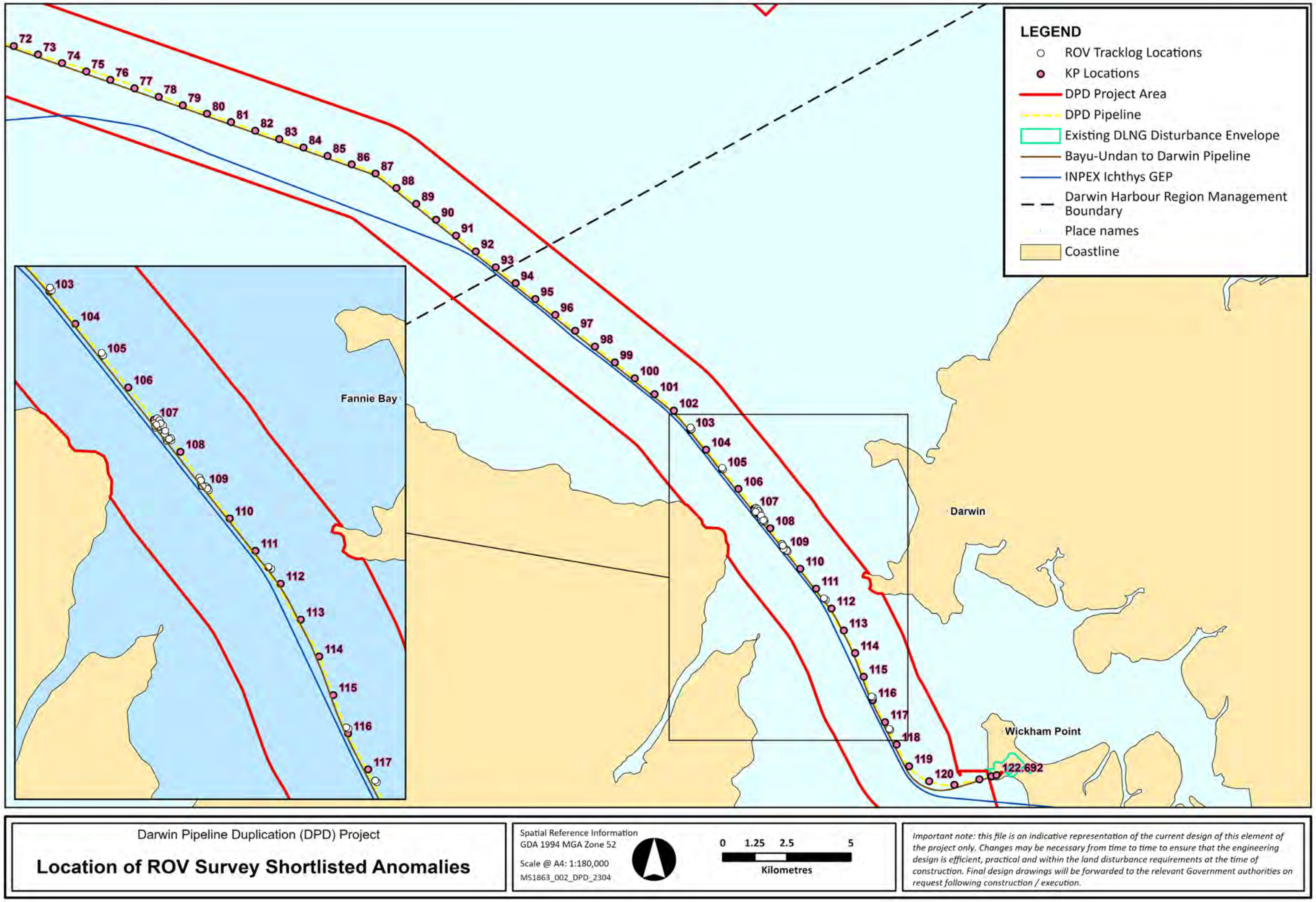

Figure 11-7 Location of ROV survey shortlisted anomalies

Figure 11-8 ROV survey target locations overlaid on a map of known historic maritime infrastructure in Darwin Harbour.

The value of an object or a group of objects (a 'site') that is considered to have cultural significance depends on what aspects of cultural activity the community values. Part 2.2 of the *Northern Territory Heritage Act 2011* has provisions to declare a 'Heritage Place' or 'Heritage Object'. The criteria for heritage assessment are set out in Part 1.2, Division 2, Section 11 of the *Northern Territory Heritage Act 2011.* The NT heritage assessment criteria have been established to select sites/objects of 'special' significance to be protected (**Table 11-5**). The significance of a site/object is assessed on the rarity and their condition. The allocation of a level of significance to a maritime cultural find, will determine what management and mitigation measures would be appropriate and proportionate against a proposed impact. To date, no site/object found in the study area can be considered to have special significance.

Table 11-5 Levels of cultural heritage significance

Classification	Significance
Special	A rare or unique object or site in a relatively good state of preservation that provides an irreplaceable insight on the development of the NT and Australia. Eligible for listing as a 'Heritage Place' or 'Object'
High	A rare object or sire type in a relatively good state of preservation that provides a new insight on the development of the NT and Australia.

Classification	Significance
Moderate	A rare object/site in a poor state of preservation or a common object/site in a relatively good state of preservation that provides an insight into the development of the NT.
Low	A common object or site type in a poor to fragmentary state of preservation that contributes to the understanding of the development of the NT.
Minimal	A ubiquitous object type, usually of recent manufacture, which provides little new information to the understanding of the development of the NT.

Individual ROV surveys on 10 of the 16 isolated maritime heritage targets (noting the other targets were along transects) identified six instances of natural features, that are not considered to be of cultural origin and are not discussed any further. The remaining four heritage targets were concluded to be of cultural significance although their identity could not be conclusively confirmed. These results are summarised in **Table 11-6**.

Table 11-6 ROV survey findings of targets of cultural significance and classification

Target Identification Number	Likely Identification	Sensitivity	Classification
174	Winch or windlass	Cultural	Unknown, likely **Low**
NCL_SC_016	Telegraph cable	Cultural	Unknown, likely **Minimal** to **Low**
MA_007	Metal structure, possibly a wreckage	Cultural	Unknown, likely **Minimal** to **Moderate**
MA_001	Buoy mooring and cable	Cultural	Minimal
Transect ID			
Heritage Transect 1 (incl. MA_003, 011; NCL_SC_020, 021, 022, 023, 024, 025; 165, 167, 244, 246, 247	Anti-submarine net mooring trot (Trot 17)	Cultural	High
Heritage Transect 2 (incl. MA_002; NCL_SC_026; 164 and 260	Anti-submarine net mooring trot, with ship's anchor as northernmost mooring	Cultural	High
Heritage Transect 3 (incl. NCL_SC_017, 018, 019; 166)	Anti-submarine net mooring trot	Cultural	High

Cosmos Archaeology (**Appendix 16**) concluded that pipelaying activities for the DPD Project would likely impact an anti-submarine defence mooring trot (Trot 17) identified on ROV heritage transect 1, but would be unlikely to impact other identified cultural objects. Cosmos Archaeology recommended that if the targets could not be avoided then further identification and mitigation measures should be applied in consultation NT Heritage Branch. Mitigation measures could include intervention and relocation of Trot 17, followed by a documented survey of its new location, as was applied to trots during the INPEX Ichthys project. Cosmos Archaeology also recommended the establishment of no-anchoring zones around identified anomalies and known cultural heritage sites within the DPD Project anchoring corridor.

11.3.5 Indigenous heritage and sacred sites

The Darwin region was traditionally occupied by the Larrakia people, whose country runs from Cox peninsula in the west to Gunn Point in the north, Adelaide River in the east and down to the Manton Dam area southwards (Larrakia Nation, 2023). The waters of Darwin Harbour, Bynoe Harbour, Shoal Bay, Adam Bay, and parts of Beagle Gulf also form part of Larrakia country (Cosmos Archaeology, 2022). The Larrakia people maintain an innate connection to the land and sea in the region. Cultural, spiritual and heritage sites of significance are located throughout the region where traditional harvesting remains an important practice (DHAC, 2020). Offshore from Darwin Harbour, the waters around the Tiwi Islands (including Bathurst Island, Melville Island and the Vernon Island) similarly hold a spiritual connection, and a source of food and wellbeing, for the Tiwi people (Tiwi Land Council, 2021).

Cultural heritage and sacred sites in the Northern Territory are protected by the *Heritage Act (2011)* and the *Northern Territory Aboriginal Sacred Sites Act 1989* respectively. The purpose of the *Heritage Act (2011)* is to provide for the conservation of the Territory's cultural and natural heritage, whereby the significance of a place or object includes its aesthetic, historical, scientific and social significance. Sacred sites are places within the landscape that have a special meaning or significance under Indigenous traditions, including hills, rocks, waterholes, trees, plains, lakes, billabongs (AAPA, 2022). There are many sacred sites within Darwin Harbour and the surrounding waters. In coastal and sea areas, sacred sites may include features which lie both above and below the water (AAPA, 2022).

There are registered Indigenous sacred sites within Darwin Harbour that are within or adjacent to the DPD Project area, as published within the INPEX Ichthys EIS (INPEX Browse Ltd, 2010). These sites include three rocky seabed areas or shoals and sand/rock bars (INPEX Browse Ltd, 2010).

The Aboriginal Areas Protection Authority (AAPA) is an independent statutory authority established under the *Northern Territory Aboriginal Sacred Sites Act 1989* (AAPA, 2022). AAPA is responsible for overseeing the protection of Aboriginal sacred sites on land and sea across the whole of Australia's Northern Territory. AAPA protects Aboriginal sacred sites through:

+ Sacred site avoidance surveys and issuing of Authority Certificates for any proposals of development;
+ The provision of information to the public about existing sacred sites data through abstracts of Authority records and access to the Registers maintained by the Authority; and
+ The registration of Aboriginal sacred sites (AAPA, 2022).

Authority Certificates are based on consultations between AAPA and custodians and provide clear instructions on what can and cannot be done in and around sacred sites (AAPA, 2022). An Authority Certificate provides a statutory indemnity against prosecution in relation to the works or uses covered by the Certificate, provided the applicant complies with any conditions imposed to protect sacred sites (AAPA, 2022). Certificates are voluntary and are considered to provide an effective risk management tool for developers and act as site protection measures for custodians (AAPA, 2022).

Santos has applied for and received an Authority Certificate (C2022-098), from AAPA on 23 December 2022, which covers seabed disturbance in Subject Land areas (refer **Figure 11-10** for Subject Land area in Darwin Harbour). The certificate identified that the registered sacred site 5073-105 overlaps the Subject Land area within Darwin Harbour and that a restricted works area (RWA) shall apply within which no work or damage can occur.

In their referral submission (see **Table 5-1)**, the AAPA have stated that if Santos obtains and complies with an Authority Certificate issued to Santos for all activities proposed to be undertaken, then the risk of potential impacts to cultural values associated with sacred sites will be appropriately minimised.

Santos will ensure that the conditions of the certificate and requirements of the *NT Aboriginal Sacred Sites Act 1989* and the *Heritage Act (2011)* will be made known to Project contractors and will be followed.

Santos has undertaken ongoing engagement with the Larrakia members of the Wickham Point Deed Reference Group (refer **Section 4**) with respect to the DPD Project and progress of its AAPA Certificate application, in addition to engagement through with the Northern Land Council, the Tiwi Land Council (including some Clan groups) and Larrakia Nation (including Larrakia Sea Rangers). Since receiving the Authority Certificate Santos has engaged with the Wickham Point Deed Reference Group on potential mitigation measures for the DPD Project with respect to activities in the vicinity of the restricted works area (RWA). Santos also intends to involve the Larrakia Sea Rangers in its environmental monitoring program for the DPD Project within Darwin Harbour.

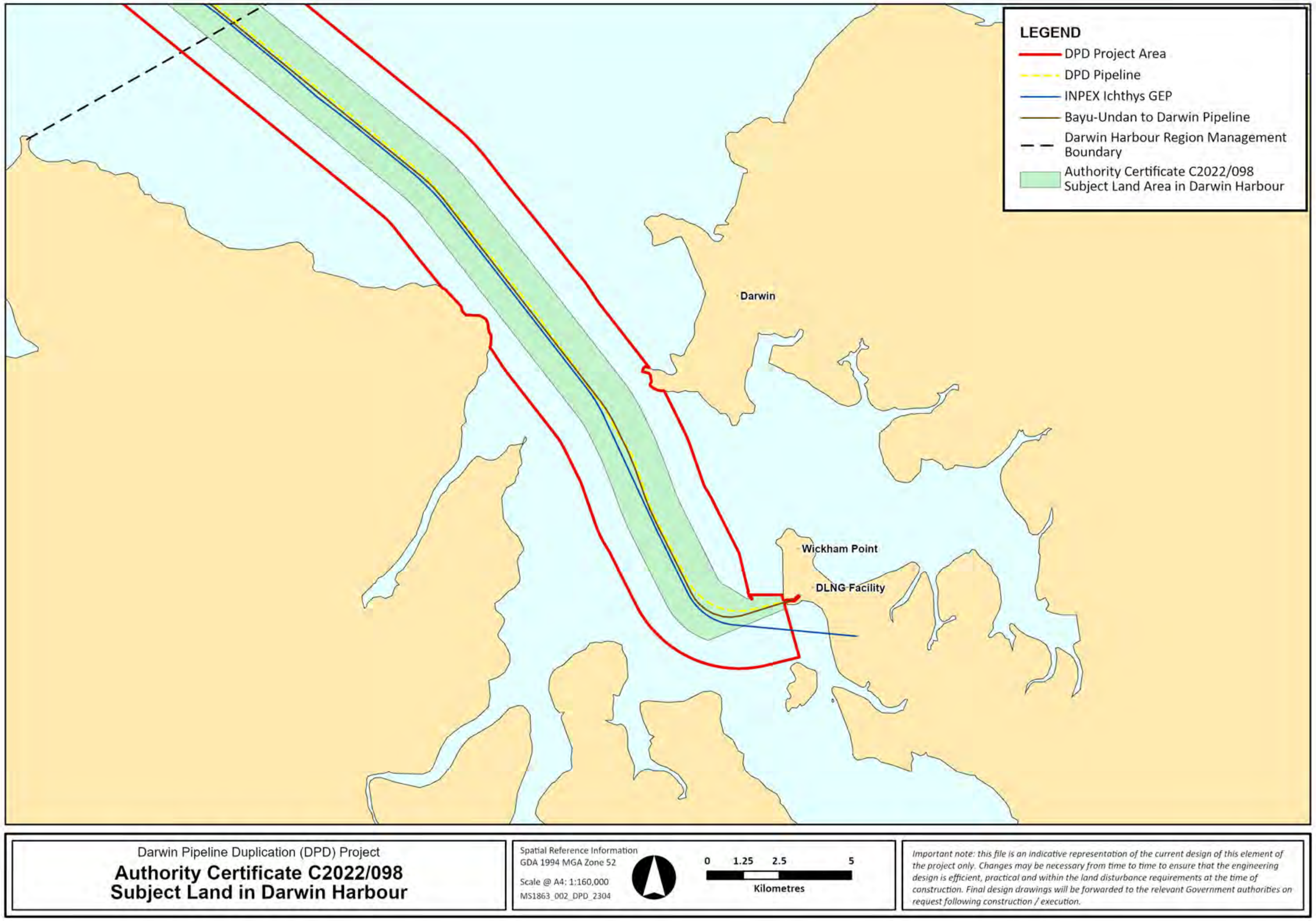

Figure 11-9 Authority Certificate C2022/098 Subject Land in Darwin Harbour

11.3.6 Potential significant impacts

Seabed disturbance

Seabed disturbance from pipeline installation and associated anchoring by the nearshore pipelay barge, pre-lay trenching and spoil disposal and installation of other infrastructure (e.g. concrete mattresses) has the potential to disturb cultural heritage sites. Based on the maritime heritage survey work completed, the known maritime heritage shipwreck site at greatest risk of impact from the DPD Project activities is USAT Mauna Loa. However, USAT Mauna Loa has a 100 m exclusion zone, and the DPD pipeline route has been deliberately altered such that the pipeline will be laid 15 m from the boundary of this exclusion zone. Therefore, this known site is not expected to be impacted from the Project pipeline.

The maritime heritage assessment also identified an anti-submarine defence mooring weight and chain (known as a trot) (considered to have high heritage value) that, if not avoided or mitigated, could be permanently impacted (damaged and/or covered over) by the laying of the pipeline (refer **Section 11.3.4**). If these objects cannot be avoided Santos will adopt mitigation measures in consultation with a maritime heritage archaeologist and NT Heritage Branch to ensure impacts are mitigated. This could include carefully relocating the trot nearby the proposed route and documenting the position such that pipelay does not damage the object.

In addition to the laying of pipeline and associated structures and pre-lay trenching, temporary anchoring activities by the nearshore pipelay barge, within a 900 m wide corridor on either side of the DPD pipeline route, between KP91.5 and the onshore termination point cultural heritage objects. These anchor chains present a hazard to maritime cultural heritage sites within their deployment zone, as the sweeping chains and anchor points (refer **Section 2.4.1.1**) can damage or move archaeological sites and artefacts.

Within the DPD Project anchoring corridor there are eight known shipwrecks (**Table 11-3**). Two of these, USAT Mauna Loa and USAT Meigs, fall under the protection of the *NT Heritage Act 2011* and may be protected under the USA *Sunken Military Craft Act 2004*. The remaining six wrecks are not currently under legislative protection. Two objects of cultural heritage, inspected during ROV surveys, are also within the anchoring corridor, Targets 174, and NCL_SC_016.

The anti-submarine net mooring trots 16, 17, and 18 are within this corridor. It is highly likely that many of the remaining trots are also located within the DPD Project anchoring corridor. Additionally, there are a large number of unsurveyed anomalies, identified by Cosmos Archaeology, from geophysical seabed data that are within the anchoring corridor that could potentially be cultural sites.

In terms of indigenous heritage and sacred sites, the AAPA Authority Certificate received by Santos (C2022/098) identified a registered sacred site representing a submerged sandbar that falls within the anchoring corridor but is not under the proposed DPD pipeline route. Therefore, this site has the potential to be impacted by nearshore pipelay barge anchoring if the restricted works area requirements are not followed.

In order to avoid anchoring impacts to maritime cultural sites and sacred sites, these sites will be protected by anchoring exclusion zones visible onboard Project vessels and vessels will abide by Anchor Management Plans that will be prepared to specifically address the seabed disturbance.

Santos is also engaging with Larrakia through the Wickham Point Deed Reference Group to develop further management measures in relation to DPD Project construction activities in the vicinity of the restricted works area.

In order for vessel to be able to respond to any previously unidentified objects (i.e., unexpected objects) on the seabed, which may be considered culturally significant, an Unexpected Maritime Archaeological Finds Protocol has been developed by Cosmos Archaeology, and will be implemented for the DPD Project, this includes:

+ Unexpected finds, stop work triggers and notification procedures;
+ Heritage induction for contractors;
+ Recording and reporting methods and procedures; and
+ Artefact collection and retention policies.

Based on the results of the sediment dispersion modelling, levels of suspended sediment, including SSC and sedimentation, will be restricted to the trenching areas and consequently, no impact beyond these footprints is expected. There is no impact predicted to the any Indigenous Sacred Sites or the USAT Mauna Loa as a result of trenching activities.

Hydrocarbon spill – marine diesel oil

The release of MDO from a Project vessel is considered an unlikely event as it is for commercial vessels that move in, out and within Darwin Harbour on a daily basis. Historical records show that vessel collisions are infrequent events and collisions resulting in rupture and release of fuels even more infrequent. With controls in place as outlined in **Section 12**, including those dictating Darwin Port operations, vessel collisions will be prevented.

Maritime heritage

There are numerous shipwrecks and other maritime heritage sites within and outside Darwin Harbour (refer **Section 11.3.4**) that could potentially be impacted by an unplanned release of MDO.

Surface hydrocarbons will have no impact on underwater shipwrecks. Entrained and dissolved hydrocarbons in the water column pose the greatest risk of impacts to shipwrecks. Microbial communities (biofilms) on structures and in the surrounding seafloor play important roles in shipwreck preservation and degradation, and in recruitment of macro-organisms (Hamdan et al., 2018). Hydrocarbons in the water column may potentially impact those microbial and encrusting communities that may in turn affect the structural integrity of the shipwreck. In the highly unlikely event of an unplanned surface release of MDO, any shipwreck in close proximity to the release location would potentially be impacted. However, at the 10-20 m water depth, concentrations of entrained and dissolved hydrocarbons are not expected to exceed moderate threshold values (**Section 8.5.5**). Therefore, significant impacts to shipwrecks are not expected in the unlikely event of a hydrocarbon spill.

Indigenous heritage

There are registered submerged sacred sites occurring within Darwin Harbour (**Figure 11-9**) as well as coastal sacred sites within Darwin Harbour and adjacent shorelines.

Any hydrocarbons (surface, dissolved or entrained) that reach the coastline or submerged sacred sites from an unplanned release of MDO has potential to impact on registered sites and indigenous heritage places and could damage their heritage value.

11.3.7 Environmental management

The controls to manage impacts and risks to Culture and Heritage are presented in **Table 12-1** and have been carried through to EMPs as relevant. Controls have been informed by referral commitments and subsequent feedback and consultation with government and the public and have been reviewed through ENVID workshops (refer **Section 7.4**) and during EMP development. The management table (**Table 12-1**) should be viewed as a consolidated list of measures to avoid or mitigate impacts of the DPD Project.

11.3.8 Conclusion of residual impacts and risks and predicted outcome

The assessment of residual impacts and risk to Culture and Heritage from the DPD Project is summarised in **Table 11-7**. The management measures proposed in **Table 12-1** are considered effective and appropriate to reduce potential impacts and risks to Culture and Heritage to a level that is considered acceptable. Impacts from planned events were assessed as having a Minor impact to Culture and Heritage while unplanned events were assessed as presenting a Low risk to Culture and Heritage.

Whilst Santos has made every attempt to avoid all known heritage and cultural sites during the planning of the pipeline route, there is still the potential for unexpected heritage items or cultural sites to be uncovered and/or disturbed during the DPD project. Santos will apply an Unexpected Finds Protocol, supported by Maritime Archaeologist, and will liaise with the relevant authorities to carry out works in the specified location in accordance with regulatory requirements.

Santos considers that the development of the DPD Project will be consistent with the NT EPA's objectives for sacred sites, and culture and heritage.

Table 11-7 Residual impact risk rating for Culture and Heritage

Aspect	Potential impact	Residual impact and risks rating
Planned events[1] (residual impact)		
Seabed disturbance	Disturbance of cultural and heritage sites from DPD Project construction activities.	Minor
Unplanned events[2] (risk rating)		
Hydrocarbon spill - marine diesel oil	Hydrocarbon spills have the potential to cause an adverse impact to recreational and commercial fishing as a result of temporary closure of fishing areas as well as contamination of fish. Impact to Marine Environmental Quality from loss of hydrocarbons (MDO/MGO) from: + A bunkering incident. Consequence assessment: Minor. Likelihood assessment: Possible. + A vessel collision. Consequence assessment: Moderate. Likelihood assessment: Unlikely.	Low

[1] All planned events have been rated as if they will occur, therefore only the activity's consequence (ranging from negligible to critical) has been considered for the risk assessment, refer to **Table 7-3**.

[2]. The assessment of the unplanned events considered both the likelihood (refer **Table 7-2**) and the consequence (refer **Table 7-3**) of an activity, and therefore the residual risk rating has been calculated using **Table 7-4**.

12 Management Actions

The manage actions (MA) that will be used to manage (avoid and mitigate) impacts and risks to NT EPA Environmental Factors from the DPD Project are presented in **Table 12-1** and have been carried through to EMPs (attached) as relevant. Controls have been informed by referral commitments and subsequent feedback and consultation with government and the public and have been reviewed through ENVID workshops (refer **Section 7.4**) and during EMP development. The management actions table should be viewed as a consolidated list of measures to avoid and mitigate impacts of the DPD Project.

Table 12-1 Management actions that will be used for avoidance, mitigation and monitoring of impacts to the relevant environmental factors for the DPD Project

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
Planned Events								
Seabed disturbance	**Avoidance**							
	MA12	The pipeline route has been surveyed (geophysical and geotechnical) to evaluate seabed in conjunction with engineering design requirements. Trenching, stabilisation and freespan correction/prevention will only be undertaken at identified areas (using standard positional accuracy measures used in the industry).	X	X		X	X	X
	MA20	In shallower waters, anchor exclusion areas will be implemented to avoid sensitive habitats and heritage sites.	X	X		X	X	X
	-	Placement of pipe to be based on subsea heritage and habitat assessment studies to enable the avoidance of designated sensitive benthic habitats, and heritage and culturally sensitive areas.	X	X		X	X	X
	Mitigation							
	MA28	Adaptive management process is defined within the Trenching and Spoil Disposal Management Plan (**Appendix 4**). Environmental monitoring of	X	X		X	X	X

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
		water quality with management measures applied if water quality exceeds trigger levels.						
	MA13	Overflow from the TSHD will be undertaken through the adaptive management processes. There will be an 'environmental valve', 'green valve' or Anti-Pollution Valve (APV) where available (attached to O/F to reduce air entrained, to reduce billowing and facilitates sediment sinking) as standard which will be used as a first step to capture fine sediment from disposal at dredge.	X	X		X	X	X
	MA14/ MA15	Standard operating procedure for spoil disposal will be used. Spoil will not be disposed of in a single location, so will avoid developing a single large mound at the spoil disposal ground.	X	X		X	X	X
	MA17	Dynamically Positioned (DP) pipelay vessel will be used to install the pipeline in deeper waters. The DP vessel can be used in deeper water from KP23 (Territorial water boundary) to approx. KP91.5 where shallow water (<20 m) occurs, and will not require anchoring.	X	X		X	X	X
	MA18	An Anchor Management Plan will be developed to allow safe anchoring of vessels undertaking pipelay, trenching and pile driving activities in the vicinity of nearshore heritage or sacred sites.	X	X		X	X	X

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	MA19	Use of trained and competent anchor handling operators.	X	X		X	X	X
	MA22	Differential Global Positioning System (DGPS) for pipelay vessel to maintain accurate vessel position during installation.	X	X		X	X	X
	MA23	Checks prior to installation to confirm: + DGPS used to confirm ILT foundation structure position during installation; and + Underwater positioning system (USBL/transponders) and ROV to confirm installation location and positioning of pipeline (within required location accuracy to reduce disturbance to the seabed).	X	X		X	X	X
	MA24	Installation plan developed and includes: + requirement for trained and experienced vessel crews; and + trenching will be restricted to only areas where required.	X	X		X	X	X
	MA25/ MA26	Based on subsea heritage and habitat assessment studies, span-specific rectification plans developed that include: + Pre-span method selection; + Real-time monitoring of span rectification; + Post-rectification inspections; and	X	X		X	X	X

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
		+ Permanent rock installation will be limited to only those pipeline sections requiring stabilisation and/or anchor protection.						
	Monitoring							
	MA29	Continuous monitoring of anchor wire tensions to prevent anchor drag on seabed. Additionally wire length measurement of the winch will be monitored. Based on experience this parameter is a good indicator to prevent anchor drag. These two parameters are monitored to act as mitigation to prevent anchor drag.	X	X		X	X	X
	MA28	Adaptive management process as defined within a Trenching and Spoil Disposal Management Plan (**Appendix 4**). Environmental monitoring of water quality with management measures applied if water quality exceeds trigger levels.	X	X		X	X	X
Contingency treated seawater discharge- from wet buckle scenario	**Avoidance**							
	MA71	Pipeline installation procedures to be prepared and followed.	X	X			X	
	MA71	Maintenance requirements for pipelaying to minimise risk of operational failure.	X	X			X	
	MA71	Shallow water pipelay barge has redundancy in its anchors for stability.	X	X			X	

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	MA71	Deep water pipelay vessel – has redundancy in its station keeping abilities and operates in accordance with approved activity specific operating guidelines.	X	X			X	
	Mitigation							
	MA72	Chemical selection procedure for all chemicals, including treated seawater, discharged to the marine environment.	X	X			X	
	MA73	Calibrated chemical dosing system in place to ensure accuracy.	X	X			X	
	MA74	If contingency use and discharge of treated seawater is required, the lowest required concentration of treatment chemical will be evaluated and used (up to a maximum of 550 ppm) in order to meet pipeline preservation requirements.	X	X			X	
	MA71	Maintenance requirements for pipelaying to minimise risk of operational failure.		X			X	
	Monitoring							
	MA76	In the unlikely event that the pipeline requires contingency filling and subsequent dewatering of treated seawater in response to a wet buckle event and prolonged repair, water quality monitoring of the dewatering at	X	X				

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
		the discharge location will be conducted to confirm the concentration and dispersion of treatment chemicals.						
Noise emissions	**Avoidance**							
	-	Use of trenching vessels has been reduced as far as practicabl.		X			X	
	Mitigation							
	MA49	Vessel inductions for all crew to address marine fauna risks and the required management controls.		X				
	MA50	Vessels and helicopters to abide by Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interactions with marine fauna.		X				
	MA56	Standard protocols for managing trenching vessel noise impacts included within the Marine Megafauna Noise Management Plan (**Appendix 7**).		X				
	MA62	Soft start (ramp-up) of hydraulic tools by BHD, where practicable		X				
	MA62	Soft start (ramp-up) of trenching equipment, where practicable, will apply to the CSD and TSHD.		X				
	MA54	Vessels will adhere to Port of Darwin vessel speed limits.		X				

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	MA55	Vessel engines and Project equipment/machinery maintained as per planned maintenance system.		X				
	MA51	Personnel trained in marine fauna observation (MFO) present on pipelay, trenching and rock installation vessels during daylight hours, including one crew member with MFO training on the bridge at all times.		X				
	MA52	All marine fauna interactions and observations to be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW as required.		X				
	MA56	Observation and shut-down zones for marine fauna have been developed based on noise modelling results and standard protocols. For trenching activities, excluding hydraulic hammering this includes: + An Observation Zone of 150 m and an Exclusion Zone of 50 m for marine mammals and turtles will be in place around trenching vessels (TSHD, CSD and BHD) for trenching activities; and + Observation Zone monitored for 10 minutes prior to commencing trenching during daylight hours only.		X			X	
	MA56	Contingency hydraulic hammering management measures (not applicable for Xcentric Ripper tool).		X				

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	-	Contingency hydraulic hammering protocols for managing noise impacts included within the Marine Megafauna Noise Management Plan (**Appendix 7**).		X				
	-	Hydraulic hammering for no greater than 8 hrs over a 24 hr period.		X				
	-	No hydraulic hammering at night.		X				
	-	Increased Observation and Exclusion Zones for hydraulic hammering based on noise modelling results will be applied as follows: + If up to 8 hours of rock breaking is required, an increased Observation Zone of 2.5 km (marine mammals) and 1 km (turtle) will apply and an increased Exclusion Zone of 150 m for marine mammals and turtles will apply; + If up to 6 hours of rock breaking is required, an increased Observation Zone of 2 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100 m for marine mammals and turtles will apply; + If up to 4 hours of rock breaking is required, an increased Observation Zone of 1.5 km (marine mammals) and 750 m (turtle)		X				

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
		will apply and an increased Exclusion Zone of 100 m for marine mammals and turtles will apply; and + If up to 2 hours of rock breaking is required, an increased Observation Zone of 1 km (marine mammals) and 500 m (turtle) will apply and an increased Exclusion Zone of 50 m for marine mammals and turtles will apply.						
	-	A separate vessel with MFO onboard will be required to patrol the Observation Zone prior to and during hydraulic hammering.		X				
	MA55	Maintenance of equipment/machinery.		X			X	
Light emissions	**Avoidance**							
	MA58	The pipelay vessel will have an enclosed pipe welding deck.		X				
	MA61	Vessel searchlights will only be operated in an emergency situation.		X				
	Mitigation							
	MA60	Housekeeping measures will be adopted, including requiring all crew to keep shutters on windows closed at night, to limit light emissions from vessels.		X				

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	MA59	Orient lights to area of direct work. Reduce overspill where practicable.		X				
	Monitoring							
	MA62	Santos will document vessel light spill on Darwin Harbour turtle nesting beaches as part of the DPD Project's environmental monitoring program.		X				
GHG emissions	**Mitigation**							
	-	Maintenance undertaken in accordance with maintenance regime by qualified personnel.			x			
	-	Implementing Marine Order 97 (Marine Pollution Prevention - Air Pollution) including (as required by vessel class) ensuring that vessels maintain a Ship Energy Efficiency Management Plan (SEEMP).			X			
	-	Implement a risk-based inspection (RBI) schedule for vessel-based pipeline inspection, maintenance and repair (IMR) activities, in accordance with industry standards, to ensure the safe operation and integrity of the pipeline and to optimise the frequency of IMR vessel activities (with associated emissions).			X			

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
Physical presence	**Avoidance**							
	MA11	Pipeline will not be laid in the vicinity of the Jewfish aggregation area within the Charles Point Wide RPA.					X	
	MA12	The pipeline route has been surveyed (geophysical and geotechnical) to evaluate seabed in conjunction with engineering design requirements. Trenching, stabilisation and freespan correction/ prevention will only be undertaken at identified areas (using standard positional accuracy measures used in the industry).				X	X	
	Mitigation							
	MA10	Causeways will be temporary structures and will be removed following trenching and installation.				X	X	
	MA01	Intertidal and shoreline construction is in pre-disturbed area (DLNG footprint).				X	X	
	-	Minimise placement of rock berms and when placed, where practicable the rock berms will be placed in trenches and will not protrude above natural seabed level.				X		
	-	All anchor pennant buoys will have lights and radar reflectors.					X	

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	-	The design of the pipeline has been performed to reduce risks from loss of containment events to ALARP for the life of the Project.					X	
	-	Installation procedures shall be developed for all activities and will form the basis of constructability assessments and hazard workshops used to ensure all aspects of the works are conducted safely.					X	
	-	Key stakeholders, will be invited to risk assessment workshops.					X	
	MA24	Company has engaged competent and skilled contractors with proven experience and capability to perform the installation activities.					X	
	-	All Project vessels shall undergo an extensive Santos Marine assessment and third-party Marine Warranty Survey prior to mobilisation.					X	
	-	All engineering and installation activities and designs will be verified and validated by independent third-party verification bodies, such as DNV and Marine Warranty Surveyors where applicable.					X	
	-	Installation, testing and operations shall be performed under a DITT accepted and independently validated Pipeline Management Plan.					X	
	MA101	Barges will have a 500 m exclusion zone for duration of construction activities.					X	

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
Ground disturbance (onshore)	**Avoidance**							
	MA32	The area is within the previously disturbed footprint from construction of the Bayu-Undan to Darwin pipeline and DLNG facility.				X	X	
	Mitigation							
	MA35	When required, geotextiles will be installed under the primary construction area preventing intermingling of soil and inhibits erosion of the existing ground.				X	X	
	MA36	Area returned to natural grade to match existing topography.				X	X	
	MA39	Implement ASS and groundwater management and monitoring requirements within the ASSDMP if ASS or groundwater is encountered during onshore construction activities. The ASSDMP includes requirements for: + ASS Stockpiling, laboratory testing and treatment; + Groundwater laboratory testing and treatment; and + Maintenance of testing and inspection records.				X	X	

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
Unplanned Events								
Hydrocarbon spill	**Avoid**							
	MA102	No Intermediate Fuel Oil and Heavy Fuel Oil will be used in in the operational area.	X	X		X	X	X
	MA100	Vessel equipped and crewed in accordance with Australian maritime requirements.	X	X		X	X	X
	MA101	A Notice to Mariners will be issued for offshore works advising all major shipping traffic formally. In addition, pipelay vessels will have attendant vessels that may act as guard vessels for work within the harbour.	X	X		X	X	X
	MA96	Chemicals and hydrocarbons will be transferred and stored in accordance with standard maritime practices as per vessel SOPEP.	X	X		X	X	X
	MA99	Vessel-specific bunkering procedures and equipment consistent with Santos marine vessel vetting requirements including: + Use of bulk hoses that have quick connect 'dry break' couplings; + Correct valve line-up; + Defined roles and responsibilities, and the specific requirement for bunkering to be completed by trained personnel only;	X	X		X	X	X

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
		+ Visual inspection of hoses prior to bunkering to confirm they are in good condition; + Testing of the emergency shutdown mechanism on the transfer pumps; + Assessment of weather/sea state; + Maintenance of radio contact with Vessel during bunkering operations; + Bunkering checklist; and + Visual monitoring during bunkering.						
	Mitigation							
	MA97	Spill clean-up kits available in all areas, including high risk areas.	X			X	X	X
	MA103	Implement tiered spill response in the event of a hydrocarbon spill as outlined in an oil pollution emergency plan for DPD Project construction and operations.	X	X		X	X	X
	MA104	Oil spill tracking buoys will be made available on primary project vessel/s with Santos CSR/s and/or at local supply base for immediate deployment to assist with tracking of an oil spill.	X	X		X	X	X

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	Monitoring							
		Operational and scientific monitoring to be undertaken in event of a hydrocarbon spill as outlined in an oil pollution emergency plan for DPD project construction and operations.	X	X		X	X	X
Dropped objects	**Avoidance**							
	-	Lifting and operational procedures in place and implemented.		X			X	
	MA75	Implementation of Santos approved standards and procedures for outboard lifts.		X			X	
	MA78	All lifting and winching equipment will undergo inspection, testing and certification as per applicable laws and applicable codes and Standards.		X			X	
	MA80	Identification of no lift zones where relevant in proximity to subsea assets and infrastructure as documented in relevant lifting and operational procedure/s.		X			X	
	MA18/ MA20	Program anchor plots - avoid sites of significance or infrastructure.		X			X	
	-	Anchor handling controls - anchor deployment and recovery only in approved safe lifting zones.		X			X	

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
	Mitigation							
	MA79	Dropped objects recovered where safe and practicable to do so.		X			X	
	MA82	Emergency response implemented to minimise potential for impacts in the event of a loss of containment from the Bayu-Undan or other gas pipeline as a result of a dropped object during DPD Project installation.		X			X	
Invasive marine species	**Avoidance**							
	MA84	Vessels equipped with effective anti-fouling coatings as required for class.		X		X	X	
	MA85	Ballast water management will comply with the International Convention for the Prevention of Pollution from Ships (MARPOL) requirements (as applicable to class), *Australian Ballast Water Management Requirements and Biosecurity Act 2015*.		X		X	X	
	MA86	Apply risk-based IMS management for vessels and immersible equipment - vessel and immersible equipment must be assessed as having a low risk of IMS prior to coming onto activity as per Santos IMS procedures.		X		X	X	
	MA87	Vessels having suitable anti-fouling coating (marine growth prevention system) in accordance with the *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006*.		X		X	X	

Potential Impact	Management Action (MA) Reference	Management Measures	Marine Environmental Quality	Marine Ecosystems	Atmospheric Processes	Coastal Processes	Community and Economy	Culture and Heritage
Marine fauna interactions	**Mitigation**							
	MA49	Vessel inductions will address marine fauna risks and the required management controls.		X			X	
	MA50	Vessel movements will comply with Part 8 of the EPBC Regulations 2000.		X			X	
	MA51	Personnel trained in marine fauna observation present on pipelay, trenching and rock installation vessels during daylight hours, including one crew member with MFO training on the bridge at all times.		X			X	
	MA56	An Observation Zone of 150 m and an Exclusion Zone of 50 m for marine mammals and turtles will be in place around trenching vessels (TSHD, CSD and BHD) for trenching activities.		X			X	
	MA56	A Marine Fauna Observation and Management Protocol for Trenching Activities (included in a Trenching and Spoil Disposal Monitoring and Management Plan) will apply to the Observation and Exclusion Zones.		X			X	
	MA89	Use of turtle 'tickler' chains on the trailing arms of the TSHD.		X			X	
	MA52	All marine fauna interactions and observations will be appropriately recorded and reported to relevant authorities.		X			X	

13 Cumulative Impact Assessment

The environmental impact and risk assessment process applied to this proposal includes a method to assess cumulative impacts from both DPD Project activities and existing and proposed project activities that may overlap the DPD Project area in time and/or space (refer **Section 7.5.1**). This section presents the implementation and outcome of that assessment process.

13.1 Identification of relevant projects and activities

There are a number of existing activities and proposed projects within Darwin Harbour and the wider region that have the potential to impact the environment, which have been evaluated as part of the cumulative impact assessment for this proposal. These include government and private infrastructure projects, Darwin Harbour dredging activities, and resource processing operations.

Relevant projects which may result in cumulative impacts as defined in **Section 7.5.1** were identified by searching the following databases:

+ NT EPA environmental impact assessment register;
+ NT EPA consultation hub (open and closed consultations);
+ Department of Chief Minister and Cabinet Major Projects; and
+ Department of Planning, Infrastructure and Logistics list of government projects.

In addition to these databases, existing Darwin Harbour uses and activities were also considered.

The projects identified by this search were then screened for development status. Projects whose approval had been revoked or withdrawn were excluded. The remaining projects were then screened for potential spatial and temporal interaction with the Project. The final list of relevant projects identified is provided in **Table 13-1.**

Table 13-1 Relevant Projects

Project	Project Impact Type	Description	Assumed Key Impacts Based on Current Knowledge and Related to the Project	Construction / Operation Timeframes	Additional Information
Department of Infrastructure, Planning and Logistics – Middle Arm Sustainable Development Precinct	Capital and maintenance dredging. Industrial Development.	This project involves development of approximately 1,500 ha of land on Middle Arm Peninsula, including landside and marine enabling infrastructure. The Middle Arm Peninsula is located within Darwin Harbour, approximately 7 km by road from the City of Palmerston, and 8 km across the harbour from the Darwin Central Business District. The project includes the establishment of a 'development ready' sustainable precinct aimed to attract industries, with a focus on low emission petrochemicals, renewable hydrogen, carbon capture and storage and minerals processing. Dredging activities are required to facilitate the development of this project.	The project's self-assessment identified 12 of the environmental factors that have the potential to be significantly impacted by the DPD project activities. Key impacts based on current knowledge and the referral information are likely from: + Changes to the physiology of Darwin Harbour seabed from dredging, marine infrastructure construction and shipping operations may result in impacts to hydrodynamics and indirect impacts to water quality and sediment deposition; and + Significant impacts to Marine Ecosystems and threatened species may occur due to disturbance of habitat during dredging, marine infrastructure construction and shipping operations.	The proponent Department of Infrastructure, Planning and Logistics is seeking approval for construction and development activities that may occur over a period of 50 years across the full Precinct life-cycle including design, construction and operational phases. Santos has been advised that construction is not expected to occur prior to 2025.	Middle Arm Sustainable Development Precinct https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/middle-arm-sustainable-development-precinct
Department of Chief Minister and Cabinet – Darwin Ship Lift and Marine Industries Project	Capital and Maintenance Dredging Marine and Coastal Infrastructure Development.	The project involves the construction and operation of a common user ship lift, repair and maintenance facility approximately 700 m east of the existing East Arm Wharf and Marine Supply Base in Darwin Harbour. The project will enable maintenance and servicing of a broad range of industries including the Australian Defence Force and Australian Border Force vessels and for commercial and private vessels (oil, gas, pearling, fishing and other marine industries). Dredging activities are required to facilitate the development of this project.	Key impacts based on current knowledge and the referral information are related to: + Impacts to water quality during the project construction phase, specifically elevated suspended sediment concentrations associated with dredging and placement of dredged material on shore as fill for land reclamation; + Impacts to benthic communities in intertidal and shallow subtidal 'soft sediment' habitats within, and adjacent to, the dredging and reclamation footprints; + Potential impacts upon other marine flora and fauna communities, such as those comprised of filter feeders (e.g. sponges, soft corals), hard corals and macroalgae, however as per	Project construction is expected to be completed in 24-36 months following completion of approvals and detailed design by the end of 2022, with the Project planned to be operational by 2025. Dredging is expected to occur throughout 2023 and be completed by Q2 2024.	Darwin Ship Lift and Marine Industries Project https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/darwin-ship-lift-and-marine-industries-project

Project	Project Impact Type	Description	Assumed Key Impacts Based on Current Knowledge and Related to the Project	Construction / Operation Timeframes	Additional Information
			modelling it is predicted that these communities are not at risk of significant impacts; + Impacts to an isolated stand of remnant mangrove community of ~1.0 ha extent will be removed during reclamation works; and + Impacts to road users from road logistics associated with the project.		
Australia-Asia Powerlink Australia Assets Pty Ltd – Australia-Asia Powerlink Project	Onshore and Offshore Infrastructure Development.	The onshore project components are located within the NT. The offshore components, comprised of the Subsea Cable System, extends to approximately 748 km within the Australian Exclusive Economic Zone and then approximately 147 km on the Continental Shelf up to the boundary of the Seabed Treaty with Indonesia. The project involves six key components, the main components of interest to the Project includes the: The Overhead Transmission Line to transmit electricity from the Solar Precinct to Darwin. Darwin Converter Site including Voltage Source Converters, energy storage and network connection to supply electricity to the Darwin region. Cable Transition Facilities at Murrumujuk and Gunn Point Beach to transition power cables between land and sea. Subsea Cable System extending from the Cable Transition Facilities to Singapore.	The project may result in the following environmental impacts of relevance to the Project: + Increased turbidity in marine waters caused by cable laying activities; + Direct disturbance or loss of benthic habitats; + Habitat degradation due to elevated turbidity; + Changes to fauna behaviours due to noise or light; and + Fauna mortality / collisions with vessels.	Construction of the Australia Asia PowerLink will take approximately four years and is proposed to start in early 2024. Installation of submarine cable is expected to occur between 2025 and 2029 dependent upon availability of cable.	Australia-Asia Powerlink Project https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/australia-asia-powerlink-project
Department of Infrastructure, Planning and Logistics – Mandorah Marine Facilities	Capital and Maintenance Dredging. Marine and Coastal Infrastructure Development	The project is located adjacent the existing Mandorah Jetty. The proposed facility uses two large breakwaters to form a harbour with new ferry berthing and passenger boarding infrastructure. The project includes capital dredging of an access channel, turning basin and berthing areas for the ferry, as well as safe navigation of recreational vessels to and from the boat ramp.	The project may result in the following environmental impacts of relevance to the Project: + Dredging has the potential to release contaminants from seabed sediments into the marine environment and release waste and pollutants to the marine environment; + Potential water quality (turbidity) issues due to sediment plumes generated by dredging actions;	Santos has been advised that this project may commence in 2023 subject to approvals. The dredging period may take 2 to 3 months.	Mandorah Marine Facilities https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/mandorah-marine-facilities

Project	Project Impact Type	Description	Assumed Key Impacts Based on Current Knowledge and Related to the Project	Construction / Operation Timeframes	Additional Information
			+ Destruction of Marine Ecosystems within the footprint; and + Interaction with marine fauna.		
Department of Defence – HMAS Coonawarra - Dredging and Dredged Material Management	Capital and Maintenance Dredging.	The Department of Defence proposes to carry out two capital dredging campaigns of approximately 100,000 m^3 to 120,000 m^3 as part of upgrades to the Royal Australian Navy wharf facilities and basin navigation area at HMAS Coonawarra. Dredge spoil is proposed to be discharged at a location near the HMAS Coonawarra in Darwin Harbour, Larrakeyah, Darwin. The proposed action includes ongoing maintenance dredging at HMAS Coonawarra in the order of 10,000 m^3 to 15,000 m^3 every 5 to 7 years.	The project may result in the following environmental impacts of relevance to the Project: + Dredging and dredged material disposal have the potential to effect Marine Environmental Quality via impacts to water quality within the dredge area and in the vicinity of the discharge location; + Impacts and disturbance to benthic communities within the basin; and + Potential for direct impacts to marine fauna from vessel movements and dredge machinery.	Dredging for the current project is anticipated to commence in early 2023. This would be completed over a period of approximately two months. The future Eastern Wharf dredging works would be undertaken as a separate campaign, approximately two to three years after the completion of the first priority NCIS-5 project dredging campaign (2024 or 2025). This would be completed over a period of 2-3 months. Future maintenance dredging is also proposed at 5-7 year intervals.	HMAS Coonawarra - Dredging and Dredged Material Management https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/hmas-coonawarra-dredging-and-dredged-material-management
TNG Limited – Darwin Processing Facility	Industrial Development.	TNG Limited (TNG) proposes to construct and operate the Darwin Processing Facility at Middle Arm located within the Darwin Harbour. The facility would process magnetite concentrate railed from TNG's (separately proposed) Mt Peake project, 1,400 km south of Darwin. The project includes: + Construction and operation of a magnetite concentrate Processing Facility. + Construction and operation of a rail siding, unloading and loadout facilities on the Adelaide-Darwin railway. + Loading of trains at the rail siding, with products to be railed to East Arm Wharf. + Development of support infrastructure. + Clearing of a partially vegetated allotment formerly utilised for extractive industries.	It was noted that project would not directly interact with the marine environment, disturb benthic habitats or result in clearing of mangrove communities but noted that there may be some indirect impacts from increases in concentration of total suspended solids from sedimentation and contaminants such as hydrocarbons and metals from stormwater if primary containment measures fail.	The NT EPA directed TNG Ltd to provide additional information on 20 May 2021. Construction is scheduled to commence following receipt of statutory approvals and subject to finance and TNG Board Financial Investment Decision Approval. Construction activities expected to occur over a 24 month period.	Darwin Processing Facility https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/darwin-processing-facility
INPEX – Ichthys Maintenance Dredging	Capital and Maintenance Dredging.	The existing Ichthys LNG project includes a periodic maintenance dredging program within an approved dredge area. This is located near the Ichthys LNG Plant. A Maintenance Dredging and Spoil Disposal Management Plan has been prepared to allow a maximum volume of 1.5 Mm^3 to be dredged within an	Potential impacts include: + Vessel collision causing injury to fauna; + Entrainment of marine turtles and sawfish;	The maintenance dredging could begin as early as mid-2023 subject to regulatory approvals and operational requirements, but is expected to occur in 2024 following completion of DPD Project trenching.	Ichthys Maintenance Dredging https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/completed-

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Project	Project Impact Type	Description	Assumed Key Impacts Based on Current Knowledge and Related to the Project	Construction / Operation Timeframes	Additional Information
		approved five year period, with no single campaign exceeding. The dredge area lies within East Arm, Darwin Harbour. The dredge spoil disposal area (DSDA) is located to the north of Darwin Harbour, within the Beagle Gulf, approximately 12 km north-west of Lee Point. It is located approximately 45 km from the dredge area in water depths between 15 m and 20 m below LAT.	+ Accidental disturbance and removal of coral or smothering of coral and seagrass; + Accidental loss of hydrocarbons and impact to environment; and + Sedimentation accumulation in intertidal areas and subtidal areas.		assessments/register/ichthys-gas-field-development-inpex
Darwin Port Operations Pty Ltd – Darwin Harbour Maintenance Dredging	Capital and Maintenance Dredging.	Darwin Port Operations Pty Ltd (Darwin Port) operates port facilities within Darwin Harbour; these include Fort Hill Wharf, East Arm Wharf and the Marine Supply Base (MSB). Darwin Port has a need to periodically undertake maintenance dredging to remove unconsolidated sediment (e.g. clay, silt, sand) that is naturally transported and deposited into existing berth pockets at East Arm Wharf and Fort Hill Wharf, and into the berth pockets, turning basin and channel of the MSB.	Potential impacts include: + Displacement of protected marine species; + Vessel collision with protected species; + Mortality of biota entrained with dredged sediments and smothering of biota; and + Increased sedimentation and associated impacts.	The frequency of maintenance dredging is dependent upon the rates of sediment accumulation at the three locations but it is estimated that the berth pockets at East Arm Wharf and Fort Hill Wharf will require maintenance dredging at intervals of no less than six years, and that maintenance dredging at the MSB will be required no more frequently than every three years (Streten, Tsang & Harries 2017). There is no information to suggest that dredging will be required in 2023 or 2024.	Darwin Port Long Term Dredging Management Plan https://www.darwinport.com.au/sites/default/files/uploads/2018/LTDMP 60553579_Darwin Port LTDMP_Rev1 5 Feb 18 with Appendix A.pdf
Defence Housing Australia – Lee Point Master-planned Urban Development	Residential and Commercial Development.	Defence Housing Australia is proposing a development on 132.5 ha of land at Lee Point. The development will include urban residential uses at varying densities, rural residential allotments, land for community development and open spaces.	Potential impacts expected from the project are: + To Casuarina Beach and turtle nesting sites as a result of light impact; and + Traffic delays, congestion, and road safety risk.	The project would proceed with the aim of releasing one stage each year, with a total estimated construction timeframe of seven years. It is understood construction has not yet commenced.	Lee Point Master-planned Urban Development https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/completed-assessments/register/lee-point-urban-dev
KTT Investment Pty Ltd – North One Hotel and Apartments	Residential and Commercial Development.	KTT Investment Pty Ltd submitted a referral for consideration under the *Environment Protection Act 2019* to develop in the Town of Darwin into accommodation for tourism, consisting of beachfront and lagoon villas, a hotel, serviced apartments, dining facilities, a market, function centre, bar and recreation facilities.	Potential impacts from the project are: + To Little Mindil Beach and Shore birds; and + Traffic delays, congestion, and road safety risk.	Construction of the development is anticipated to occur over a 3-year period. There is no information to suggest that this project is going ahead.	North One Hotel and Apartments https://ntepa.nt.gov.au/your-business/public-registers/environmental-impact-assessments-register/assessments-in-progress-register/north-one-hotel-and-apartments

Project	Project Impact Type	Description	Assumed Key Impacts Based on Current Knowledge and Related to the Project	Construction / Operation Timeframes	Additional Information
Existing Harbour Users	Existing.	The Port of Darwin is Australia's nearest port to Asia and is a gateway for trade in the north. The Port of Darwin supports the offshore oil and gas fields in the Arafura Sea, Timor Sea and waters off the coast of Western Australia and provides services for naval ships and several types of trading vessels (Radke, et al. 2019). The yearly vessel visits for Darwin Harbour for recent years are shown below (Darwin Port, 2022): + 2021-22 – 1,510 vessel visits. + 2020-21 – 1,416 vessel visits. + 2019-20 – 1,472 vessel visits. + 2018-19 – 1,808 vessel visits. + 2017-18 – 1,615 vessel visits. + 2016-17 – 1,150 vessel visits. + 2015-16 – 1,320 vessel visits. + 2014-15 – 1,715 vessel visits. + 2013-14 – 3,178 vessel visits. + 2012-13 – 2,766 vessel visits. + 2011-12 – 1,502. vessel visits.	Potential impacts include: + Displacement of protected marine species; + Vessel collision with protected species; + Increased sedimentation and associated impacts; and + Accidental loss of hydrocarbons and impact to environment.	Existing users utilise the Darwin Harbour all year round.	Not available.

13.1.1 Degree of cumulative impacts for relevant projects

The degree of cumulative impact between the Project and identified nearby projects and activities was determined based on the potential for spatial and temporal interaction. The following classifications based on Rees (1995) were used:

+ High – There is potential for direct spatial overlap of impacts and temporal overlap of impacts associated with the projects;
+ Medium – Impacts are not likely to directly overlap spatially but are so close in space that assimilation of combined impacts into the environment is likely. Additionally, impacts are so close in time that impacts are not dissipated before further impacts occur; and
+ Low – Impacts do not directly overlap spatially and are separated in space such that combined impacts environment are unlikely. Impacts may be either be close or separated in time.

Table 13-2 lists the classification for each of the projects identified in **Table 13-1** and is ordered from high to low classification.

Within the Darwin Harbour, there are five projects identified as having the potential for cumulative impact over time with the Project. These projects are:

+ Department of Infrastructure, Planning and Logistics – Mandorah Marine Facilities;
+ Department of Defence – HMAS Coonawarra – Dredging and Dredged Material Management;
+ Department of Chief Minister and Cabinet – Darwin Ship Lift and Marine Industries Project;
+ INPEX – Ichthys Maintenance Dredging; and
+ Australia-Asia Powerlink Australia Assets Pty Ltd – Australia-Asia Powerlink Project.

The locations of high and medium classified projects and their projected timeframes and duration for construction and operation in relation to the DPD Project area are shown in **Figure 13-1** and **Figure 13-2** respectively.

In addition to these five projects, the impacts from existing Darwin Harbour users and activities and impacts and disturbance resulting from the previous construction and ongoing operation of the Bayu-Undan to Darwin pipeline and the Ichthys pipeline have also been considered through the cumulative impact assessment process for the relevant environmental factors and values, refer **Sections 13.2** to **Section 13.5**. Management measures for impacts that have potential to result in significant cumulative impacts were identified where required.

Table 13-2 Assigned Classification of Projects Relevant to Cumulative Impacts

Project	Distance From Project area	Degree	Rationale – Based on current timing and spatial estimates
Existing Harbour Users (including vessel traffic)	0 km	High	Spatially adjacent to the Project. Located in the Darwin Harbour. Potential for vessel interaction during operation of existing harbour users and during the construction of the Project.
Department of Infrastructure, Planning and Logistics – Mandorah Marine Facilities	0-2 km	High	Spatially adjacent to the Project. Located in the Darwin Harbour. Construction and dredging potentially commencing in 2023 and could potentially extend into 2024. Potential for vessel interaction and dredge plume interaction with the DPD Project during construction and dredging.
INPEX – Ichthys Maintenance Dredging	0-1 km (Spoil Disposal Ground located next to Ichthys LNG project spoil disposal ground)	Medium	Spoil grounds are adjacent although dredging areas are separated by >5 km. Located in the Darwin Harbour. Potential for dredging to commence in 2024 although it is expected dredging would commence after completion of DPD Project trenching.
Department of Defence – HMAS Coonawarra - Dredging and Dredged Material Management	0-1 km (immediately adjacent)	Medium	Spatially adjacent to the Project. Located in the Darwin Harbour. Dredging for the Coonawarra NCIS-5 project is expected to be completed in 2023, prior to trenching for the DPD Project. Low likelihood of overlapping plume.
Department of Chief Minister and Cabinet – Darwin Ship Lift and Marine Industries Project	5-6 km	Medium	The Ship Lift construction and dredging area is >5 km from the DPD Project trenching areas. Located in the Darwin Harbour. Construction timeframes currently align. However, there is low potential for vessel interaction during construction given the separation between projects. There is also expected to be no/negligible overlap in sediment plumes generated by Ship Lift dredging and DPD Project

Project	Distance From Project area	Degree	Rationale – Based on current timing and spatial estimates
			trenching. The greatest potential for overlap in activities is from road logistics for both projects sharing the same transport routes and potentially simultaneous operations at East Arm Wharf during DPD Project rock loading.
AA Powerlink Australia Assets Pty Ltd – Australia-Asia Powerlink Project	25 km (Spoil Disposal Ground from the Cable Transition Facilities at Murrumujuk and Gunn Point Beach)	Medium	Spatially distant however the Subsea Cable System will run from the shoreline and would cross the DPD Project pipeline. Construction timing may overlap however installation of the subsea cable system is scheduled to occur from 2025-2029, following completion of the DPD Project. Potential for vessel interaction near the spoil disposal ground and along the pipeline section outside of the Darwin Harbour as will occur after the DPD Project.
Darwin Port Operations Pty Ltd – Darwin Harbour Maintenance Dredging	1-2 km	Low	Spatially adjacent to the Project. Located in the Darwin Harbour. Construction timeframes unlikely to align.
Department of Infrastructure, Planning and Logistics – Middle Arm Sustainable Development Precinct	0-1 km (immediately adjacent)	Low	Spatially adjacent to the Project. Located in the Darwin Harbour. Construction timeframes do not align and therefore low potential for vessel interaction during construction.
KTT Investment Pty Ltd – North One Hotel and Apartments	1 km	Low	This is an onshore development with no overlap in the marine environment with the DPD Project. While there is potential for associated road transport activities to use the same road network as transport activities supporting the DPD Project, there is currently no indication that activities will coincide

Project	Distance From Project area	Degree	Rationale – Based on current timing and spatial estimates
			with the DPD Project construction period.
TNG Limited – Darwin Processing Facility	10 km	Low	Located within Darwin Harbour but not spatially close to the Project. Daily vehicle movements external to the site (primarily between East Arm Wharf and the site).
Defence Housing Australia – Lee Point Master-planned Urban Development	15 km	Low	The project construction has not yet commenced. Spatially not located close to the Project. However cumulative impacts are mainly related to traffic and transport related impacts.

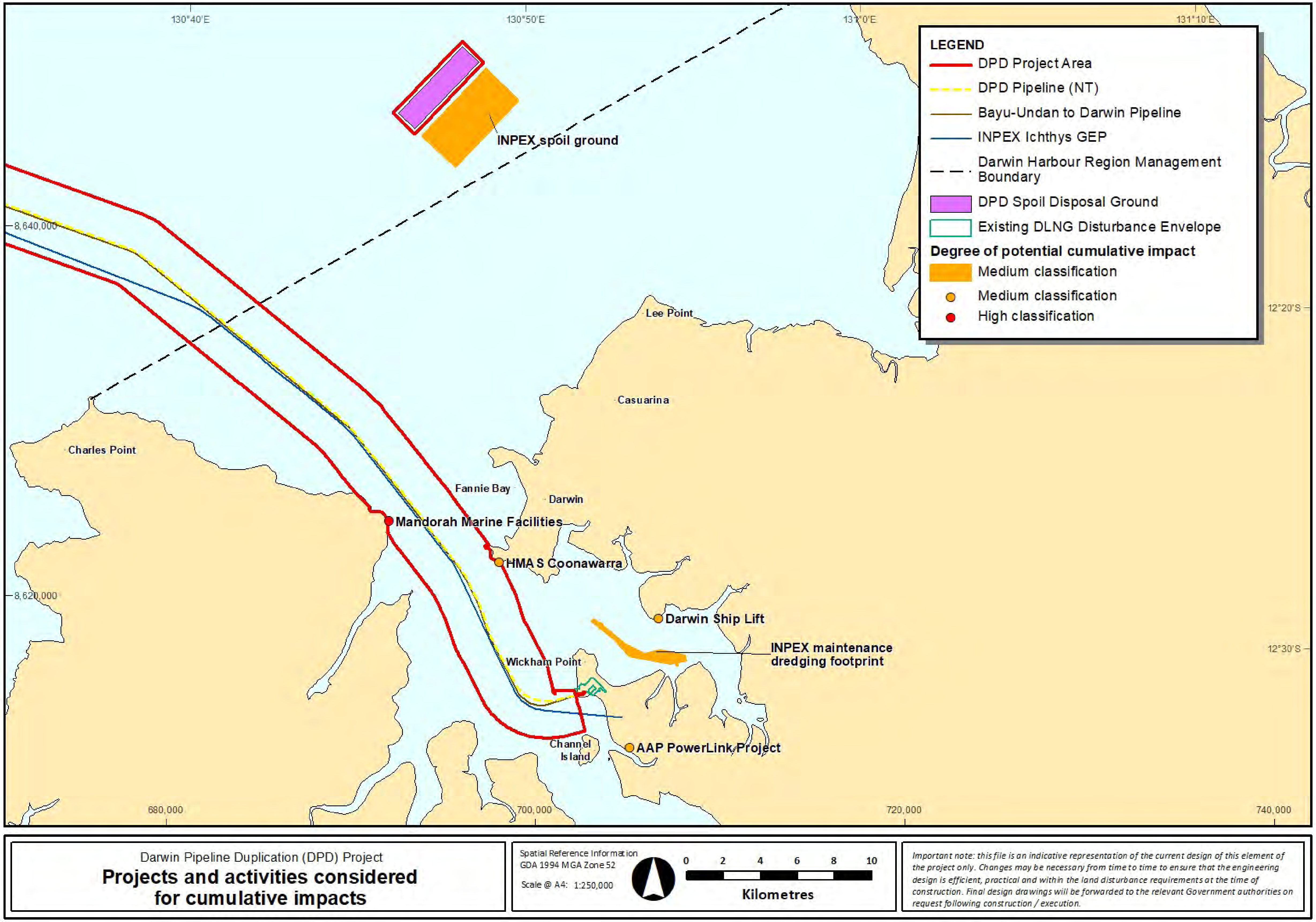

Figure 13-1 Projects and activities considered for cumulative impacts

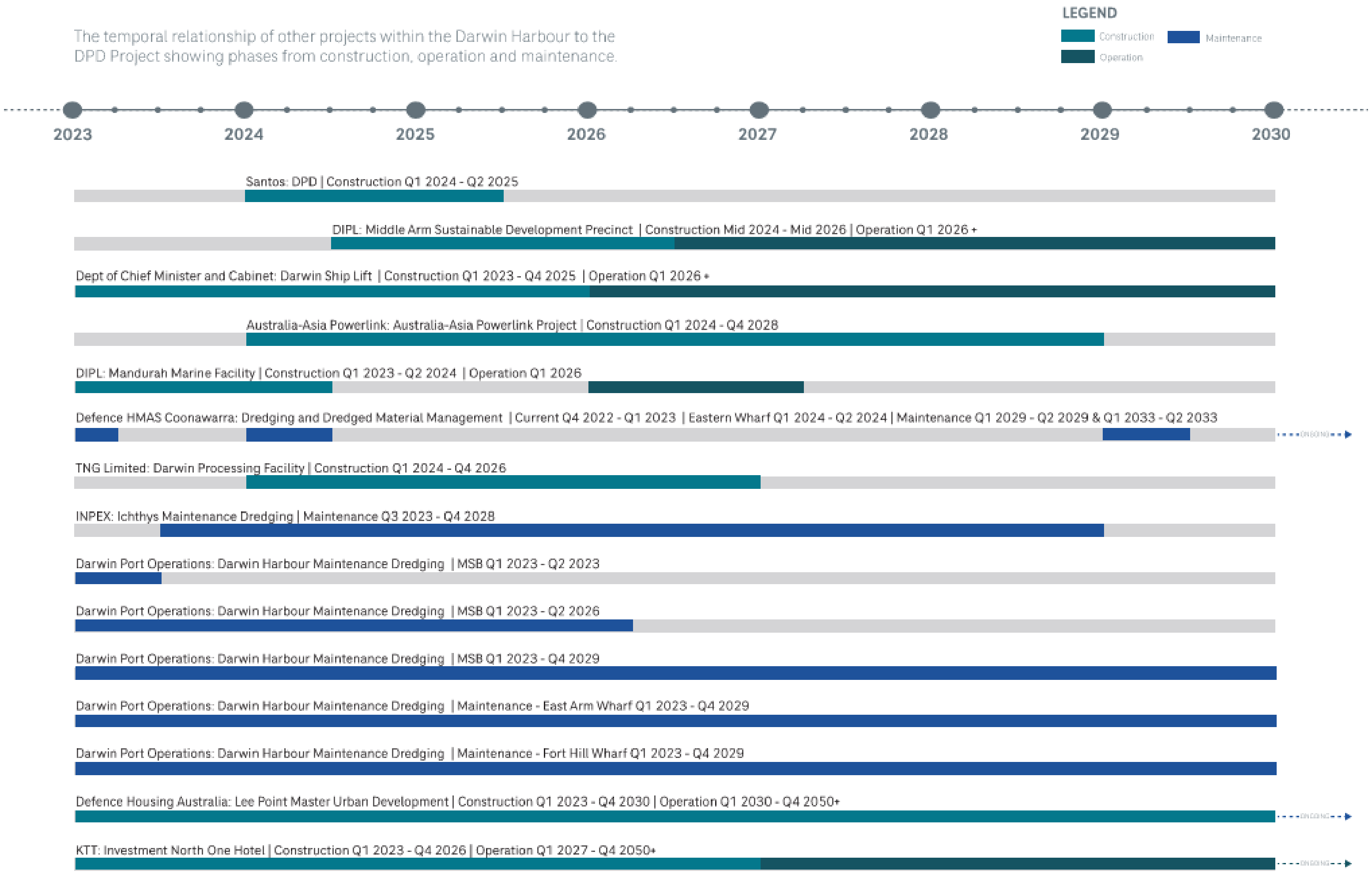

Figure 13-2 Indicative timeline of DPD project and other projects that may create cumulative impacts

13.2 Marine Environmental Quality

13.2.1 Potential cumulative impacts from dredging

Impacts to Marine Environmental Quality from dredging, both direct and indirect, have been presented in **Section 8.5.1** and the residual impacts from the DPD planned activities were assessed to be Minor. While these impacts are not predicted to be significant, if multiple dredging programs were to occur concurrently, or if nearby dredging programs were to occur in close succession to one another, there is an increased risk that the cumulative impacts may be greater than from any one activity. There are numerous variables which influence the potential magnitude of these impacts including proximity, duration and dredging methodology, as well as the volumes and type of dredged material. The type, sensitivity and resilience of the different receptors present are also factors that influence the potential for cumulative impacts. External factors such as weather and seasons can also influence the potential for cumulative impacts, as well as the availability of the appropriate dredging vessels and equipment which can limit a proponent's ability to schedule activities at a practical level to reduce or avoid concurrent activities.

The following subsections discuss the potential for spatial and temporal impacts from the respective dredge programs relating to high and medium risk projects listed in **Table 13-2**. The assessment has been modified to account for potential schedule delays and/or program cancellations that could occur since development of the modelling.

13.2.1.1 Mandorah Marine Facilities

The proposed Mandorah marine facilities (Mandorah project) covers an area of approximately 6 ha and involves dredging of an access channel, turning basin and berthing areas. The dredging footprint is approximately 1.5 km from the DPD Project pipeline route at its closest point (refer **Figure 13-1**). The draft dredging and spoil disposal management plan for the project states that 15,000 m^3 of unconsolidated marine sediments in Stage 1 and 70,000 m^3 of rock materials will be dredged for the project. Onshore disposal will occur for the rock and offshore for the unconsolidated sediments (Cardno, 2022c).

Dredging of the unconsolidated marine sediments will be undertaken with a CSD and spoil will be disposed of by piping it offshore to a disposal site located approximately 600 m from the DPD Project pipeline route at its closest point and approximately the same distance from the nearest DPD Project trenching area (Trenching Area C1A and Pre-sweep Area 3, labelled as Trench Extent 6 and 10 respectively in **Figure 2-4**).

To determine the potential for influence and impact to Marine Environmental Quality, sediment transport modelling (Cardno, 2022b) was undertaken using a similar approach to that used by Santos for the DPD Project. The modelling was used to identify potential impact zones including a Zone of High Impact (ZoHI), a Zone of Moderate Impact (ZoMI) and a Zone of Influence (ZoI) using thresholds for SSC and sedimentation for both dry and wet seasons, that were informed by INPEX Ichthys baseline water quality data (Cardno, 2022b; Cardno, 2022c).

To evaluate the potential for cumulative impacts if both activities were to occur concurrently, the spatial extents of the worst case Zones of Influence (e.g. both wet and dry) from the spoil disposal site of the Mandorah project and the worst case Zone of Influence for the closest DPD Project trenching activities (CSD and TSHD trenching area C1A and Pre-sweep Zone 3, labelled Trench Extent 6 and 10 respectively on Figure 2-4) were compared. This revealed that these Zones of Influence do not overlap and are separated by more than 400 m. Given this separation, the fact that the Zone of Influence does not indicate impact, and the lack of sensitive receptor habitat (i.e. hard corals or seagrasses) between these areas, it is unlikely that there will be (or have any potential for) cumulative impact on water quality to the extent where this would influence benthic habitat.

In a temporal context, dredging for the Mandorah project is currently scheduled for 2023 into 2024, and may occur concurrently with the overall DPD trenching program. The likelihood of concurrent and proximal trenching shall be established and temporal/spatial separation of the dredging activities will be explored in consultation with the Mandorah project.

While there is predicted to be no overlap in zones of influence between Mandorah and DPD Project dredging/trenching activities, there could be interaction of turbidity plumes at very low concentrations, i.e. below the Zone of Influence thresholds. It is considered that the greatest risk for interaction of turbidity between the Mandorah project and DPD Project activities is if the offshore disposal of sediments for the Mandorah project occurs concurrently with DPD Project trenching at the closest trenching and pre-sweep zones. Through consultation with DIPL, Santos understands the spoil discharge is expected to occur over a 3-6 weeks duration. Therefore, there is a reduced likelihood of this discharge and DPD trenching to be occurring at the same time and same place. Through continued consultation, opportunities to avoid spoil disposal/trenching operations at the same time in the same area will be explored.

13.2.1.2 INPEX – Ichthys Maintenance Dredging

INPEX is proposing to undertake maintenance dredging in East Arm, adjacent to the onshore Ichthys LNG facility and East Arm Wharf. The footprints of the proposed maintenance dredging and DPD trenching zones are > 5 km apart at their closest point near Wickham Point, and the spoil disposal area for each program are adjacent, with INPEX disposal grounds abutting the DPD disposal grounds to the southeast. Maintenance dredging proposed for INPEX shall occur in 2024 following completion of trenching for the DPD Project.

The INPEX Maintenance Dredging and Spoil Disposal Management Plan (2023-2027) (INPEX Operations Australia Pty Ltd, 2022) contemplates a scenario where the INPEX maintenance dredging and the DPD Project trenching operations could occur concurrently. The INPEX dredging area is over 4.5 km from the DPD Project pipeline route at its closest point and based on sediment transport modelling for both projects, there is no overlap of the Zones of Influence from these activities. When considering the INPEX spoil disposal activities at its offshore disposal site located over 15 km north-east of the closest DPD Project trenching zone (trenching area C1A), there is no overlap of the Zones of Influence, however there is potential for excess suspended sediment (below Zone of Influence threshold concentrations) to overlap. However, the concentration of the overlapping plume associated with trenching and spoil disposal is negligible (e.g. ≤1 mg/L) and over areas of soft bottom benthos/sediment so the potential for cumulative impact is not likely.

The only exception are small, localised areas off Wagait Beach and the DLNG facility where modelling predicts small, localised areas of excess suspended sediment concentration plumes up to 2.5 mg/L. There is a small area of potential overlap of these modelled outputs, in particular the 3 - 5 mg/L contour in both the wet and dry season off Wagait Beach and 5 - 10 mg/L contour in both the wet and dry season adjacent to the DLNG facility. Based on this overlap, there is potential for cumulative 95th percentile excess suspended sediment plumes for the Project’s maintenance dredging and DPD trenching to reach 7.5 mg/L off Wagait Beach and 12.5 mg/L adjacent to the DLNG facility for short periods of time. This is on the basis that the most intensive dredging for both campaigns is undertaken simultaneously, which is unlikely. Even if this were to occur, the area that the suspended sediment concentration overlap occurs over is soft bottom benthos/sediment, with no overlap with coral or seagrass habitat.

13.2.1.3 HMAS Coonawarra - Dredging and Dredged Material Management

Department of Defence proposes to carry out two capital dredging campaigns of approximately 100,000 m^3 - 120,000 m^3 as part of upgrades to the Royal Australian Navy wharf facilities and basin navigation area at HMAS Coonawarra, which is approximately 1.8 km from the closest part of the DPD Project pipeline route (**Figure 13-1**). The first of those campaigns is referred to as NCIS-5 and is expected to occur in 2023, prior to commencement of DPD Project construction.

The proposed action includes ongoing maintenance dredging at HMAS Coonawarra in the order of 10,000 m^3 to 15,000 m^3 every 5 - 7 years (NT EPA, 2022). Dredged spoil from operation of a CSD will be pumped via a pipeline to a location approximately 300 m southwest of HMAS Coonawarra breakwater for disposal into the channel. This location is approximately 1.5 km away from the nearest part of the DPD Project pipeline route and approximately the same distance away from the nearest trenching pre-sweep area (Pre-sweep Area 2 in **Figure 2-4**). A small amount of hard pegmatite rock may need to be removed by BHD if the CSD cannot remove, if this is the case, associated BHD spoil will be disposed onshore.

The NCIS-5 - HMAS Coonawarra Draft Dredging and Disposal Management Plan (KBR, 2022) presents modelled Zones of Influence (ZoI) and Zones of Moderate Impact (ZoMI) informed by sediment dispersion modelling. Comparing the worst-case extent for a Zone of Influence from the NCIS-5 dredging with a worst-case Zone of Influence for the DPD Project reveals that these zones do not overlap and are approximately 900 m separated at the closest point. Given this separation and the lack of sensitive receptor habitat (i.e., hard corals or seagrasses) between these areas, it is unlikely that there will be a cumulative water quality (turbidity/sedimentation influence on either water quality or benthic habitat from these projects.

It is expected that Coonawarra dredging will be separated in time from the DPD Project dredging, with NCIS-5 dredging expected to occur during 2023 and over a period of 2 months while DPD Project trenching will not occur until 2024. Given this, and also the spatial separation of Zones of Influence between these projects, there is considered to be a low likelihood of impacts to benthic habitats from cumulative effects on water quality from these dredging/trenching campaigns.

Santos will continue to consult with the Department of Defence on the timing of dredging programs.

13.2.1.4 Darwin Ship Lift and Marine Industries Project

The NT Government is proposing to deliver the Darwin Ship Lift and Marine Industries Project, which includes the construction of northern Australia’s largest common user ship lift and adjacent maintenance facility in East Arm (AECOM 2021). Construction requires the dredging of approximately 500,000 m^3 to create an access channel, manoeuvring/turning basin and berth pockets. All dredged material will be placed onshore, and where possible utilised for land reclamation. At its closest point, Ship Lift facilities are >5km (closest straight-line distance) from the DPD Project shore crossing, although Middle Arm lies between these two points. The original construction schedule indicates dredging operations will occur between Q4 2022 and Q2 2024 inclusive (AECOM 2021), however the main construction contractor, Clough, went into voluntary administration in December 2022 and was acquired by Webuild in February 2023. This may delay the project.

This small overlap on proximal projects modelled in a worst-case credible scenario suggest that the potential for cumulative impact with the DPD Project, which is at its closest point is 5.5 km to the southwest, is unlikely. As per the Draft Dredging and Spoil Disposal Monitoring and Management Plan (AECOM, 2022) the modelled distribution of dredging and tailing disposal turbidity and sedimentation are very localised to the Ship Lift construction footprint and the closest Zone of Influence from dredging is >5km away from the closest Zone of Influence from DPD Project trenching. Therefore, there is no overlap in areas where water quality could potentially influence benthic habitat.

13.2.1.5 Australia-Asia Powerlink Project

The Australia-Asia PowerLink (AAPowerLink) by Sun Cable proposes to install three subsea cable systems extending from a cable transition facility near Gunn Point, to Singapore (Sun Cable 2022). There are currently two proposed cable routes, both run west from Gunn Point and either pass to the approximately 3 km south or 1 km north of the dredge spoil disposal areas of the DPD project and INPEX. The AAPowerLink alignments cross the DPD alignment approximately 16 km and 30 km offshore respectively.

Installation requires open trenches (one for each cable) to be excavated through the intertidal zone using conventual excavators (shore or barge based), which will be back filled with excavated material once cable pull is complete. Subtidal cable once laid, will be buried using high-pressure water injection or jet trenching, with the latter suited to intertidal and shallow water sections. The jetting system works by fluidising the seabed sediment causing the cable to sink under its own weight through the fluidised sediment, with sediment returning to their pre-jetted condition once jetting ceases. Jetting and subsequent fluidisation causes sediment to enter the water column where it can be transported to the far-field and potential impact sensitive receptors similar to dredging and spoil disposal.

Modelling of jetting was completed assuming simultaneous burial of all three cables starting at the Gunn Point shore crossing moving along the cable route for 50 km over a seven-day period and repeated three times (i.e. three passes of jet trencher) to achieve modelled burial depth (Sun Cable, 2022). The modelling used predicted turbidity levels to identify High, Medium and Low risk zones (for impact), but none of these zones overlap the DPD Project Zone of Influence for the spoil disposal site. While there is no overlap in the Zones of Influence predicted, if the activities were to occur concurrently, there could be interaction of turbidity plumes at very low concentrations, i.e. below the Zone of Influence thresholds. However, even if this were to occur, the lack of sensitive habitats in the area means there is a very low likelihood of potential for cumulative impacts.

Given the recent decision for Sun Cable to enter into voluntary administration, the likelihood of concurrent dredging in areas in proximity to the capital dredging program and spoil disposal area is low. Nonetheless Santos will remain in consultation with Sun Cable to determine likelihood of any potential conflicting or concurrent dredging programs with a view to minimising the potential for any cumulative impacts where possible.

13.3 Marine Ecosystems

Impacts to Marine Ecosystems have been presented in **Section 9** and the residual impacts from the DPD planned activities were assessed to be Minor or Negligible. Consequently, it is unlikely that the Project activities could contribute towards a significant impact. However, the potential for cumulative impact from direct and indirect seabed disturbance and from noise and unplanned vessel interactions has been assessed in the following sections.

13.3.1 Cumulative direct habitat disturbance

Direct impacts to seabed habitats from planned events will be restricted to the DPD Project infrastructure footprints, including the spoil disposal ground which do not overlap with other current, or proposed project activities. The benthic habitats under the DPD Project infrastructure footprints comprise predominately filter feeders which are widely represented elsewhere in Darwin Harbour and the wider region. No sensitive hard coral or seagrass habitats are at risk from direct impact. Consequently, direct impact is not expected to have a significant impact to the function of the ecosystem and while other current and proposed activities will also have direct impacts to benthic habitats, overall spatial overlap is minor and indicates cumulative impacts are unlikely to be significant.

Based on the calculations presented in **Table 9-4**, the direct and indirect impact to benthic habitats from the Project make up < 0.15% of the bare ground, < 0.12% of the macroalgae and < 0.18 of the sponge or sponges/filterers/octocoral habitat in Darwin Harbour. The habitat loss predicted by the Mandorah Marine Facilities (Cardno, 2022a) is <0.001% of coral, 0.04% of sponge and 0.02% of seagrass along the east side of Darwin Harbour (Note, as the percentage loss is given as a proportion of the habitat along the east side of Darwin Harbour, the loss as a percentage of habitats across Darwin Harbour would be considerably smaller). In the Ichthys EIS supplement (INPEX Browse Ltd, 2011) predicted the loss of 0.9% of coral and filter-feeder habitat, 0.8% loss of macroalgae, and <5% of sand, mud and gravel. While no data for the Bayu-Undan to Darwin pipeline were available, a conservative approach would be to base habitat loss on the current Project given its parallel alignment and similar installation methods.

When the benthic loss from each of these projects is combined (conservatively), less than 5% of the bare ground, <1% of hard coral, seagrass macroalgae and sponges or sponge/filterer/octocoral habitat found across Darwin Harbour has or will be lost from these developments. Other projects that are proposed, such as the INPEX maintenance dredging, the Ship Lift and Marine Industries Project and the HMAS Coonawarra dredging programme all predict no impact to seagrass, coral or macroalgae, suggesting any cumulative impact to benthic habitats would be the loss of bare sediment or to be very conservative, loss of filter feeder habitat which is the most abundant habitat type found across Darwin Harbour.

However, while there has been/would be loss of particular benthic habitats, these habitats have been/will be replaced by additional hard substrate in the form of pipelines and other infrastructure. Recent studies investigating habitats and fish associated with oil and gas infrastructure, including the existing Bayu-Undan to Darwin pipeline (McLean et al., 2021) documented that the sessile biota growing on the pipeline, which included potential prey for marine turtles such as soft corals and sponges, had much higher densities compared to the habitats surrounding the pipeline where such biota were either absent, or present at much lower densities. Furthermore, the fish assemblages observed on and around subsea pipelines, are of higher diversity than those found off the pipelines (McLean et al., 2020) and there is evidence in the literature that the presence of such subsea infrastructure can promote biodiversity and abundance through an increase in habitat complexity and crevices (McLean et al., 2022).

13.3.2 Cumulative indirect habitat disturbance

Indirect impacts to Marine Ecosystems, e.g. from increased SSC and sedimentation from the DPD Project will be temporary and have been predicted to be low. As the spatial extent of potential indirect impacts have also been predicted to be restricted to footprints where direct impacts will occur, and similarly Zones of Influence are within or very localised around footprints, it is unlikely that the Project could contribute to significant cumulative indirect impacts. While other current and proposed activities will also have indirect impacts to benthic habitats, as there is no overlap in Zones of Influence form other dredging project and the DPD Project (refer to **Section13.2.1**) and the habitats that may be impacted from other dredging projects are well represented across Darwin Harbour, there is a low likelihood that cumulative impacts could become significant.

This argument extends into the assessment as to whether cumulative impact (direct and indirect) of benthic habitats could indirectly impact marine fauna. While some of the habitats that will be impacted by current and proposed activities provide foraging material and habitat for a range of marine fauna including reptiles and fish, the proportionately small loss of habitat as a percentage of that available in Darwin Harbour (quantified above) is unlikely to have an indirect impact on those fauna or the wider ecosystem function, especially where habitat is being replaced with infrastructure which can improve diversity and provide hard substrate that can be exploited by sessile biota which in turn can become a source of food for marine fauna.

13.3.3 Cumulative noise/vessel interaction impacts

With the reliance on vessels to trench and install the pipeline, the Project will temporarily increase vessel traffic in the harbour, although the Project vessel movements will not add significantly to vessel traffic on an annual basis (i.e., Project vessel movements are within the range of inter-annual variation in traffic recorded for the harbour), and if Project activities overlap with the timing of other projects, overall vessel traffic will be greater. It is estimated that the DPD Project may increase the harbour vessel traffic (vessel movements) by 3 to 5% (refer to **Section 2.8**). Such increases may result in higher levels of both sound and light emissions compared to just one project's activities occurring at any one time. However, Santos considers the proposed controls and mitigations to be effective and as such, considers it unlikely that cumulative activities could result in significant impacts to Marine Ecosystems from noise and light emissions.

AECOM (2021) noted that potential cumulative impacts from underwater noise and vibration during the construction phase of a project may occur if concurrent substantial noise and vibration generating activities (e.g. piling and dredging) are being undertaken either within a project's boundary, or between a project and adjacent developments.

Construction activities will generate underwater noise and vibration from dredging operations, however, the noise and vibration levels will be of a more continuous nature than those arising from intermittent and percussive piling. It is considered that marine species will be able to temporarily avoid the areas where noise and vibration levels may be intolerable (AECOM, 2021).

AECOM (2021) further noted that whilst project-related construction activities may conceivably occur concurrently, noise levels from separate activities are not necessarily additive due to the waveform nature of their propagation (i.e. they may interact antagonistically, thereby reducing their magnitudes). However, it is not possible to reliably estimate the potential increase or decrease in noise and vibration levels that may arise from concurrent project activities as they are dependent upon the precise timing that they are generated.

Santos has reviewed the noise impacts from projects that are currently undergoing assessment through the NT EPA, and it has been noted that it is not possible to accurately predict the potential cumulative impacts from noise and vibration that may arise from project activities within Darwin Harbour, as they are dependent upon the precise timing and that they are generated by the activities. Santos has assessed however, the potential effects of DPD Project underwater noise against the ambient noise conditions of Darwin Harbour which includes the regular commercial shipping traffic (**Section 9.5.2**).

Santos has considered the feedback received during submissions that there is concern for the dolphin population in Darwin Harbour, as monitoring from 2011 to 2019 (Griffiths et. Al., 2020) has shown unexplained negative trends in abundance of the Australian humpback dolphin, Australian snubfin dolphin and bottlenose dolphin populations in Darwin Harbour. Furthermore, results of NT-wide surveys of dolphins show that they have a wide distribution; occur within nearly all coastal waters; recorded to have their highest densities at sites not currently designated as BIAs (Palmer et al. 2017), and are species that have highly mobile behaviour. Given the short timeframe of the construction for the Project (in particular the timeframe for dredging of 2-3 months), Santos has concluded that the increase in activity within Darwin Harbour is not likely to have a significant impact on marine fauna, including coastal dolphins.

Santos will liaise with relevant proponents and authorities on timeframes and locations and will work with identified stakeholders to reduce the potential for cumulative impacts where possible through its Stakeholder Engagement process (**Section 4**).

13.4 Atmospheric Processes

Santos recognises the scientific consensus on climate change and supports the objective of the Paris Agreement to limit global temperature rise by 2100 to less than 2°C and pursue efforts to limit the temperature rise to 1.5°C above pre-industrial levels.

Santos acknowledges that emissions generated during the construction and operation of the DPD Project will contribute to the overall concentration of GHG emissions in the Earth's atmosphere. As discussed in **Section 10**, the emissions resulting from the construction of the DPD project will comprise a short-term occurrence and will be limited to this phase of the Project. These emissions, due to the limited duration of construction activities, are minor in nature and are not expected to result in any meaningful contribution to global GHG emissions. Once construction is completed, the operation of the DPD project is not anticipated to represent a significant source of GHG emissions due to its role in the passive conveyance of hydrocarbon gas from the Barossa FPSO to DLNG. The IMR activities undertaken on this pipeline will represent short-term activities which will be undertaken on an 'as needed basis' in line with a risk-based inspection schedule.

The estimated emissions from the DPD Project do not trigger the NT Government's Large Emitters Policy as stated earlier, since the DPD Project will not represent an emissions source of 100,000 tonnes or more CO_2-e per year. Based on the above, the operation of the DPD Project will not materially contribute to global GHG concentrations.

13.5 Other Environmental Factors

Impacts to Coastal Processes have been presented in **Section 11.1** and the residual impacts from the DPD planned activities were assessed to be Minor or Negligible. Impacts are expected to be localised and/or temporary and there are no other activities or projects identified that are considered to cumulatively interact with the DPD Project to significantly alter hydrological or geophysical processes. Furthermore, as the Digital Earth Australia Coastlines shoreline movement analysis (Geoscience Australia, 2020) showed the coastline in the shore crossing area has remained net stable (no significant trend of growth or retreat of shoreline material) between 1988 and 2020 despite there being two pipelines and shore crossings constructed, the construction of a third pipeline is unlikely to have any cumulative impact to Coastal Processes.

Impacts to Community and Economy have been presented in **Section 11.2** and the residual impacts from the DPD planned activities were assessed to be Minor or Negligible. Therefore, it is unlikely that the DPD Project could act cumulatively with other activities or projects to create significant impacts or risks.

During the construction phase of the DPD Project, there is a potential for cumulative impact from increased vessel activity related to current activities and other projects in the vicinity, if project timeframes overlap. However, it is worth noting that potential cumulative impact would be mainly restricted to the construction phase as operation vessels activity for the DPD Project are expected to be minimal and therefore, potential cumulative impacts are expected to be temporary.

If construction activities overlap, the increased cumulative vessel activities have the potential to reduce the visual amenity to the local community, visitors and users of the Darwin Harbour, however, as discussed in **Section 11.2.5.1** the required vessels for the DPD Project will not significantly impact the current commercial vessel movement within the harbour and also, the reduced visual amenity will only occur for a short period of time during the construction phase, thus contribution from the DPD Project on cumulative visual impacts are not expected to be significant.

The DPD Project is not expected to significantly impact the social, recreational, and ecological values of the harbour, and therefore cumulative impacts to these sectors are not expected to be significant. However, if the DPD Project and other construction projects overlap, there is a potential social cumulative impact to the local community with all projects competing for labour. Nevertheless, these projects will have a positive cumulative impact to the local economy by providing local employment and injecting capital to local business providing services to the Project.

Santos will liaise with relevant proponents and authorities on timeframes and locations and will work with proponents to reduce cumulative impacts across other developments where possible through the Stakeholder Engagement process (**Section 4**).

The impact assessment for Culture and Heritage has predicted Minor and Low residual impacts and risks only as discussed in **Section 11.3** and shown in **Table 11-7.** It is unlikely that the DPD Project could contribute to the extent that potential cumulative impacts are significant.

13.6 Conclusion

Through the cumulative impact assessment process, those current and existing activities and the proposed projects and activities with impacts that have the potential to combine with those from the DPD Project were identified and assessed. The potential for cumulative impacts was evaluated for the relevant environmental factors and values with consideration of the controls that both Santos and other proponents have presented. The assessment of cumulative impact has been based on publicly available information and supplemented by information that has been made available by other proponents.

While the timing of some proposed activities is yet to be confirmed, a precautionary approach to the cumulative impact assessment was taken, where possible temporal overlap was assessed as if there was temporal overlap.

A low potential for significant cumulative impact was identified for all NT EPA environmental factors assessed. This was attributed in part to the limited spatial overlap of the DPD Project with other current and proposed projects and activities and to the fact that the residual consequence of all the planned impacts from the DPD Project (as presented in this document) are no greater than Minor.

The TSDMMP for the DPD Project outlines the management and mitigation measures for trenching and disposal activities (refer to **Appendix 4**) and the implementation of these measures will assist in reducing the adverse impacts that may result from the DPD Project and its interaction with other projects that may occur at the same timeframes or location. The management and mitigation measures proposed (refer **Table 12-1**) are considered effective and appropriate to reduce potential impacts and risks, including cumulative impacts, to a level that is considered acceptable.

Santos considers that the development of the Project will be consistent with the NT EPA's objectives for Marine Environmental Quality, Marine Ecosystems and Atmospheric Processes. Santos will continue to liaise with relevant proponents and authorities on timeframes and locations and will work with these stakeholders to minimise the potential for adverse cumulative impacts where possible through the Stakeholder Engagement process (**Section 4**).

14 Whole of Environment Assessment

The DPD SER presents the findings of the impact assessment process undertaken for each of three key environmental factors requested by the NT EPA in its Direction to Provide Additional Information (Marine Environmental Quality, Marine Ecosystems, Atmospheric Processes). The impact assessment considered direct and indirect impacts, cumulative impacts and impacts on the whole of the environment that could occur due to connections and interactions between each factor. This section provides a summary of the impact assessment findings and discusses predicted outcomes in relation to the NT EPA's environmental objectives and the principles of environment protection and management (as set out in Part 2 of the EP Act).

14.1 Marine Environmental Quality

The impact assessment undertaken for the Marine Environmental Quality factor (**Section 8**) concludes that the DPD Project will have Negligible to Minor residual impacts and Low risks to Marine Environmental Quality in Darwin Harbour and within the Project area.

A Minor impact to Marine Environmental Quality, as per Santos' impact assessment criteria (refer **Section 7.4.2**) is an impact that is detectable but short-term, across a localised extent with rapid recovery. Residual impacts are primarily associated with pre-lay (pre-lay trenching and spoil disposal), which will result in temporary and localised elevated turbidity in the marine waters during the trenching campaign (2-3 months). The requirement for trenching (and associated rock protection) has been reduced as far as possible through a quantitative risk assessment which looked at external impacts and risk-commensurate protection requirements. The option of re-using trenching spoil and backfill material was also evaluated but dismissed due to the sediment not meeting technical requirements for pipeline stabilisation and protection. Detailed sediment dispersion modelling conducted (**Appendix 3**) predicts that the area within which turbidity and sedimentation from trenching and spoil disposal could potentially influence benthic habitats (i.e., a Zone of Influence) is extremely localised to within or immediately adjacent to the Project footprint (trenching and spoil disposal areas). Furthermore, there are no sensitive or rare benthic habitats within these areas. This assessment considered both the modelled distribution of turbidity and sedimentation and the natural levels experienced in the ecosystem taken from existing baseline water quality data at sensitive habitat locations.

To manage impacts of turbidity and sedimentation of Marine Environmental Quality, Santos has prepared a Trenching and Spoil Disposal Management and Monitoring Plan (**Appendix 4**) which includes management measures, an adaptive management and monitoring plan to react in real time to water quality effects from trenching and spoil disposal and to ensure that the predicted minor impacts to Marine Environmental Quality are not exceeded.

Contaminants of concern have also been assessed in sediments along the pipeline route, and within trenching areas, in line with national and NT water quality guidance as outlined in **Appendix 3**. Other than arsenic, which occurs in naturally high levels within Darwin Harbour sediments, contaminants were below NAGD screening levels, and therefore considered to pose a low risk to the environment through dredging and spoil disposal and deemed suitable for offshore marine disposal.

Other impacts to Marine Environmental Quality considered were the contingency discharge of treated seawater and filter backflushing associated with pipeline pre-commissioning activities. Due to the nature of the discharges these were considered to have Negligible impact.

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Risks to Marine Environmental Quality from invasive marine species and hydrocarbon spills were also considered, however with standard maritime practices, and additional Project controls, the risk of these events occurring was considered to be Low.

The importance of Marine Environmental Quality in supporting Marine Ecosystems is recognised in **Section 9.5.1**, including the potential for turbidity and sedimentation to impact on benthic habitats and marine fauna they support. Given turbidity and sedimentation effects are localised to trenching and spoil disposal areas and the habitats under these areas are common and widespread through Darwin Harbour and adjacent waters, indirect impacts to Marine Ecosystems were considered to be Minor.

The findings of the impact assessment undertaken for the Marine Environmental Quality factor indicate that the DPD Project will have a short-term impacts at a Minor level and employ avoidance and mitigation measures to reduce impacts to a level that is as low as practicable and consistent with meeting the NT EPA's objective of *protecting the quality and productivity of water, sediment and biota so that environmental values are maintained*.

14.2 Marine Ecosystems

The impact assessment for the Marine Ecosystems factor (**Section 9**) concludes that the DPD Project will have a Minor residual impact on marine habitats and marine fauna associated with direct disturbance of benthic habitats in the trenching corridor, indirect impacts associated with the short-term marine water quality impacts and impacts on marine fauna associated with noise and light emissions. With respect to habitat, a Minor impact to Marine Ecosystems, as per the Santos impact assessment criteria used (refer **Section 7.4.2**) is an impact that is detectable but does not result in a significant loss of area/function with rapid recovery. With respect to marine fauna, a Minor impact is classified as one that does not result in a significant decrease in local population size/ viability and/or a significant disruption to the breeding cycle/ area of occupancy/ habitat critical to the survival of a species.

Significant impacts to marine benthic habitats are not expected from direct disturbance associated with the DPD Project and there are no impacts predicted to rarer and sensitive habitats. The area of habitat directly disturbed by the DPD Project footprint has been quantified and related to mapped habitats within Darwin Harbour. Based on these calculations, trenching and infrastructure footprints combined will impact less than 1% of the benthic habitats across Darwin Harbour and more specifically, < 0.18% of the sponge or sponges/filterers/octocoral habitat, < 0.12% of the macroalgae habitat and ~0.12% of the bare ground habitat found across Darwin Harbour. Given the small proportion of habitat directly disturbed it expected that the impacts to fauna that use these habitats will be minor, mitigated also by the new habitat provided by DPD Project infrastructure (e.g. pipeline and rock protection) which will likely attract and may increase the abundance of marine fauna. It is important to note that rarer, sensitive habitats such as seagrass beds and hard coral reef areas, which provide foraging habitat for marine megafauna (e.g. dugongs and turtles) are not located in the direct disturbance footprint and are not predicted to be impacted by the DPD Project. The same conclusions can also be applied to indirect impacts to benthic habitats and associated fauna from turbidity and sedimentation from trenching and spoil disposal. Modelling has demonstrated that zones of impact will be largely within direct disturbance footprints.

Temporary anchoring activities in Darwin Harbour, associated with pipelay, will also disturb benthic habitats and given the anchoring spread (within 1,000 m of the pipeline route) will occur closer to more sensitive shallow water habitats such as hard coral and seagrass. However, anchor exclusion zones will be applied to prevent disturbance to sensitive and rare habitats and will similarly be applied to avoid disturbance to cultural heritage sites.

Underwater noise impacts have been assessed through modelling and application of physiological impact and behavioural response thresholds for key marine megafauna species (dolphins, dugongs and turtles) (**Section 9.5.2**). With the application of avoidance and mitigation measures, including an adaptive monitoring and management protocol as outlined within the Marine Megafauna Noise Management Plan (**Appendix 7**), physiological impacts to these species will be avoided. Behavioural responses to Project noise are expected to be similar to marine fauna responses to the noise emissions from other large vessels that use the harbour.

While Project vessels will be working at night and producing light spill, the effect on marine fauna, including marine turtles, is expected to be minor. Impacts will not be significant due to the distance away from nearest turtle nesting beaches (Casuarina Beach and Cox Peninsula), the low significance of these beaches on a regional scale, the considerable ambient lighting already within Darwin Harbour and the management measures that will be adopted (refer **Section 9.5.3.3**).

With respect to unplanned events, the risk of impact to Marine Ecosystems from vessel-fauna interactions, dropped objects, hydrocarbon releases and invasive marine species introduction was assessed as Low or Very Low, with avoidance measures in place. These risks of impacts are continually present within Darwin Harbour from daily commercial vessel movements and will be managed effectively through standard maritime/Darwin Port controls and additional Project measures.

The impact assessment undertaken for the Marine Ecosystems Factor demonstrates that the adoption of avoidance and mitigation measures for the DPD Project will reduce impacts to as low as practicable and to Minor level. Therefore, the Project activities are considered consistent with meeting the NT EPA's objective of *maintaining the environmental values for biodiversity, ecological integrity and ecological functioning*.

14.3 Atmospheric Processes

The impact assessment for the Atmospheric Processes factor (**Section 10**) concludes that the DPD Project will have short to medium term residual impacts associated with the installation and operation of ~100 km of pipeline infrastructure in NT jurisdiction which will facilitate the passive conveyance of produced Barossa gas to the DLNG facility for processing. Construction phase GHG emissions will be produced from fuel combustion (vessels, logistics, plant and equipment, travel and power generation). The DPD Project's Scope 1 emissions are anticipated to be approximately 80,000 t CO_2-e which represents 0.02% of Australia's GHG emissions and 0.29% of NT GHG emissions (refer **Section 10.2.1.2**). Over the construction phase of the DPD Project, construction vessels and machinery will be maintained as per planned maintenance systems and vessels will abide by maritime requirements for managing emissions. Over the operations phase, the DPD pipeline will convey natural gas and the only vessel activities (with associated combustion emissions) will be infrequent inspection campaigns to ensure pipeline integrity based on a risk-based inspection schedule (RBI). These measures are expected to be effective in reducing emissions to as low as practicable.

In terms of the broader Barossa Development, annual Scope 1 and 3 emissions represent 0.86% of Australia's 2022 GHG emissions and 0.042% of 2021 global GHG emissions (**Section 10.2.1.2**). The Barossa Development is therefore not a significant contributor to global GHG emissions.

Santos has established a target of net-zero Scope 1 and 2 emissions by 2040, which includes implementing energy efficiency measures to operations, integrating renewable energy, investing in low emission technologies, deploying CCS technology and investing in nature-based carbon offsets. The management measures are therefore consistent with the NT EPA's objectives for Atmospheric Processes of *minimising greenhouse gas emissions so as to contribute to the NT Government's goal of achieving net zero greenhouse gas emissions by 2050*.

14.4 Cumulative Impacts

The outcomes of the cumulative impact assessment undertaken for each NT EPA environmental factor indicate there is low likelihood for significant cumulative impact for the environmental factors or values (**Section 13**). Furthermore, within the DPD Project there are no impacts that are expected to work synergistically to the extent that a significant impact would occur.

14.5 Summary

The impact assessment for the DPD Project concludes that the Project's activities will have Negligible to Minor residual impacts and Low risks to Marine Environmental Quality in Darwin Harbour and within the Project area. The risk of invasive marine species and hydrocarbon spills is considered Low with the employment of standard maritime practices and additional Project controls. Residual impacts on marine habitats and marine fauna associated with direct disturbance of benthic habitats in the trenching corridor, indirect impacts associated with the short-term marine water quality, and impacts on marine fauna associated with noise and light emissions are all expected to be minor. The DPD Project will have short to medium term residual GHG impacts associated with the installation and operation of pipeline infrastructure in NT jurisdiction. However, the DPD Project and the broader Barossa Development will not be a significant contributor to global GHG emissions.

15 Consideration of Project Against Legislated Principles and Duties

In accordance with the guideline for preparing an SER (NT EPA, 2021b) the SER must outline how the Project meets the requirements of section 42(b) and Section 43 of the EP Act. These sections set out the purpose of the environmental impact assessment process and the general environmental duty of proponents. While each of the principles and obligations have been addressed throughout the SER sections and actions relating to stakeholder engagement, this section provides a concluding summary and a clear linkage.

15.1 Ecologically sustainable development

The Project has been considered against the principles of Ecologically Sustainable Development (ESD) as set out in Part 1 Division 1 of the EP Act and in accordance with the NT EPA guidance for preparing an SER (NT EPA, 2021b) and is included in section 3A of the EPBC Act. ESD as defined in the EP Act as *'development that improves the total quality of human life, both now and in the future in a way that: (a) maintains the ecological processes on which all life depends; and (b) recognises the need for development to be equitable between current and future generations.'* The core objectives and principles of ESD established in the EP Act are consistent with those of the National Strategy for Ecologically Sustainable Development (NSESD) (ESD Steering Committee, 1992).

As required under the EP Act the principles of ESD have been considered in Project planning and design. A description of how the Project is aligned with these principles is provided in **Table 15-1**. Details of the key management actions proposed, or already applied in the Project planning and design, so the Project aligns with these principles are provided.

Table 15-1 Principles of Ecological Sustainable Development Addressed

Principle	Details	Relevant key Management Actions	Demonstration of Alignment
Decision-making principle	+ Decision-making processes should effectively integrate both long-term and short-term environmental and equitable (unbiased) considerations.		As part of the planning and design Santos has considered short-term and long-term economic, environmental, social and equitable issues, with the strategic objective to create an opportunity for a positive contribution. Impacts through temporary environmental disturbance have been weighed against short-term (during planning and construction) and long-term (during operations) local economic benefits (refer **Section 11.2.4**). The Project provides an opportunity for re-purposing the Bayu-Undan to Darwin pipeline for CO_2 transport and subsequent injection into the Bayu-Undan underground geological formations for permanent storage. This initiative provides an opportunity for long term GHG emissions reduction from the Barossa Development (**Section 3.1**).
	+ Decision-making process should provide for community involvement in relation to decisions and actions that affect the community.	Continued stakeholder engagement through the Stakeholder Engagement Plan (SEP) (**Section 4**).	Santos continues to apply a Stakeholder Engagement Plan (SEP) to include community involvement into the planning and environmental impact assessment process (refer to **Section 4**). Public submissions on the DPD Project referral have been assessed and responded to within the SER (**Section 5**).
Precautionary Principle	+ If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.	Studies have already been implemented to reduce uncertainty around key environmental impacts associated with the Project. A monitoring and adaptive management program will be undertaken during trenching and spoil disposal to further ensure impact predictions are validated in real-time and responded to reduce potential for unexpected environmental damage.	A risk assessment has been developed for the Project which carefully identifies and evaluates associated environmental impacts and risks, mitigation and resultant residual impacts (refer to **Section 7.4**). The risk assessment process has considered the applicable stages of the DPD Project and the assessment of residual impacts and risk is based on conservative scenarios and assumptions. In instances where there was uncertainty around baseline information or uncertainty on the mechanisms and pathways for impacts, further studies have been undertaken to reduce uncertainty and support the impact and risk assessment. Benthic surveys have been undertaken to ground truth potentially important habitats and heritage sites. A range of modelling studies have been undertaken to further understand the potential direct and indirect impacts form the Project. Sediment dispersion modelling, treated seawater discharge modelling, underwater noise modelling and hydrocarbon spill modelling have all been undertaken to provide additional data. Validation of impact predictions is incorporated into trenching and spoil disposal environmental monitoring and management, whereby real time measurement of water quality effects will be collected and assessed through an adaptive management process, as outlined within the TSDMMP (**Appendix 4**).
	+ Decision-making should be guided by: - A careful evaluation to avoid serious or irreversible damage to the environment wherever practicable; and - An assessment of the risk-weighted consequences of various options.	Route selection and other technical studies have been undertaken to reduce the direct disturbance of the pipeline route on the environment as far as practicable (**Section 3.2**).	Santos considered various route options for the DPD Project which incorporated environmental factors and has selected a route where disturbance to the environment is reduced as far as practicable (**Section 3.2**). The location and siting of the DPD pipeline from the offshore connection point to the onshore termination point at the DLNG facility has undergone considerable consultation with stakeholders and regulating authorities. The pipeline route has been re-designed to avoid interference with existing pipeline routes as far as possible (i.e. Bayu-Undan and Ichthys pipelines), avoid encroachment into the shipping channel and avoid sensitive habitats and cultural heritage areas.
Principle of evidence-based decision-making	+ Decisions should be based on the best available evidence in the circumstances that is relevant and reliable.	Local and relevant data has been used in the impact and risk assessment.	Decisions during the planning and assessment phase of the Project have been made with the consideration of relevant information obtained from a variety of sources and professionals in appropriate fields. In all cases where a known source of direct field verified data is available, this has been used in preference to desktop data.

Principle	Details	Relevant key Management Actions	Demonstration of Alignment
		A monitoring and adaptive management program will be undertaken during trenching and spoil disposal to further ensure impact predictions are validated in real-time and responded to reduce potential for unexpected environmental damage.	Santos has employed best practice modelling studies to support its impact and risk assessment process. For example, benthic surveys have been undertaken to ground truth potentially important habitats and heritage sites. A range of modelling studies have been undertaken to further understand the potential direct and indirect impacts form the Project. For example, sediment dispersion modelling, treated seawater discharge modelling, underwater noise modelling and hydrocarbon spill modelling. Validation of impact predictions is incorporated into trenching and spoil disposal environmental monitoring and management, whereby real time measurement of water quality effects will be collected and assessed through and adaptive management process, as outlined within the TSDMMP (**Appendix 4**).
Principle of intergenerational and intragenerational equity	+ The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of present and future generations.	Avoidance and mitigation measures to ensure that the health, diversity and productivity of the environment is maintained are outlined in **Section 12**	Santos is committed to ensuring the Project will not adversely impact on future generations and instead aims to provide opportunities for future generations. Avoidance and mitigation measures to ensure that the health, diversity and productivity of the environment is maintained are outlined in **Section 12**. Following the application of these measures, Project impacts are assessed to be minor and will not lead to long term degradation of environmental health. The Project would provide an opportunity for Barossa and other third-party users to bring gas to DLNG to support ongoing DLNG operation to meet energy demand and continue to support local jobs and economy. A balance is required between meeting the short term needs of the current generation, while acting through initiatives such as the International Paris Agreement to preserve the environment for the benefit of future generations. The Project presents an opportunity to achieve emissions reduction targets consistent with the NT EPA objective.
Principle of sustainable use	+ Natural resources should be used in a manner that is sustainable, prudent, rational, wise and appropriate.	Use of pre-existing pipeline corridors and infrastructure where possible. Application of emission reduction targets and measures to meet NT EPA objectives for Atmospheric Emissions.	Santos is committed to using natural resources sustainably. The underlying premise of the DPD Project is to utilise pre-existing corridors and infrastructure to the maximum extent possible. The spoil ground has been selected to be directly adjacent to the Ichthys spoil ground. The onshore component of the DPD Project is contained to the shore crossing and connection into DLNG, following the existing corridor and within a pre-existing industrial land use, separated from sensitive land uses. The Project presents an opportunity to achieve emissions reduction targets consistent with the NT EPA objective. Santos is committed to developing carbon solutions that can be utilised to generate carbon credits to offset the emissions of Santos and its customers. This includes the expansion of high-quality nature-based solutions and the development of new technologies such as direct air capture. Santos already generates Australian carbon credit units (ACCU) from nature-based projects and continues to evaluate further opportunities.
Principle of conservation of biological diversity and ecological integrity	+ Biological diversity and ecological integrity should be conserved and maintained.	Use of pre-existing pipeline corridors and infrastructure where possible. Measures will be applied to ensure NT EPA objectives for Marine Environmental Quality and Marine Ecosystems (**Section 12**).	The Project has been designed with consideration and commitment to ensuring the protection and conservation of biological diversity and integrity. The Project is effectively a pipeline duplication with the offshore and nearshore components following the Bayu-Undan to Darwin pipeline and the Ichthys pipeline corridor. The onshore section of the Project is contained wholly within the existing DLNG disturbance envelope. This consideration and commitment to the Project alignment has minimised the potential risks and impacts ensuring the protection and conservation of biological diversity and integrity of the environment in NT waters.

Principle	Details	Relevant key Management Actions	Demonstration of Alignment
			Santos is committed to measures to avoid and mitigate impacts and risks to Marine Environmental Quality and Marine Ecosystems (**Section 12**) and to align with the NT EPA's objectives for these factors.
Principle of improved valuation, pricing and incentive mechanisms	+ Environmental factors should be included in the valuation of assets and services.		The Project supports the extension of the DLNG facility, creates a new asset and preserves the Bayu-Undan to Darwin pipeline for potential future re-use opportunities including CCS (**Section 3.1**). The Project will positively contribute to the Northern Territory economy during construction and ongoing operations phases (**Section 11.2.4**), without causing significant environmental or social impacts (**Section 14**).
	+ Persons who generate pollution and waste should bear the cost of containment, avoidance and abatement.		As a long-term operator in Northern Australia, Santos has a well-established system for the management of wastes and discharges and assumes full responsibility for these aspects. The generation of some waste during construction and operations is unavoidable, however, Santos has committed to minimising waste where possible and recycling, reusing and treating waste appropriately (**Section 15.3**). Waste management, disposal and monitoring (where required) have been factored into Santos contractual arrangements for the Project.
	+ Users of goods and services should pay prices based on the full life cycle costs of providing the goods and services, including costs relating to the use of natural resources and the ultimate disposal of wastes.		Supply chain management is inherently imbedded into the Santos management system. The Santos management system ensures the appropriate selection of vendors and suppliers who will adhere to environmental conditions applied in by the DPD Project. Procurement of goods and services for the proposed Project provides the value-based continuity of supply of gas to DLNG, while creating the opportunity for CCS.
	+ Established environmental goals should be pursued in the most cost-effective way by establishing incentive structures, including market mechanisms, which enable persons best placed to maximise benefits or minimise costs to develop solutions and responses to environmental problems		The achievement of environmental goals is reflected in the core strategic imperative of the Project. Specifically, the DPD Project creates the opportunity for the Bayu-Undan to Darwin pipeline to be re-purposed for CCS. Santos is aiming to plan and execute the Project as efficiently as possible in order to eliminate waste and reduce environmental and social impacts. Environmental requirements are embedded in Santos' contract/procurement processes to responsibly incentivise our contractors to make sure environmental objectives are considered in conjunction with commercial objectives and ensure cost-effective environmental management.

15.2 Environmental decision-making hierarchy

Section 26 of the NT EP Act sets out the environmental decision-making hierarchy as follows:

"In making decisions in relation to actions that affect the environment, decision-makers, proponents and approval holders must apply the following hierarchy of approaches in order of priority:

- Ensure that actions are designed to avoid adverse impacts on the environment;
- Identify management options to mitigate adverse impacts on the environment to the greatest extent practicable; and
- If appropriate, provide for environmental offsets in accordance with the *Environment Protection Act 2019* for residual adverse impacts on the environment that cannot be avoided or mitigated."

The DPD Project route selection process has incorporated environmental factors to ensure the route avoids sensitive seabed areas as far as practicable (**Section 3.2**).

The application of the environmental decision-making hierarchy is inherent within the Santos impact and risk assessment process (**Section 7.4**), whereby avoidance and mitigation measures are specifically discussed and assessed in Project planning (e.g. ENVID workshops) and are selected through a process to ensure the measures reduce impacts and risks to as low as reasonably practicable (ALARP) and to a level that is considered acceptable.

The management measures that will be applied to avoid and mitigate impacts and risks to NT environmental factors are detailed in **Section 12**. These measure are carried forward into Environmental Management Plans (EMPs) appended to this SER. The EMPs provide further detail on the ALARP assessment process applied.

Offsets have not been considered because the environmental impact and risk assessment process did not identify any residual impacts that were considered significant. All residual impacts to the environment were assessed as Minor or Negligible with risks assessed as Low or Very Low.

15.3 Waste management hierarchy

In the design and planning of the Project the waste management hierarchy has been applied to actions which have the potential to significantly impact the environment in accordance with NT EPA guidance for preparing an SER (NT EPA 2021b). The waste management hierarchy is set out in section 27 of the EP Act as a formal method for ensuring minimal waste generation.

The waste management hierarchy as described in the EP Act (section 27) is, "In designing, implementing and managing an action, all reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment."

For subsection (1), waste should be managed in accordance with the following hierarchy of approaches in order of priority:

- Avoidance of the production of waste;
- Minimisation of the production of waste;
- Re-use of waste;
- Recycling of waste;
- Recovery of energy and other resources from waste;

+ Treatment of waste to reduce potentially adverse impacts; and
+ Disposal of waste in an environmentally sound manner.

As included in its Offshore CEMP (**Appendix 17**) the Santos Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02) requires that for all waste generated by contractors under its influence, the hierarchy of waste management applies whereby wastes are (in order of preference) avoided, reduced, re-used, recycled, treated and/or correctly disposed. A waste inventory must be documented and onshore waste disposal records standardised (Waste Monitoring and Reporting Procedure - SMS-EXA-OS01-PD02-PD01) to allow accurate and consistent waste tracking.

DPD Project contractors are required to demonstrate that waste management processes are aligned with regulatory and Santos requirements through the provision of Waste Management Plan for Santos acceptance.

Santos has determined that the reuse of trenching spoil for the DPD Project pipeline stabilisation/protection is not suitable based on technical grounds. Instead, rock supplied through a local quarry (Mt Bundey) will be used. Santos will investigate the potential for spoil reuse as opportunities arise. Santos has liaised with DIPL (Ship Lift Project) on the potential for spoil reuse to support construction and has provided technical data for evaluation.

15.4 Ecosystem-based management

Santos has considered ecosystem-based management when planning and assessing actions which may have significant environmental ramifications. As defined in the EP Act ecosystem-based management is "*management that recognises all interactions in an ecosystem, including ecological and human interactions.*"

Santos has completed various baseline studies including geotechnical, benthic habitat, water quality, sediment quality and onshore vegetation studies specific to the Project to accurately understand the existing baseline environment relevant to the Project. These studies have provided valuable data sets on the relevant ecosystems within the Project area ensuring environmental decisions are made based on relevant scientific data. In addition, Santos has completed Project-specific modelling studies to predict potential significant direct and indirect impacts from Project activities. The results of these modelling studies have enabled relevant, and effective management and monitoring strategies to be developed to reduce these impacts to acceptable. Environmental monitoring will continue to be conducted during and after construction of the Project allowing decision makers to take an adaptive approach to management ensuring management strategies and frameworks can be improved to reflect the best available scientific data.

Santos has undertaken a thorough environmental impact and risk assessment to address and manage potential environmental impacts and risks. This process of identifying and mitigating environmental risks was informed by the site-specific surveys and studies which explored not only direct impacts but indirect and cumulative impacts which could develop from external and internal ecosystem interactions.

15.5 Impacts of a changing climate

Santos acknowledges the current climate is changing on a local and global scale largely as a result of anthropogenic GHG emissions and that international, national and state level targets have been pledged. A GHG emission assessment was undertaken to assess the emissions generated during the construction and operation of the DPD Project that will contribute to the overall concentration of GHG emissions in the Earth's atmosphere (**Section 10**). GHG emissions from the construction and operation of the DPD Project are not expected to result in any meaningful contribution to global GHG emissions.

15.6 General duty of proponents

The EP Act establishes seven general duties of proponents with regard to the environmental impact and risk assessment process. These duties and how they have been addressed for the Project are detailed in **Table 15-2**.

Table 15-2 General duty of proponents addressed in the SER

Duty	How Addressed
To provide communities that may be affected by a proposed action with information and opportunities for consultation to assist each community's understanding of the proposed action and its potential impacts and benefits.	Santos has developed a Stakeholder Engagement Plan (SEP) to include community involvement into the planning and environmental impact assessment process (**Appendix 11**). This framework aims to inform and engage stakeholders and provide avenues for consultation and discussion. Engagement commenced in late 2021 and has been ongoing. Engagement with key relevant stakeholders has been undertaken as part of this SER, with feedback considered. Santos is supportive of the process of consultation provided through the SER public comment period.
To consult with affected communities, including Aboriginal communities, in a culturally appropriate manner.	Santos commits to informing, consulting, and involving local communities in relevant decisions and collaborating and empowering Traditional Owners and Indigenous groups through advice seeking discussions and direct decision involvement where appropriate. Principal consultation occurs through the Wickham Point Deed Reference Group which comprises Traditional Owner membership.
To seek and document community knowledge and understanding (including scientific and traditional knowledge and understanding) of the natural and cultural values of areas that may be impacted by the proposed action.	Santos has received an Authority Certificate through AAPA (C2022/098). As part of this application, AAPA consults with Indigenous custodians to identify and record any Sacred Sites in the area and any conditions to be observed to protect these sites during the conduct of works. Principal consultation occurs through the Wickham Point Deed Reference Group which comprises Traditional Owner membership. Santos has also consulted with the NT Government Heritage Branch with respect to the potential for undiscovered heritage sites within the Project area. Santos has completed a maritime heritage assessment (Cosmos Archaeology, 2022) to address this concern. Santos is committed to ongoing communication with the local community and providing avenues for input and feedback as well as seeking knowledge from Traditional Owners and indigenous

Duty	How Addressed
	communities through the facilitation of relevant discussions.
To address Aboriginal values and the rights and interests of Aboriginal communities in relation to areas that may be impacted by the proposed action.	Santos recognises and understands the importance of Indigenous community participation in the environmental decision-making process and respects their values and customs. Principal consultation occurs through the Wickham Point Deed Reference Group which comprises Traditional Owner membership.
To consider the principles of ecologically sustainable development in the design of the proposed action.	Project actions which have the potential to generate significant environmental risks have been considered against the relevant principles of ESD. Decisions have been made with reference to consideration of multiple options, based on relevant and scientific information and with the consultation of relevant personnel. Santos is committed to maintaining environmental integrity and ensuring development is sustainable and with minimising impact on ecological health and diversity (**Table 15-1**).
To apply the environmental decision-making hierarchy in the design of the proposed action.	The assessment has sought to achieve residual risks that are ALARP through application of the environmental decision-making hierarchy (to avoid or mitigate potentially significant environmental impacts) and implementation of an adaptive management approach in accordance with current NT EPA guidelines and industry standards (e.g. AS/ISO 31000 risk management series).
To consider the waste management hierarchy in the design of the proposed action.	In the drafting of waste management and monitoring measures, Santos has considered the waste management hierarchy and implemented appropriate avoidance, minimisation, reuse, recycling and treatment techniques.

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Santos

Appendix 1: Additional information requirements for the Supplementary Environmental Report

Attachment 1 – Additional information requirements for the Supplementary Environmental Report Santos - Darwin Pipeline Duplication Project

Environmental Factor	Context	Additional Information Required
WHOLE OF ENVIRONMENT		
General	Section 42(c) of the *Environment Protection Act 2019* (EP Act) requires that the environmental impact assessment process considers the potential for less environmentally damaging alternative approaches, methodologies or technologies for actions. The potential significant impacts of the proposal to construct and operate a new pipeline to provide gas to DLNG have not been compared to the potential significant impacts of alternatives to the project, including providing gas to DLNG utilising existing pipelines.	1. Provide the rationale for duplication of the existing Bayu-Undan pipeline, given that the potential significant environmental impacts of the proposal could be avoided through use of the existing pipeline. 2. Provide a detailed analysis of the potential significant environmental impacts of alternative approaches, methodologies or technologies for the action, demonstrating how the decision to proceed with the preferred option has been made with consideration of section 42(c) of the EP Act, and application of the environmental decision-making hierarchy, waste management hierarchy and principles of ecologically sustainable development. The analysis of alternatives must include the option of repurposing the existing Bayu-Undan pipeline for transport of gas to DLNG.
	Section 43 of the EP Act includes general duty of proponents.	3. Provide an update to demonstrate how the general duty requirements have been met in relation to information in the SER.
AIR		
Atmospheric processes	The extent of the impact from greenhouse gas emissions is uncertain and the ability to meet the NT EPA's environmental objective for atmospheric processes requires assessment. The emission of greenhouse gases would be an indirect consequence of the operation of the DPD, and the DPD is a substantial cause of those emissions[1].	4. Provide details of the greenhouse gas emissions over the life of the proposal (from extraction from the reservoir through to completion of liquefaction) including: a) estimates of annual and total scope 1, scope 2 and scope 3 emissions over the life of the proposal b) a breakdown of scope 1, scope 2 and scope 3 emissions according to the emission source locations within the NT and / or elsewhere in Australia and / or outside of Australia

[1] The Environment Protection Act 2019 (Section 10(1)(b)) definition of an impact includes 'an event or circumstance that is an indirect consequence of the action and the action is a substantial cause of that event or circumstance'.

Environmental Factor	Context	Additional Information Required
	The referral does not account for operational greenhouse gas emissions from the extraction and supply of natural gas from Barossa through the pipeline to DLNG. The referral does not discuss the avoidance, minimisation or offset of greenhouse gas emissions associated with the extraction and supply of product that would be transported through the pipeline.	c) a breakdown of emissions by source, including but not limited to stationary energy, fugitives and transport d) a comparison of estimated emissions from the proposal against the proponent's emissions across its entire business, and Northern Territory and Australian greenhouse gas emissions as reported in Australia's National Greenhouse Accounts. 5. Demonstrate how the proposal will be implemented to meet the NT EPA's objectives for the Atmospheric Processes environmental factor and the NT Government's goal of achieving net zero greenhouse gas emissions by 2050. 6. Provide overarching long-term emissions target trajectory and proposed interim targets, and the measures and methods that will be used to meet the targets. 7. Demonstrate application of the decision-making hierarchy (part 2 of the EP Act), and that all reasonable and practicable measures would be applied to avoid and/or reduce emissions, including through best practice design, technology and management. 8. Provide a description of any regulatory frameworks (including any licences, approvals or permits required), for greenhouse gas emissions within the NT, elsewhere in Australia or outside of Australia.
SEA		
Marine environmental quality	Increased suspended sediment generated during the construction of the proposal has the potential to cause significant direct and indirect impacts on water quality and benthic fauna and habitats. The referral suggests that trenching is expected to result in 'pulses' of increased turbidity, causing reduced impacts compared to continued high turbidity. The basis for this assumption is unclear. The proponent has not conducted sediment dispersion modelling. The proponent committed to conduct sediment dispersion modelling to predict the extent, intensity and persistence of dredge generated sediment plumes, and the extent, severity and	9. Provide interpreted outcomes of proposal-specific sediment dispersion / plume modelling. The model must be developed using relevant contemporary modelling methodology, and address all proposal activities that have the potential to generate turbid plumes. 10. Revise the impact assessment for sedimentation in the context of: a) proposal-specific data, b) sediment dispersion/plume modelling outputs, and c) updated habitat data (see below). 11. Provide a draft trenching/dredging and spoil disposal management plan (DSDMP) for sub-sea trenching activities that includes:

Environmental Factor	Context	Additional Information Required
	duration of resultant impacts on water quality and biota.	a) baseline (pre-construction) condition of habitats within the zone of influence of the proposal (as required above) and relevant parameters to be monitored to detect impacts b) quantitative trigger levels for relevant parameters (and description of their derivation) corresponding to investigative and/or adaptive management actions that must be taken in the event that monitoring indicates trenching/dredging activities are likely to impact sensitive receptors c) quantitative limit values relevant parameters (and description of their derivation) corresponding to stop work, recommencement and/or investigative actions if sensitive receptor monitoring results exceed limit values.
Marine environmental quality	The referral indicates that a cofferdam and / or temporary groyne may be required at the proposed pipeline shore crossing (~30 m north of the existing Bayu-Undan pipeline crossing). Construction and operation of these structures has the potential to impact water quality and would potentially involve the removal of sensitive mangrove habitat.	12. Provide details of any infrastructure and methods required for construction of the pipeline at the shore crossing 13. Identify and map potential impacts (including cumulative impacts) and proposed measures that would be applied to ensure construction impacts are not significant.
Marine environmental quality	Hydrotest water which may contain biocide, oxygen scavengers, dye and / or other chemicals may be used during scheduled flood / clean / gauge / testing (FCGT) and dewatering, or in the case of an unexpected failure in the pipeline during installation, or wet buckle event. Section 3.5.2.7 of the referral specifies that during planned activities all FCGT fluids would be discharged to Commonwealth waters, but that in the case of an unexpected event discharge to NT waters could occur.	14. Demonstrate how marine environmental quality would be protected in the event of discharge of hydrotest water in NT waters. 15. Demonstrate that any discharge of hydrotest water in Commonwealth waters would not cause an exceedance of the 99% species protection level in any NT waters e.g. if a discharge were to be near the jurisdiction boundary. 16. Describe the proposed mitigation measures to manage potential impacts of hydrostatic test water discharges to the marine environment. Include detail about hydrostatic test water discharge characterisation, dispersion modelling, physical and toxicity impacts, marine fauna impacts, chemical selection and dosing, discharge volume and rate, and criteria for toxicant concentrations in discharge water. Include consideration of how the 99% species protection concentration (ANZG) would be met for high conservation ecosystems or chemicals that have a tendency to bioaccumulate.

Environmental Factor	Context	Additional Information Required
Marine ecosystems	The works proposed, including but not limited to trenching/dredging, spoil disposal, and pipeline trench backfill activities, have the potential to cause direct and indirect impacts to benthic habitat including through removal, smothering or reduction of photosynthetically active radiation. In the referral these impacts are addressed on the basis of predictive habitat modelling, data collected for the INPEX project, and data collected by RPS. However, these data are not considered adequate to assess the potential impact of the proposal on benthic habitats within the pipeline footprint and the zone of influence.	17. Provide the outcome of additional benthic habitat surveys of the proposal footprint and the zone of influence in Darwin Harbour, at the proposed spoil disposal site, and on knolls and rocky/mixed sedimentary environments within the zone of influence outside of Darwin Harbour. Surveys should use appropriate methods, with sufficient sampling intensity to provide robust understanding of baseline extent and composition of benthic primary producer habitats (see submission from the Department of Environment, Parks and Water Security). Survey design should be developed in consultation with the Flora and Fauna Division of Department of Environment, Parks and Water Security. 18. Revise the assessment of potential impacts to benthic habitats (including seagrass meadows in Fannie Bay, Shoal Bay and Casuarina Coastal Reserve) using the benthic habitat survey data and sediment dispersion model outputs.
Marine ecosystems	Noise generated during the construction of the proposal has the potential to cause significant direct and indirect impacts on marine megafauna including turtles, dugongs and dolphins. The proponent has committed to conducting underwater noise modelling.	19. Provide an underwater noise assessment conducted using contemporary best practice, including interpreted outcomes of underwater noise modelling, and modelling of cumulative noise resulting from the proposal and existing activities at sensitive receptors. 20. Provide a detailed draft marine megafauna management plan for construction activities that includes: a) baseline (pre-construction) cumulative noise within the zone of influence of the proposal and relevant parameters to be monitored to detect impacts b) noise trigger levels for relevant parameters (and description of their derivation) corresponding to actions that must be taken in the event that monitoring indicates that construction activities are likely to impact protected species c) management actions to be applied if noise triggers are exceeded in accordance with the environmental decision-making hierarchy.
Marine ecosystems	The proposal may have significant environmental impacts on marine biota through disturbance of the Charles Point Reef Fish Protection Area.	21. Provide an assessment of potential impacts to important subsea structure/s within the Charles Point Reef Fish Protection Area and the measures that would be applied to ensure impacts are not significant.

Environmental Factor	Context	Additional Information Required
	The referral states that the only disturbance in the area would be a localised and temporary decrease in water quality, however Fisheries has advised that the reef protection area contains important subsea structure which was the primary reason for the declaration of the area for protection. Fisheries has provided Santos a spatial layer of the important area.	
Marine environmental quality Marine ecosystems	Cumulative impacts have been given perfunctory attention in the referral. There are a number of proposed actions being considered by the NT EPA that are proposing dredging in Darwin Harbour, and there will be ongoing maintenance dredging requirements for existing projects in the harbour. The pressures on the harbour environment are increasing and must be appropriately considered and managed by proponents.	22. The monitoring program for the draft DSDMP must provide for the assessment of cumulative impacts associated with trenching/dredging and spoil disposal, including from the addition of concurrent or consecutive dredging programs. The DSDMP should include: a) a communications strategy for engaging with government authorities and other proponents undertaking or proposing to undertake dredging in the harbour; and b) a proposed approach to managing dredging in coordination with other proponents/dredging projects to avoid significant cumulative impacts to Darwin Harbour from dredging activities.

Appendix 2: Register of all submissions received on the DPD Project referral

Santos

Register of all Government Submissions and Key Issues

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Aboriginal Areas Protection Authority (AAPA / the Authority)	1	1	The referral states that 'Santos will continue to engage with AAPA to ensure the requirements of the Aboriginal Sacred Sites Act are met'. The Authority confirms that Santos has engaged with us on this proposal and has lodged an appropriate application for an Authority Certificate (application 202203003). In the application, the pipeline corridor component of the Subject Land in the harbour/sea is about 2km wide, narrower than this part of the Project area as defined in the referral (~4 km wide). The Authority notes that the Authority Certificate will only apply to the land/sea within the Subject Land defined in the application. The Authority considers that if Santos obtains and complies with an Authority Certificate issued to Santos for all activities proposed to be undertaken, then the risk of potential impacts to cultural values associated with sacred sites will be appropriately minimised.	Cultural heritage
Department of the Chief Minister and Cabinet (CM&C)	2	1	The upcoming assessment by the Proponent and any approval conditions and management plans should carefully consider and address any potential economic impacts during the construction phase of the project. In particular, there should be no significant impact on existing commercial and recreational shipping in Darwin harbour, general harbour users and the offshore commercial fisheries in and adjoining the project area. This should be captured in the Terms of Reference.	People and Community
Department of the Chief Minister and Cabinet (CM&C)	2	1	Workforce composition and procurement has not been addressed in detail, likely, due to the preliminary stage of the project. CM&C recommends the upcoming assessment and any management conditions should detail workforce composition and how local employment and procurement opportunities will be maximised to satisfy the 'community and economy' environmental objectives. This should be captured in the Terms of Reference	People and Community
Department of the Chief Minister and Cabinet (CM&C)	2	1	The proponent intends to meet requirements of the requirements of the Aboriginal Sacred Sites 1989 Act. CM&C notes an AAPA certificate will be required.	Cultural heritage
Department of the Chief Minister and Cabinet (CM&C)	2	1	The stakeholder engagement plan provides a robust list of stakeholders and consultation format undertaken, however, lacks detail regarding the outcomes of the consultation process. The Referral contains minimal detail regarding stakeholder feedback and specifically if any concerns were raised including any mitigation strategies. A register of stakeholder feedback and strategies for addressing any concerns raised should be considered.	Consultation

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	2	The referral makes use of INPEX monitoring results and then concludes that most activities (e.g. dredging, elevated turbidity, sediment disposal, sedimentation of suspended sediments) have had no impact on sensitive receptors or environmental values. However, this misrepresents INPEX's own assessment that more often than not their monitoring could not conclusively attribute changes to environmental conditions due to project impacts and/or other variables (e.g. cumulative impacts from other projects, natural variability). As such, most of the assumptions that the proponent has presented potentially bias the risk assessment in favour of the project, by reducing the likelihood that an impact may occur or reducing the severity of the impact. The proponent should at least rely on its own plume and sediment transport models to inform risk assessment of the project activities. The project has not considered indirect impacts and established the zone of influence of project activities. As such, the risk assessment provided in the referral is limited in its use.	Sediment / plume modelling
Department of Environment, Parks and Water Security (DEPWS)	3	2	Further, the referral provides many statements without evidence. For example, section 9.4.2: In support of this conclusion, there is no evidence that the existing Bayu Undan to Darwin pipeline (26 inch) or lchthys (42 inch) have significantly impacted coastal processes. No evidence has been provided to demonstrate how this conclusion was reached. In the same section (9.4.2) the referral states that only seabed disturbance has the potential to impact on coastal process. This is not completely accurate as backfill of the trench and reinforcement of the pipeline (rock placement) can alter the seafloor topography and thus change seafloor currents. Changes in seafloor currents can cause significant changes in sediment transport, sediment deposition and erosion, and thus potential impacts on seafloor communities (infauna and epifauna). These flow on impacts. should be discussed and assessed. The referral notes that during trenching, spoil disposal and backfill activities, the increased turbidity and sediment levels in the water may result in a visible surface plume which is often associated with such activities. While such plumes may lead to a decline in aesthetics during these activities, they will be localised and temporary in nature. This is an unsubstantiated comment, as no plume modelling has been undertaken. Further, given that dredging will take close to two years the term "temporary" may not be appropriate.	Comparison to ichthys
Department of Environment, Parks and Water Security (DEPWS)	3	3	The Flora and Fauna Division agrees with the proponent's assessment that construction activities will occur within cleared and disturbed lands within the existing Darwin LNG facility disturbance envelope and therefore the construction and operation has a low risk to biodiversity and environmental values.	Conservation areas

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	3	Table 9.1 seems to infer that primary productivity and nutrient cycling are not impacted on by the project activities. Consequently, the referral has not assessed this potential impact for its significance. Primary production can be impacted by elevated suspended sediments in multiple ways; either by reduced light availability or suspended sediments trapping phytoplankton and zooplankton which are subsequently removed from the primary production cycle as the suspended sediments settle out on the seafloor. Further, dredge spoil disposal and seabed mining have a direct impact on infauna and the nutrient/trophic process within sediments. Changes to sediment composition from disposed sediment could also permanently change sediment chemical processes. As such, the primary productivity and nutrient cycling should be assessed as part of the risk assessment.	Coastal processes
Department of Environment, Parks and Water Security (DEPWS)	3	3	The referral has not established its zone of influence and therefore cannot determine whether the project will impact on significant conservation areas. For example, seagrass meadows occur within Shoal Bay. It is proposed that the dredge spoil disposal site is located next to that of INPEX. No modelling has been undertaken to determine if suspended sediments and light availability will impact on neighbouring seagrass meadows. Further, sediment chemistry around the INPEX dredge spoil site seems to indicate that sediment has moved from the dredge spoil ground into neighbouring areas. It is unclear how far the sediments have moved and to what extent this impacts on benthic fauna (infauna) and conservation significant areas, like seagrass meadows.	Coastal processes
Department of Environment, Parks and Water Security (DEPWS)	3	3	The referral notes that: *Based on these monitoring observations for the significantly larger program of works, it would seem unlikely that with an appropriate management and monitoring framework that there is the potential for impacts from this Project to be any greater than those observed during Ichthys.* The referral has not taken into account the cumulative impacts nor assessed the zone of influence to support this statement.	cumulative impacts
Department of Environment, Parks and Water Security (DEPWS)	3	4	The referral has not considered changes to sediment quality as a significant impact and therefore did not discuss. However, dredge disposal can have a significant impact on marine environmental quality. It has a direct impact on benthic fauna and flora and therefore has the potential to change ecosystem processes (nutrient pathways, water quality and trophic structures).	Sediment / plume modelling

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	4	The referral notes that there will be impacts to water quality from pipeline trenching, dredge spoil disposal and seabed mining activities. These activities will impact on suspended sediment conditions, light availability at the seafloor in the Darwin Harbour and Shoal Bay and sediment transport characteristics. Although the proponent has committed to undertake further dispersion modelling, the referral solely relies on INPEX's assessment to inform their risk assessment on impacts to water quality. This is not considered acceptable. Dispersion modelling is critical for determining the zone of influence and identifying where direct and indirect impacts overlap with sensitive habitats. Without this, the proponent is unable to scope the full impact of its activities on water quality, other than areas of direct impact. There is the potential that environmental conditions are site specific and therefore INPEX's assessments are not directly applicable. In particular, it is noted that dredging will occur in the western part of Darwin Harbour which has more complex hydrodynamics than East Arm. This could result in inappropriate assumptions feeding into the risk assessments. The Flora and Fauna Division recommends that plume dispersal and sediment transport modelling is undertaken and risk assessment is undertaken considering modelling outputs and potential indirect impacts. Further, the Flora and Fauna Division recommends that the 'Dredging and Dredge Spoil Placement Management Plan' includes a monitoring program. The objective of this would be to validate the sediment transport and plume models. This has relevance to assessing the health of sensitive	Sediment / plume modelling
Department of Environment, Parks and Water Security (DEPWS)	3	4	The referral notes: During trenching, spoil disposal and backfill activities, the increased turbidity and sediment levels in the water may result in a visible surface plume which is often associated with such activities. While such plumes may lead to a decline in aesthetics during these activities, they will be localised and temporary in nature. This is an unsubstantiated comment, as no plume modelling has been undertaken. Further, given that dredging will take close to two years the term "temporary" may not be annropriate.	General marine
Department of Environment, Parks and Water Security (DEPWS)	3	5	The referral assesses the risk to biodiversity and environment values on the basis of direct impacts from project construction and operational activities. It has inferred potential indirect impacts, however has not established zone of influence and thus cannot adequately assess whether significant habitats or environmental values are impacted on.	General marine

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	5	The referral uses benthic habitat data from 2019 (Galaiduk et al. 2019 and Siwabessy et al. 2016). There is more recent benthic modelling undertaken by the Australian Institute of Marine Science (AIMS) (2021) which should be used to inform ecosystem values. The modelling takes into account a wider variety of environmental drivers and has adjusted its modelling approach to take into account the rarer benthic community types. The referral cannot solely rely on modelled habitat data. The proponent has undertaken some benthic surveys for the purpose of laying the pipeline. However this effort is inadequate for the purpose of verifying whether the modelled benthic habitat data represents which benthic communities actually occur within the pipeline corridor and the zone of influence. These surveys do not allow the accurate assessment of the extent, composition and characteristics of benthic habitats. The risk assessment also downplays the value of filter feeder habitat in channel and channel slope areas. Generally the filter feeder habitats that occur on rocky and mixed substrates (various compositions of rock and coarse sediments) are diverse and provide structure for fish and other invertebrate fauna. This habitat functions as refuge, feeding and reproductive areas. These habitats are relatively rare when compared to the extent of sand and mud dominated habitats and are present within the pipeline corridor. It is recommended that proponent undertakes a dedicated benthic survey for the pipeline corridor in Darwin Harbour and on knolls and rocky/mixed sedimentary environments within the zone of influence. The benthic survey design should be based on identifying physical environmental characteristics, as outlined for example in Nicholas et al. (2019); should follow benthic habitat modelling as undertaken by Al MS	Benthic habitats

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	6	The referral notes that: ... *benthic communities (particularly corals and sponges) can be impacted by suspended sediment through three primary cause effect pathways: light reduction, increased suspended sediment concentrations, and sediment deposition (smothering).* The referral cites work undertaken by WAMSI. This is most probably appropriate for the impact risk assessment, even though it is site specific. The referral further states that: Trenching for pipeline installation will result in pulses of increased turbidity, suspended solids and subsequent reduction in light availability. In order to understand the impact to trenching, and increased turbidity, the referral should clarify how "pulses of increased turbidity" is applicable in this case. If dredging/trenching is continuous, it would be assumed that the dredging plume is continuous. It is important to understand this, as the referral uses "pulses" as the reason for not exceeding the benthic primary producers' high impact (i.e. mortality) environmental trigger of a 3-fold decrease in light levels, and a combination of 10mg/L and 2.3mol photons/m'/day over a 42-day period (WAMSI 2019). No plume modelling has been undertaken and the proponent has not determined what suspended sediment concentrations are likely to be. Therefore, there is no data to compare against WAMSI triggers and thus, the risk assessment is limited to INPEX specific circumstances. As the proponent has committed to undertake plume and sediment modelling, it is recommended that the risk assessment is reviewed in context of project specific data, plume and sediment modelling outputs, and updated habitat layers.	Sediment / plume modelling
Department of Environment, Parks and Water Security (DEPWS)	3	6	The referral only considers seagrass meadows in Fannie Bay. Considering the hydrodynamic conditions of Darwin Harbour it is unlikely that turbidity and suspended sediments will play a significant role in determining impacts to these meadows. However, this assumption should be tested through plume modelling. The referral has failed to consider impacts to seagrass meadows in Shoal Bay and Casuarina Coastal Reserve. Again it is recommended that plume and sediment transport modelling for dredge spoil disposal is undertaken so that an appropriate risk assessment can be undertaken.	Benthic habitats

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	6	The referral states: *While there will be direct impact to the seabed in this area and subsequent localised and temporary decrease in water quality, this is only expected to result in temporary behaviour changes to fish during construction. There is not expected to be any significant impact to the RPA and the addition of the Project pipeline will add additional, artificial habitat for reef fish.* No evidence has been provided to support the statement in relation to a localised and temporary decrease in water quality. Given the duration of the dredging campaign and failure to undertake plume and sediment transport modelling there is no understanding of the time duration and spatial extent in water quality decline. The referral also states: There is widespread habitat available in the immediate vicinity that marine fauna are able to access and consequently no significant change to these conservation significant areas is expected. This argument is not supported because the spatial extent of declined water quality has not been established and the proportion of impacted versus non-impacted areas has not been established. There is insufficient information to make this claim and subsequently indicates that the risk assessment requires further review. Further, the referral has not considered whether the available habitats are important for feeding or life stages of listed fish species (*Environment Protection and Biodiversity Conservation Act 1999* or *Territory Parks and Wildlife Conservation Act 1976*) and important commercial and/or recreational species. Consequently the referral's risk assessment requires revision to take into account the full suite of potential impacts.	General marine

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Environment, Parks and Water Security (DEPWS)	3	7	The referral has identified that marine megafauna and turtles occur in East Arm and Darwin Harbour. In particular, it identifies that there are three species of coastal dolphin (Australian Humpback, Snubfin and Bottlenose) that consistently use the area for foraging and social activities (Brooks et al 2017). Given their occurrence within the footprint and neighbouring areas, marine turtles are likely to use the filter feeder habitat for foraging There is potential for these species to be impacted on by the project. Potential impact pathways include vessel traffic, dredging operations, pile driving and associated underwater noise, and lighting. To reduce the risk to these species, mitigation of potential impacts is required. The referral notes that the project is committed to develop a number of environmental management plans (EMP) to mitigate potential impact and associated risks. The Flora and Fauna Division recommends that the project consider at least the following mitigation measures for incorporation into EMPs in relation to vessel traffic, dredging, pile driving and lighting: • Implementation of vessel speed limits during the construction and operation phase. • Marine megafauna observation zones and exclusion zones; • That the observation period for marine megafauna prior to commencing dredging and pile driving is 20 minutes and that the observer is solely dedicated to the task of sighting and recording marine megafauna interactions prior to, and during, dredging and pile driving operations. • Lighting specifications follow national guidelines.	Marine megafauna
Department of Environment, Parks and Water Security (DEPWS)	3	8	A cumulative impact assessment was not undertaken. The proponent proposes to discuss with other proponents/dredge operators if dredging operations would coincide with another project. The Flora and Fauna Division does not consider that this adequate to inform an assessment of the risks to this factor. The Flora and Fauna Division recommends that plume modelling should at least include all the activities from the project could impact on suspended sediment. The proponent should also provide the Dredging and Dredge Spoil Placement Management Plan for review by appropriate experts before any dredging commences.	cumulative impacts
Department of Environment, Parks and Water Security (DEPWS)	3	8	See comments for Coastal process - Project activities and significant impact	Coastal processes
Department of Infrastructure, Planning and Logistics - Lands and planning	4	1	The proponent has identified that part of the proposal is on zoned land (under the NT Planning Scheme) and may be able to utilise existing development permits in force. The proponent is encouraged to contact DIPL (Development Assessment Services) at its earliest opportunity to discuss planning requirements as further approvals may be required.	Legislation
Department of Infrastructure, Planning and Logistics - Lands and planning	4	1	The proponent should also contact DIPL (Land Development) prior to finalising the alignment of the pipeline in order to ensure it is optimally located in the context of other infrastructure within Darwin Harbour.	Project description

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Infrastructure, Planning and Logistics – Transport and Civil Services Division	5	1	**Issue**: Insufficient information has been provided to assess the risks to marine transport networks. Potentially significant impacts include but are not limited to: * marine incident as a result of: - laying pipeline close to the shipping channel on fishing vessels, recreational vessels and shipping - if pipeline left on seafloor, how will impacts from marine incident resulting in pipeline leak be managed - damaging other pipeline (Bayu Udan and Ichyts) during construction * disturbance to corridor users from movement of the anchors * congestion to other port users **Recommended action:** The proponent to submit a risk assessment and associated mitigation measures to ensure the Harbourmaster can measure the proponent's acknowledgement of the risks associated with the works impact to marine transport networks and associated port users.	Shipping traffic
Department of Infrastructure, Planning and Logistics – Transport and Civil Services Division	5	1	**Issue**: Insufficient information has been provided to assess the risks to land based transport networks. Traffic and transport regimes have changed considerably in this locality since the original establishment of Darwin LNG but are also expected to increase in the near future as a result of further industrial developments in this area. This will result in greater risks to road users and transport infrastructure along the routes to and from the proposal. **Recommended Action:** The proponent to submit a Traffic Impact Statement (TIS) to assess the road traffic impacts, to ensure the road authority can measure the proponent's acknowledgement of the risks associated with the works impact on NTG Roads, infrastructure and road safety. The assessment is to include, but is not limited to: details on what materials will be transported and their loads, traffic volumes and types of vehicles used for the transportation including the haulage routes and duration of the haulage operation specific to onshore movements including a risk assessment as part of the process to reflect how all roads and infrastructure on a local and regional level will be affected.	Shipping traffic
Department of Industry, Tourism and Trade - Energy Division	9	1	The Energy Division have no formal comments at this stage. They have been in discussion with Santos regarding this project to ascertain the proposed route and appropriate licences as well as the requirement to submit pipeline management plans.	Not Applicable

This table provides a summary of the Government Submissions received for the referral. Each submission has been assigned a number from 1-9.

Department	Submission No.	Pg number	Government Submission / Key Issue	Topic category
Department of Industry, Tourism and Trade - Fisheries Division	6	2	The proposal may have a detrimental impact on the jewfish population in the area. Fisheries have identified that the proposed pipeline passes through the Charles Point reef protection area in which there is a jewfish aggregation they wish to protect. The reef protection area contains an important subsea structure which was the primary reason for the placement of the zone. GPS co-ordinates of the zone are available on request. Fisheries note that they have been in direct discussion with Santas regarding this issue.	Charles Point RPA
Department of Industry, Tourism and Trade - Tourism Division	8	3	This project has potential to impact on tourism and tourism related recreational activities in Darwin harbour. Tourism NT recommends the proponent identify tour operators operating within the harbour who may be impacted by the project (large stakeholders in other sectors were identified in Appendix C, however tourism appears to have been overlooked). Tourism NT can assist with stakeholder identification. The proponent should engage with potentially impacted harbour tour operators in the initial discussion stage as well as during the construction stage (pipe laying) to mitigate and minimise the negative impacts on tourism.	Consultation
Department of Territory Families, Housing and Communities - Heritage Branch	7	1	A typo, but a significant one. The Heritage Branch is the NT Heritage Branch, not the NT Heritage Commission	Legislation
Department of Territory Families, Housing and Communities - Heritage Branch	7	1	7.8.1 Covers Maritime Cultural Heritage. The report states 'Engagement with the Heritage Branch is underway to confirm if additional heritage sites are present within the Project Area'. This is not incorrect, but does not accurately describe the current mitigation plan. The proponent is required to engage a maritime archaeologist to review remote sensing data of the project pipeline in order to locate targets that may indicate as yet unidentified Underwater Cultural Heritage. A scope of work for this consultancy was provided to Santos. While this work may be progressing in the background, this report does not describe the risk nor the consultancy recommended to mitigate it. Similarly the pre-referral tool located in the appendix does not appreciate potential impact to significant UCH sites not previously recorded.	Cultural heritage
Department of Territory Families, Housing and Communities - Heritage Branch	7	1	The document makes reference to both the Historic Shipwrecks Act and the Underwater Cultural Heritage Act. The former was superseded by the later.	Legislation

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Register of all Public Submissions and Key Issues

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Environment Centre NT (ECNT)	9	1	1. The Environment Centre Northern Territory Inc (ECNT) is the peak body for conservation in the NT, with over 7000 supporters.	Not Applicable
Environment Centre NT (ECNT)	9	1	5. Methane gas would be extracted from the Barossa field and transported by pipeline to the Facility for processing into LNG for export	Project description
Environment Centre NT (ECNT)	9	2 - 3	7-9 under heading of Legislative Framework	Legislation
Environment Centre NT (ECNT)	9	2	10. While not an express element of the legislative regime, the NT EPA in exercising its powers under the EP Act should have due regard to potential climate impacts on young people in particular. The Federal Court of Australia recently recognised a duty to exercise reasonable care to avoid personal injury to children from climate change impacts (Sharma v Minister for the Environment [2021] FCA 560). There is significant potential for the duty of care to apply to decision-makers exercising power under NT legislation such as the EP Act and EP Regulations.	Legislation
Environment Centre NT (ECNT)	9	3	12, 13 and 15. We reiterate our request (in separate correspondence to the NT EPA on 8 September 2021) that the NT EPA call-in a referral under s 53(1) of the EP Act of the DLNG Extension and the broader Barossa Project.	Legislation
Environment Centre NT (ECNT)	9	3	14. The Referral Document expressly states (p 17) that processing gas from the Barossa field at the Facility is “excluded” from the referral and that the DLNG Extension was “approved by the NT EPA” under the previous Environmental Assessment Act 1982 (NT) (EA Act). This is incorrect. The NT EPA decided not to assess the DLNG Extension, which is not the same as a completed assessment under the EA Act.2	Project description
Environment Centre NT (ECNT)	9	3 - 4	16. In relation to the Pipeline, we submit that the NT EPA should have exercised its power in r 47(c) of the EP Regulations to refuse to accept the referral, on the basis that it only provides information about one element of a larger action (the Barossa Project) that needs to be considered more holistically. The referred action and the DLNG Extension are necessary components of the Barossa Project, which must be assessed from a cumulative perspective.	Broader project
Environment Centre NT (ECNT)	9	4	17. Now that the NT EPA has decided to accept the referral of the Pipeline, the only means by which the action can be sensibly assessed in the context of the broader Barossa Project is by way of an “inquiry” level of assessment.	Project Assessment
Environment Centre NT (ECNT)	9	4	19. It is not clear from the Referral Document what level of assessment Santos proposes should be applied to the Pipeline.	Project Assessment
Environment Centre NT (ECNT)	9	4	21. Further, should the Pipeline be assessed by way of environmental impact statement, this should be combined with an inquiry as contemplated in r 5(2) of the Environment Regulations.	Project Assessment
Environment Centre NT (ECNT)	9	5	25. ECNT is concerned that the environmental factor of “Culture and Heritage” is not addressed in the Referral Document.	Cultural heritage
Environment Centre NT (ECNT)	9	5	a. The Referral Document acknowledges (p 50) that the selected site for the Pipeline “has some significant … heritage sensitivities”. While Santos may feel confident that the level of knowledge means that these can be managed, the high sensitivity of this environmental factor necessitates comprehensive assessment and management measures.	Cultural heritage
Environment Centre NT (ECNT)	9	5	b. The Referral Document also notes (p 49) that key stakeholders had a common concern as to the impacts of the Pipeline on “areas of cultural and indigenous heritage”.	Cultural heritage
Environment Centre NT (ECNT)	9	5	26. ECNT is concerned that the environmental factor of “Atmospheric Processes” is not addressed in the Referral Document.	GHG emissions / AQ

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Environment Centre NT (ECNT)	9	5	a. The Referral Document claims (p 120) that the greenhouse gas emissions of the Pipeline are limited to construction and that operations do not "alter" emissions beyond those already "approved". As discussed above in Section A, we strongly submit that an additional 25+ years of operation of the Facility should be properly assessed and managed. Plainly, as the Pipeline is a necessary component of the Barossa Project, it facilitates significant greenhouse gas emissions and undermines the Paris Agreement goal of limiting warming to 1.5 degrees and reaching "net zero" emissions by 2050, as stipulated in the NT Government's "Climate Change Response: Towards 2050" (July 2020).	GHG emissions / AQ
Environment Centre NT (ECNT)	9	5	b. The Referral Document includes numerous references to elements of the Barossa Project, including the Pipeline, which indicate that comprehensive assessment of this environmental factor is required, such as:	Project Assessment
Environment Centre NT (ECNT)	9	5	i. the statement on p 16 that annual rates of greenhouse gas emissions at the Facility will increase by approximately 5% when processing Barossa gas (in stark contrast to the previous finding that annual rates of emissions would be lower than current operations);	GHG emissions / AQ
Environment Centre NT (ECNT)	9	6	ii. references to the "Bayu-Undan CCS Opportunity" without providing any details of whether CCS is feasible or how Santos proposes to make this unproven technology work; and	Broader project
Environment Centre NT (ECNT)	9	6	iii. acknowledgement that, due to the extremely high content of carbon dioxide in the Barossa field, a significant but unspecified amount of greenhouse gas will simply be vented into the atmosphere in order to transport it through the Pipeline.	Broader project
Environment Centre NT (ECNT)	9	6	c. The Referral Document contains no figures or estimates for the greenhouse gas emissions associated with the Pipeline and broader Barossa Project, and does not make any reference to the indirect emissions associated with the combustion of produced LNG	GHG emissions / AQ
Environment Centre NT (ECNT)	9	6	29. It is crucial, given these values, that the Pipeline, and the broader Barossa project, is subject to a rigorous assessment at the highest level, including of the cumulative and indirect impacts of the Proposal.	Project Assessment
Environment Centre NT (ECNT)	9	7	30. The Pipeline will have very significant impacts on the three environmental factors identified by Santos in the Referral Document, namely Coastal Processes, Marine Environmental Quality and Marine Ecosystems	General marine
Environment Centre NT (ECNT)	9	7	Some of the information provided in the Referral Document is inaccurate and seems designed to de-emphasise important environmental values associated with the Harbour. For example:	Project Assessment
Environment Centre NT (ECNT)	9	7	(i) the Referral Document does not refer to the most recent research mapping benthic communities in Darwin, which predicts a very high probability of extensive hard coral habitat in Darwin Harbour, including in the areas to be traversed by the Pipeline. These areas are extremely significant for marine biodiversity, providing habitat and shelter for a vast diversity of species. None of the Darwin Harbour marine habitat maps (corals, seagrasses, mixed communities) from this report are used in the Referral Document;	Benthic habitats
Environment Centre NT (ECNT)	9	7	(ii) the Referral Document suggests instead that Darwin Harbour comprises largely sand-mud and soft sediment communities, which is contradicted by the above research;	Benthic habitats
Environment Centre NT (ECNT)	9	7	(iii) the baseline survey provided in the Referral Document (Appendix D) is restricted to the project area only, and does not refer to marine habitat studies of Darwin Harbour, or outer Darwin Harbour, which is the potential zone of influence of the Pipeline's construction and operation;	Benthic habitats
Environment Centre NT (ECNT)	9	7	(iv) the Referral Document mentions the need to build a cofferdam but does not specify its size or even if it is required. The impacts of shoreline erosion associated with a cofferdam needs further assessment;	Coastal processes
Environment Centre NT (ECNT)	9	7	(v) the list of threatened species is inaccurate and is a significant underestimate. Only 7 marine threatened species are listed, and 2 migratory species;	Threatened species
Environment Centre NT (ECNT)	9	7	(vi) no detail is provided on the source of rock for infill of the trench or the quantity needed, or where the dredge spoil will be dumped. If the rock for the trench infill is coming from reef areas significant damage to habitat for already overfished fish stocks may occur.	Project description

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Environment Centre NT (ECNT)	9	7-8	b. The potential impacts from the proposed dredging and reclamation activities on bathymetry and coastal processes have not been adequately established in the Referral Document. The proponent must comprehensively investigate the potential impacts of the proposed dredging and trenching associated with the project as outlined in the NTEPA Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory to ensure that the environmental values of the coast are protected, taking into account the latest research regarding benthic habitats in Darwin Harbour	Coastal processes
Environment Centre NT (ECNT)	9	8	c. Existing pressures on Darwin Harbour include industrial activities, urban runoff and discharges, maintenance dredging and clearing of mangroves. The most recent Darwin Harbour report card demonstrated degraded sediment quality and elevated metal concentrations at nearby East Arm. Construction and operation activities have the potential to disturb marine sediments, with a great deal of uncertainty regarding the characteristics of the material to be dredged. It is crucial that detailed geotechnical investigations occur to address uncertainties in the sediment characteristics. Further studies (including modelling) are also required to establish the zone of influence and the scale of any likely sediment plumes. Further investigation into borrow grounds, spoil dumping grounds and dredge plumes are required. Dredge plume modelling should include hydrodynamic and ecological modelling and ascertain impact prediction to inform an impact management program.	Sediment / plume modelling
Environment Centre NT (ECNT)	9	8	Cumulative impacts of underwater noise, air quality and water quality also need to be assessed in the context of the plans to further industrialise the harbor. There is potential for the Pipeline to contribute significantly to cumulative impacts. Full characterisation of the contamination of marine sediments in the Project Area is required to obtain a greater understanding of recently accumulated sediments and to assess the impact of proposed dredging and trenching on marine environmental quality	cumulative impacts
Environment Centre NT (ECNT)	9	8	d. The Referral Document lists various risks to water quality such as treated sea water release during a wet buckle event and unplanned marine diesel spills. The report does not refer to the hydrodynamic modelling studies which suggest the harbor is poorly flushed due to the lack of big river flows and the diurnal tidal cycle resulting in 20 day flushing times. Any chemical or petroleum release into the harbor is likely to remain in the Harbour for a considerable period of time as seen from the 2016 oil spill from the cargo vessel Antung that spread some 30 km. Considering up to 600 m3 of treated seawater containing Biocides and Oxygen Scavengers may be discharged into Darwin Harbour in the event of an accident, modelling of wet buckle release of treated seawater and hydrocarbon spills will be essential to understand impacts.	Spills
Environment Centre NT (ECNT)	9	9	e. The impacts of project activities on marine ecosystems provided in the Referral Document rely on key information and assumptions that are out of date and lacking in critical information. Santos repeatedly claim that this project is smaller than the Inpex Ichthys project therefore the environmental impacts will be acceptable. Very little evidence is available suggesting there was an acceptable level of impact from construction of Inpex Ichthys LNG.	Comparison to ichthys
Environment Centre NT (ECNT)	9	9	For example, key condition indicators for the Anson-Beagle bioregion for dredging impacts include seagrass extent and density, and combined regional pressures requires assessment of marine megafauna abundance. Limited surveys on marine megafauna populations suggest significant impacts did occur with almost half of the recorded Humpback Dolphin population leaving the harbor. The last marine Turtle survey was conducted in 2014. Without repeated surveys it is impossible to ascertain the level of impacts from developments. This project may push the remaining marine megafauna from the harbor considering the projects proximity to the relative safe haven of the undisturbed West Arm. Updated data on marine megafauna populations, coral extent and seagrass health are essential to understand the impact of this proposal.	Marine megafauna
Environment Centre NT (ECNT)	9	9	f. The Pipeline will impact significant marine conservation areas including the Charles Point Reef Fish Protection Area and Weed Reef, and this should be explicitly addressed. Construction of a gas pipeline through the Charles point reef fish protection area needs thorough investigation considering the importance of this zone to the overfished stocks of Golden Snapper and Northern Mulloway. Weed Reef is regarded by Traditional Owners and eco tour operators as the primary location for Dugongs in Darwin Harbour. Trenching activities will have a significant impact on dugong habitat.	

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Environment Centre NT (ECNT)	9	9	g. The Referral Document states that Fannie Bay is the closest seagrass to the pipeline route, however this information is based on the incomplete habitat mapping data from 2016 and is incorrect. Benthic habitat mapping surveys should be completed that include the nearshore areas and alternative pathway options need to be assessed.	Benthic habitats
Environment Centre NT (ECNT)	9	9 - 10	h. Marine megafauna data is poor and many assumptions provided in the referral report are incorrect. While Inpex provided funding for marine mammal research in 2016, that research has not been continued. The last available research suggested that almost 50% of Dolphins had left the harbor after the construction of Ichthys LNG and no recent data is available to verify these results. Snubfin Dolphins and Bottlenose Dolphins are well documented in Darwin Harbour and yet the referral only mentions the presence of Australian Humpback Dolphins. Other assertions about absence of whales from the project area are also incorrect with recent sightings of Humpback Whales recorded along the west coast of Bathurst Island and Van Diemen Gulf. Comprehensive marine megafauna population assessments and applied research into the causes of population decline are required along with ongoing biodiversity monitoring. Targeted marine benthic habitat surveys of the areas to be disturbed during construction, and assessment of underwater noise impacts during construction and operation are required	Marine megafauna
Environment Centre NT (ECNT)	9	10	i. The Pipeline is part of the larger Barossa Project, which entails the development of a major new gas field with the highest carbon dioxide content of any Australian offshore field. Approximately 15 Mt/pa of life cycle greenhouse gas emissions will be released for a period of 25 years from this project, generating over 350 million tonnes of carbon dioxide equivalents. Darwin Harbour already experiences 8.3mm/pa sea level rise and research indicates the 20,000ha mangrove estate within the harbor is only just coping with this rapid change. Darwin mangroves play a key role in preserving water quality by intercepting catchment-derived pollutants and they substantially influence the movement of sediment through the estuary. The future health of Darwin Harbour depends substantially on the protection of the mangrove estate against further pressures from climate change. Increasing carbon dioxide and other greenhouse gas emissions from the Barossa Project, will increase sea level rise and amplify impacts on coastal processes. The indirect impacts of climate change of the Pipeline, and Barossa Project should also be assessed.	GHG emissions / AQ
Environment Centre NT (ECNT)	9	10	31. The Pipeline and broader Barossa Project will have a potentially significant impact on the "Cultural Heritage" environmental factor.	Cultural heritage
Environment Centre NT (ECNT)	9	10 - 11	32. There are numerous terrestrial and marine sacred sites in both Darwin Harbour, and on the Cox Peninsula. The area north of Charles Point is of particularly high cultural value to the Kenbi Traditional Owners and Larrakia and Belyuen residents and the Pipeline route may well traverse areas of cultural and spiritual significance. The zone of influence of the project may be far greater than the Pipeline footprint itself, due to sediment plumes, turbidity and altered light. This may have adverse impacts on sacred sites and culturally significant areas. The Referral Document stops short of stating that the proponent will obtain an authority certificate under the Northern Territory Aboriginal Sacred Sites Act. This should be a precondition of any environmental approval.	Cultural heritage
Environment Centre NT (ECNT)	9	11	33. In addition, there are also numerous cultural heritage sites in Darwin Harbour. Hiscock and Hughes relates that there are significant prehistoric shell mounds throughout Darwin Harbour. Further, recent research indicates that submerged cultural heritage is common in northern Australia, but under threat due to a lack of information about them. A regional assessment of submerged archaeological potential in the Northern Territory found that the submerged areas off the coast of the Northern Territory may contain a wealth of important archaeological material. Recently, research revealed archaeological material across terrestrial, coastal and submerged environments at Murujuga in north-west Australia. This research was funded by Woodside Petroleum. There is no reason why the proponent should not ensure a similar survey is undertaken as part of the environmental assessment of the Pipeline. An extensive cultural heritage survey of marine and submerged areas in the vicinity of the pipeline, preferably in partnership with Larrakia people, is required	Cultural heritage
Environment Centre NT (ECNT)	9	11	34. The Pipeline and broader Barossa Project will have a potentially significant impact on the "Atmospheric Emissions" environmental factor through large contributions to global greenhouse gas concentrations.	GHG emissions / AQ

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Environment Centre NT (ECNT)	9	11 - 12	a. There are extensive reputable scientific resources addressing the issue of climate change and the need to urgently reduce greenhouse gas emissions. i. The Intergovernmental Panel on Climate Change (IPCC) report "Climate Change 2021: The Physical Science Basis" (August 2021) found that human influence on the climate by way of anthropogenic greenhouse gas emissions was "unequivocal", already causing unprecedented changes to the climate system, and that the 1.5°C and 2°C warming levels will be exceeded during the 21st century unless deep reductions in greenhouse gas emissions occur in the coming decades. ii. The IPCC Special Report "Global Warming of 1.5°C" (October 2018) highlights the importance of emissions reductions beginning as soon as possible – by 25-45% from 2010 levels by 2030, with more rapid reductions producing better warming outcomes. iii. The International Energy Agency's report "Net Zero by 2050: A Roadmap for the Global Energy Sector" (May 2021) confirms that to achieve net zero emissions by 2050, fossil fuel use needs to decline drastically and no new oil and natural gas fields are required. iv. Extensive analysis of carbon budgets compatible with warming scenarios such as 1.5°C, for example the Climate Council document from April 2021 "Aim High, Go Fast: Why Emissions Must Plummet", which also highlights the need for rapid emissions reductions before 2050	GHG emissions / AQ
Environment Centre NT (ECNT)	9	12	b. The Barossa Project is a new fossil fuel development. The total greenhouse gas emissions that would be produced by the Pipeline and broader project have not been provided to the NT EPA. Plainly, any additional sources of greenhouse gas emissions in the current context would have a significant impact on the above goals. Given the urgency of action required and the catastrophic consequences of failure to reduce atmospheric concentrations of greenhouse gas emissions from current levels, we strongly submit that this environmental factor requires comprehensive assessment and management under the EP Act	Broader project
Environment Centre NT (ECNT)	9	12	35. The extent of community engagement that has occurred in relation to the Pipeline is minimal.	Consultation
Environment Centre NT (ECNT)	9	12	a. We do not consider ECNT was properly engaged as a key stakeholder and representative peak body organization ahead of the Referral Document. i. The Referral Document lists ECNT as a stakeholder included in Santos' "prereferral engagement". ii. Appendix C to the Referral Document states that Santos had a meeting with ECNT on 17 November 2021. At this meeting, Santos indicated its intention to refer the Pipeline for assessment to the NTEPA. ECNT stated at the meeting that it considered the referral of the Pipeline to be inadequate and misleading about the true extent of the Barossa Project's impacts. ECNT reiterated its position that the impacts of the Barossa Project, including its significant greenhouse gas emissions, should be referred for assessment to the NTEPA. iii. In the summary list on p 48-49 of the Referral Document our central concern as to climate impacts is not included	Consultation
Environment Centre NT (ECNT)	9	12 - 13	b. We are aware of significant public interest and community concern about the Pipeline and the Barossa Project which necessitates transparency and further opportunities for public participation in this assessment. This is evidenced by the high volume of individual submissions which ECNT understands have been provided to the NTEPA in relation to this referral.	Consultation
Environment Centre NT (ECNT)	9	13	c. Santos appears to rely on "opportunities for public comment as part of the referral process and subsequent assessment phases" for ongoing engagement (p 49, emphasis added). This supports the need for an assessment method which includes sufficient opportunities for public participation (e.g. an inquiry), as there are no other means by which Santos proposes to engage the community with respect to the Pipeline and the Barossa Project.	Consultation
Environment Centre NT (ECNT)	9	13	36. The capacity of communities and individuals likely to be affected by the Pipeline to access and understand information about the proposed action and its impacts is not adequately addressed by the Referral Document and Santos' engagement to date.	Consultation
Environment Centre NT (ECNT)	9	13	b. Potentially affected communities and individuals for this referral include those with limited technical expertise or education, limited time and resources to devote to reading complex project documents, limited access to the internet, and cultural or language barriers including living remotely	Consultation

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Environment Centre NT (ECNT)	9	13	c. These communities and individuals would be better able to understand information about the Pipeline and Barossa Project if the opportunities to participate in the assessment: i. included opportunities for oral engagement, which may include formal and/or informal settings (e.g. public hearings); ii. were transparent, independent and not conducted solely by Santos representatives; iii. were administered by appropriate persons (e.g. members of a panel with experience and/or suitable qualifications to engage with these affected communities); and iv. had been determined and programmed well in advance so that communities and individuals were able to make necessary arrangements to participate (e.g. subject to a terms of reference which included a schedule of how an inquiry would be conducted).	Consultation
Environment Centre NT (ECNT)	9	13	37. On the basis of these factors, we submit that the NT EPA must require an assessment by inquiry for this referral.	Project Assessment
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	2	Should be assessed as EIS based on the following;	Project Assessment
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	2	The capacity of communities and individuals to access and understand information about the project: -recreational fishing impacts in Darwin Harbour during construction - more consideration with how communication with recreational fishing community will be planned and achieved. -Medium-term social impacts that flow from the perception of damage done to fish habitat in the harbor. This is based on anecdotal evidence of some community sentiment/perception that the harbor has “not fully recovered from the Inpex dredging”. -Further assessment into impacts within Charles Point RPA. Perhaps equally significant is the potential social impact that could be realised if the fishing community perceive that the broad community support for the RFPA over the past five years is undermined by the approval of the construction of the pipeline through the area.	Recreational fishing
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	2	charles point -Damage to benthic environment in Darwin Harbour - he footprint of this corridor is expected to include areas of disturbance 50m wide, and this may be wider still, should the proposed method of “side casting” be used to keep dredge spoil adjacent to the trenching area for backfill purposes. -localised impacts from trenching will occur in the form of the removal of fish habitat that supports recreationally targeted species. Removal of hard rocky bottom substrate environment as shown in RPS sampling (sites HS61 and HS68). More information about how trenching will cover the pipeline in rocky substrate habitats could be more explicitly explained to determine whether the pipeline will provide suitable artificial habitat.	Benthic habitats
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	4	Mauna Loa - In meetings with SANTOS, AFANT provided a GPS database containing many popular fishing locations in and around Darwin Harbour. This was provided to assist SANTOS with planning a route that avoids know recreational fishing spots and valued natural features. While the proposed northern route avoids directly transecting these known locations, it passes close by (150m) the Mauna Loa WW2 shipwreck. The route proposes a disturbance with a footprint of up to 50m within the vicinity of this known heritage site, which is also known as a good fishing area/habitat for jewfish. More detail should be provided about the suitability of the proposed proximity to this site, with consideration given to improving the buffer zone, and assurances given that side-casting will not be allowed in this immediate area.	Cultural heritage

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	4	Mud crab migration - This matter was not raised by AFANT in the meeting we had with SANTOS, owing to our internal capacity to prepare within the constraints of the timeline of our meetings/ the referral. We have since however, consulted informally with fishery experts and the Mud Crab Fishery Management Framework to inform the following concern. Mud Crab spawning in the Northern Territory typically occurs from September – November. Female mud crabs leave their usual habitat for spawning, and have been recorded moving large distances offshore to release their eggs. It is assumed that to maximise the survival rate of larvae, female mud crabs seek stable conditions with high salinity and temperature for hatching the larvae (Mud Crab Fishery Management Framework, 2017). The proponent has proposed that shallow water pipelay take place in the months of October, November and December. While the exact crab migration paths are unknown, and while it may be therefore not possible to say that these actions will have a direct/knowable impact on the migration of female mud crabs on their way to spawn in deeper/ offshore waters, these events will almost certainly occur at the same time, in overlapping locations. Further engagement with NT Fisheries should be required to better understand these factors, and if necessary, to mitigate the risk of interrupting the Darwin harbor mud crab spawning migration.	Mud crab migration
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	4 - 5	It is AFANT's position that at the next stage of assessment the proponent should give greater consideration to potential pathways for unacceptable/unintended cumulative impacts to be realised. It is not necessarily reasonable to suppose that because the impacts of previous projects were similar and efforts were made to mitigate issues, that this project, being smaller will automatically avoid contributing cumulative impacts. Indeed, this seems to skirt the point that multiple developments in proximity over a relatively short time can have a compounding effect. Indeed, the fact that a number of aggregated small impacts can together produce a larger consequence is the very heart of the matter. For example, Cuddington et al. (2013) provides that Cumulative impact management should be concerned with determining a desired future state of an ecosystem, and how this can be achieved through the management developments that may have direct, indirect or interactive impacts on the ecosystem. It is reasonable to consider that the environmental resilience in the area adjacent to previous pipeline developments in Darwin harbor may be further degraded with each new dredging / trenching operation. While such impacts may eventually be determined to be manageable/ tolerable, this approach to considering cumulative impacts nonetheless requires more explicit consideration and explanation by the proponent. Regard should be had to the condition of previously disturbed benthos and the overall dredging/disturbance planned for the harbor, as well as the process of industrialization occurring within Darwin harbor. The regulator should be concerned with fostering cooperation and information sharing by industry so that such an assessment can be reasonably made by the proponent.	cumulative impacts
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	5-6	Uncertainty over the need for the development, and therefore doubt over the beneficial trade-offs against the likely environmental, social and cultural impacts. Regulator must have regard to the likelihood of the CCS project actually proceeding. The EPA should expect that a solid commitment from the proponent and any partners to the CSS element of the project will be made clear at the next stage of assessment. Indeed, it does not seem unreasonable to suggest that a viable plan for CCS (or another solid and assured reason) should be a condition for any future approval to proceed with the pipeline.	Broader project
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	6	Other factors to consider in next stage of assessment: Cultural heritage - Concern around 'Potential for impacts on recreational fishers' perception of a healthy harbor will be a foreseeable consequence of the proposed project.' While the proponent may be able to effectively manage any risks, this issue should be explicitly acknowledged under the Maintain Cultural Heritage section.	Recreational fishing
Amateur Fisherman's Association of the Northern Territory (AFANT)	1	6	Spoil ground and potential recreational fishing offsets - AFANT is aware that the Inpex spoil ground has since become an area with appeal to recreational fishers. There is anecdotal evidence that reef fish, including snapper species are now caught in this area. It is reasonable to suppose that the proposed new spoil area, though smaller in scale may eventually hold value as a fishing location. The proponent may wish to engage with fishers and AFANT to learn more about fishing activities in the borrow and spoil areas proposed. Further plans to better understand project impacts and recovery may also be warranted. Additionally, the Inpex spoil area may be investigated to better understand fish communities and habitat that has been created following the disposal of spoil. Should potential material, social and cultural impacts to recreational fishing be acknowledged by the proponent, they may consider how augmenting the proposed spoil area (or another area) with additional purpose-built reef habitat structures may expedite potential offsets provided to recreational fishers in the form of improved fishing opportunities.	Recreational fishing

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Australian Parents for Climate Action Darwin and NT - volunteer group	2	9	Specifically, we wish to see the NTEPA: (a)call in a referral under s53(1) of the Environment Protection Act of the broader Barossa Project as a whole; (b)if, the NTEPA does not call in the proposal, the Darwin Pipeline Duplication Project and the broader Barossa Project must be assessed at the highest level – a public inquiry.	Broader project
Australian Parents for Climate Action Darwin and NT - volunteer group	2	10	1. Greenhouse gas emissions will rise Santos has not addressed how they will monitor for fugitive emissions along the pipeline and at each state of processing the gas from beneath the sea floor to the ships to the harbour. In the DPDP this chain of production is well over 100km long through sensitive marine environments and Endangered marine mammal and turtle breeding grounds. Santos' referral report has no information to reassure us of these huge climate risks due to fugitive methane emissions and massive amounts of C02 produced once the pipeline is in use.	GHG emissions / AQ
Australian Parents for Climate Action Darwin and NT - volunteer group	2	10-11	2. The NT may become unliveable The project will increase global warming which will result in further heating of the NT making it too hot for people to live	GHG emissions / AQ
Australian Parents for Climate Action Darwin and NT - volunteer group	2	11	3. Minimal long-term jobs No supporting evidenmce in the referral for how the project will create more jobs i.e. how many jobs, for how long etc. Further social impact assessment is required to determine potenbtial impacts on the Darwin community. When construction of Inpex was completed, house prices plummeted, people left the NT in droves, the Darwin CBD was left virtually deserted and many small businesses had to close up. In 2022, the next bust will be permanent as the entire world moves away from fossil fuels – including gas.	Social impacts
Australian Parents for Climate Action Darwin and NT - volunteer group	2	Dec-13	4. Gas is a bad investment and risks becoming a stranded asset - future carbon capture and storage does not justify the DPDP Furthermore, CCSU is not a justification for pursuing more dirty fossil fuels. Carbon capture and storage will lock us into decades more of fossil fuels and is not feasible at any scale close to what will be required to sequester the emissions generated from the project, let alone reduce current emissions. More detail is rfequired forrm Santos on CCS project and how this will help reduce CO2 emissions.	GHG emissions / AQ
Australian Parents for Climate Action Darwin and NT - volunteer group	2	13	5. Poor consultation with Traditional Owners We understand that Tiwi Islander Traditional Owners are seriously concerned about the DPDP and do not believe that Santos has consulted adequately with them about this proposal. The Larrakia People are the Traditional Owners of the Darwin Harbour and must also be genuinely consulted in this way. This will be the third pipeline laid in Darwin Harbour, which has significant biocultural values for Larrakia, and previous consultation with Larrakia Traditional Owners does not "cover off" on new developments.	Consultation
Australian Parents for Climate Action Darwin and NT - volunteer group	2	14	6. Habitat destruction The NTEPA must consider how the DPDP will impact the Territory's precious mangrove forest ecosystems, and how the project will have far reaching impacts on these important cultural resources, well beyond the site of their photo monitoring points. Santos asserts that the DPDP will be 'smaller' than other pipelines already in use in the harbour. But the fact is this will be the third major pipeline construction. The cumulative impacts of increasing infrastructure in this already highly developed area cannot be dismissed. Up to date research and surveys must be undertaken by an independent expert in order to determine what the anticipated impacts will be on the animals themselves and their critical habitat areas.	cumulative impacts

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Australian Conservation Foundation - Elizabeth Sullivan	3	16	Emissions profile of the project We therefore believe it would be remiss for the overall emissions profile of the Barossa project not to be publicly assessed by the NTEPA under the current relevant Act. Whether the proposed Project will lead to an increase in emissions that exceeds the threshold established by previous approvals needs to be investigated, and the most appropriate method for this investigation is a public inquiry. Expert evidence suggests that emissions from the Barossa project will be significant and detrimental to Australia's carbon budget.	GHG emissions / AQ
Australian Conservation Foundation - Elizabeth Sullivan	3	16	Carbon Capture and Storage (CCS) Any decision concerning whether to undertake an assessment of the Project must consider the purpose for which the Project is being carried out, which is explicitly referred to by the proponent as making available the existing pipeline for CCS. Consequently, the claims made by the Proponent in the referral documents concerning the ability for CCS to allow net zero emissions targets to be reached must be appropriately scrutinised. The feasibility of CCS is not established, and in fact there is no successful example of an offshore gas field being used to reach emissions capture targets. We submit that a public inquiry, broad enough in its scope to investigate the feasibility and potential impacts of CCS, must therefore be undertaken.	Broader project
Karen Edyvane - Australian National University	311	2	With a primary focus of assessing the DPD potential environmental impacts on the ecosystem condition and health of the harbour - including significantly, a comprehensive and independent assessment of the status, adequacy and effectiveness of the current Darwin Harbour integrated monitoring and assessment framework to detect and assess medium and longterm anthropogenic impacts.	IMMRP
Karen Edyvane - Australian National University	311	3	I also recommend this highest level of assessment based on my expert opinion that the current water quality and environmental quality monitoring and assessment in Darwin Harbour – particularly the Integrated Marine Monitoring and Research Program (IMMRP) – fails to provide an adequate and integrated framework to detect and assess anthropogenic impacts in Darwin Harbour	IMMRP
Karen Edyvane - Australian National University	311	3	1. Lack of an Adequate & Integrated Marine Monitoring & Assessment Program for Darwin Harbour Throughout the Referral Report, the Proponent emphasizes the critical value and contribution of the monitoring undertaken under the NT Government's Darwin Harbour Integrated Marine Monitoring and Research Program (IMMRP) - both, in assessing the medium and long-term impacts of the INPEX Icthys Project and also, assessing the potential impacts of the current DPD Project. In 2016, the IMMRP was seen as holding great potential in developing an integrated marine monitoring program for Darwin Harbour: *An Integrated Monitoring and Research Program (IMRP) has thus been proposed for the Darwin region to help address many of these issues and to develop and integrate more ecologically relevant measures of ecosystem condition across marine, estuarine and freshwater habitats (DHAC, 2005; Fox, 2011). As with all such endeavours, the success of the IMRP will depend on its ability to overcome the challenges of coordinating numerous stakeholders with divergent interests and ensure funding streams and continuity of management. To this end, the recent securing of $20 million of funding for the IMRP over 40 years, as part of an offset agreement between INPEX Corporation and the NT Government, represents a significant step forward." [From Hallett et al (2016)]* While the NT has made significant progress towards an integrated marine and estuarine monitoring program in Darwin Harbour through WQPP for the Darwin Harbour – it is important to note that the establishment of the $20 million, 40-year IMMRP has primarily remained a 'long-term offsets program' for the INPEX Icthys project. And significantly, was never specifically designed as a holistic and integrated marine assessment, monitoring program to assess the ecosystem condition and ecosystem health of Darwin Harbour. As such, the current IMMRP falls far short of both, an adequate and integrated marine monitoring program to assess potential marine anthropogenic impacts in Darwin Harbour - for the following specific reasons:	IMMRP

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Karen Edyvane - Australian National University	311	3	a) The NT remains the only jurisdiction in Australia not to have an integrated monitoring and assessment system underpinned by an understanding of drivers, activities, threats, condition/impacts and responses (see Hallett et al. 2016). Hallett et al (2016) (including NTG co-authors) review of national, jurisdictional approaches to monitoring/assessing and reporting on estuarine condition, highlights the Northern Territory's lack of integrated monitoring and assessment: *"To date, however, there has been no integration of the outputs from the above biophysical and ecological monitoring programs with the report cards for Darwin Harbour, which remain strongly focused on water quality. Moreover, many of the logistical and administrative barriers identified by DHAC (2005) are still relevant today,including the inaccessibility of monitoring data, fragmented and overly-technical reporting of outputs, and thelack of accountability of monitoring agencies to the community. There also remains little coordination of monitoring activities among the government departments, industry groups and other relevant agencies* (DHAC, 2005; Fox, 2011). Current reporting uses just 2 indicators to assess "Healthy ecosystems and landscapes in the catchment and harbour – catchment disturbance index and mangrove area change." While there has clearly been recent progress by DENR in identifying proposing a suite of pressure indicators for the harbour (see Radke et al 2018) – in an integrated approach, additional stress and response indicators also need to evaluated and identified for the harbour.	IMMRP
Karen Edyvane - Australian National University	311	4	b) The current IMMRP in Darwin Harbour is very focused on water quality monitoring programs – with very little biological and biodiversity monitoring to assess 'ecosystem condition'. The lack of ecologically-relevant indicators and monitoring has been highlighted in major national reviews of WQ monitoring programs (eg. Hallett et al. 2016). And also, repeatedly, in the multiple reviews of the Darwin Harbour WQ monitoring program – both by DENR and also, DHAC (ERG and EMG). Further, the latest Darwin Harbour Integrated Report Card 2021 also highlights this major monitoring gap and has recommended the following urgent action: *"Urgent need for systematic and ongoing biodiversity monitoring programs in the harbour and catchment. Opportunities were identified through this project to partner in the future with Indigenous rangers, biosecurity departments and volunteer groups to assist in collecting this information."*	IMMRP
Karen Edyvane - Australian National University	311	4	c) Lack of an effective long-term WQ monitoring program for Darwin Harbour - The current water quality monitoring under the IMMRP is inadequate and fails to address non-anthropogenic, seasonal and climatic factors on water quality variability (see Makarynksa 2019). Throughout the Referral Report, the Proponent emphasizes the critical value and contribution of the IMMRP WQ monitoring - both, in assessing the medium and long-term WQ impacts of the INPEX Icthys Project and also, the impacts of the current DPD Project. However, DENR latest report for the IMMRP WQ program (Makarynksa 2019) – clearly highlights the inadequacies of the current DENR WQ monitoring, due to its failure to account for seasonal WQ variability and the NT's significant climatic and seasonal factors (ie. monsoonal climate). The report highlights that for the past 2 decades, WQ monitoring has only been conducted in May (two 3-hr neap tide samplings) and October (two 3-hr neap tide sampling). DENR then go on to make the following 'recommendation': *"The results indicated that the existing DENR WQMP protocol based on monitoring in May and October over a 3-hour window centred on high neap tide provides an adequate operational approach for collecting data with acceptable level of variability. However, in order to make consistent comparisons between different years to detect long-term changes in water quality in the Harbour it is recommended to collect data on seasonal basis: (1) in July and/or August (dry season) coinciding with lowest variability in natural conditions and (2) in the wet season (December to March) with highest variability and potentially highest pollutant loads to the Harbour." (page 251)* DENR also notes the need to link WQ field monitoring with other important data sources/tools (eg. satellites). The use of remote sensed data for WQ monitoring *"Linking water quality data from field campaigns and other sources (e.g. satellites) with metocean and hydrological data, with focus on discerning seasonal differences, would provide a better framework to differentiate between natural variability and anthropogenic impacts. Therefore, gaining sufficient knowledge of water quality driving forces in Darwin Harbour is paramount for a successful long-term monitoring campaign." (page 251)* *"To help with anthropogenic change detection, it is recommended to analyse data by season in conjunction with metocean and hydrological data and water quality data from other sources (if available)."*	IMMRP

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Karen Edyvane - Australian National University	311	5	2. Lack of Baseline, Ecosystem Understanding of Darwin Harbour While over the past 10 years, DENR has clearly embraced the concept of 'integrated management' and 'integrated report cards' for DH - https://dhir.org.au/ - baseline ecosystem understanding of Darwin Harbour required to assess human impacts, remains lacking: a) Lack of ecosystem understanding constrains marine assessments and monitoring in Darwin Harbour. While many scientific and technical studies have been conducted in Darwin Harbour over the past 2 decades – there has been a strong focus on water quality, toxicants and habitat mapping – leaving major gaps in understanding of the potential biological and biodiversity impacts of development. Including: — estuarine (and land-sea) ecosystem processes and function — soft sediment communities, sessile epifauna — coral reef & seagrass communities — fish nursery and feeding areas (particularly for commercial, recreational species) — movements and critical habitat (ie. feeding, nursery, calving, breeding areas) of key marine megafauna (sharks/rays, sea snakes, turtles, saltwater crocodiles, dugongs, cetaceans)	Darwin Harbour baseline
Karen Edyvane - Australian National University	311	5	b) Lack of conceptual models, collation/integration of datasets and 'ecosystem modeling' in Darwin Harbour – these critical activities underpin ecosystem monitoring/management: — development and integration of hydrodynamic, contaminant and trophic models (eg EcoPath) — lack of conceptual models — lack of a decision-support system to support monitoring, assessment and reporting DEPWS and the IMMRP have recently highlighted the importance of conceptual models to identify individual stressors and target indicators, and also, software to link monitoring results with report carding (Radke etal 2018). And further, identify the VPSIRR model (developed by the Queensland EPA) as 'best practice'. But fail to recognize that a VPSIRR model has already been developed for the NT which would be suitable for Darwin Harbour (Edyvane & Whiting 2009), or that comprehensive, trophic modelling has already been undertaken in the harbour (Martin 2005) – but has not been incorporated or integrated into current models or monitoring [see c) below].	Darwin Harbour baseline
Karen Edyvane - Australian National University	311	5	c) Failure to incorporate and integrate critical and major past studies which would greatly assist with ecosystem understanding and assessments – particularly the extensive infaunal and epifaunal surveys and decades-long research of the Darwin Harbour undertaken by the NT Museum and international researchers (Hanley et al. 1996), trophic modelling of Darwin Harbour, using 'EcoPath' (Martin 2005), and the development of water quality and environmental quality indicators for coastal and estuarine and marine environments in the NT (Edyvane & Whiting 2009). In 2006, DEPWS (DENR) received $600k in 2006 from the Commonwealth to specifically to develop a coastal, estuarine and marine (CEM) monitoring framework for the NT, supported by an NT indicators framework and also, a spatial database of marine datasets (NT Marine Atlas). Between 2006-2009, a CEM monitoring framework was developed for the NT (Edyvane & Whiting 2009) – incorporating nationally-agreed WQ and EQ indicators, following workshops and consultation with key NT government and non-government stakeholders. Significantly, indicators were developed based on a NT and also, bioregion-based, threat and conservation analysis (undertaken with key stakeholders).	Darwin Harbour baseline

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Karen Edyvane - Australian National University	311	5	Under this same project DENR also engaged the Queensland EPA in 2009, to developed a NTversion of VPSIRR model for the NT coastal, marine and estuarine ecosystems – the NT Marine Assessment and Reporting tool. This indicator framework and monitoring/reporting software was shown to the NT stakeholders, including DHAC and the NT EPA (2009) – specifically with a view to trialing and implementing this new framework and software for integrated marine monitoring and reporting in Darwin Harbour. "NT MARS (Fig 1.), the NT name for the VPSIRR (Vulnerability – Pressure – State–Impact – Risk - Response) software was developed by Rissik et al 2009 and the Queensland EPA and Australian National University. The software is designed to enable consistent monitoring, evaluation and reporting of estuarine vulnerability, risk and condition. At present, this software has been developed for estuaries, but it can easily be converted to enable the assessment of other ecological systems. In other parts of Australia this software is being altered to enable similar assessment of freshwater and terrestrial systems. It is envisaged that in the near future marine and coastal will be incorporated into this software for the Northern Territory." (Edyvane & Whiting 2009) Neither the NT CEM indicators, monitoring and report framework (Edyvane & Whiting 2009) nor NTMARS software, has ever been publicly released by the NTG or utilized by DENR or DHAC. While undoubtedly many marine studies, technical reports have been undertaken in Darwin Harbour, particularly over the past decade – integrated reviews by industry or government are rare. Unlike other areas of major oil/gas development in northern Australia (ie. the Bonaparte Basin, Browse Basin, Exmouth Gulf, Gladstone Harbour) – there are no detailed technical reports of Darwin Harbour which collate, review existing technical studies, and provide a critical and holistic overview of values, pressures, impacts, monitoring activities and overall ecosystem status.	
Karen Edyvane - Australian National University	311	6	d) Lack of investment in baseline ecosystem understanding of Darwin Harbour. In understanding the major knowledge and monitoring gaps in the Darwin Harbour IMMRP it is also important to consider the current very low level of public and private investment in understanding the ecosystems and monitoring the ecosystem 'health' of Darwin Harbour. In other jurisdictions where there has been large-scale, oil-gas infrastructure development and activities have been undertaken ie. Western Australia (Pilbara), Queensland (Gladstone Harbour), there have been major public and private industry investment in baseline marine ecosystem understanding, ecosystem modelling and assessment studies – to enable the robust environmental impact assessments and the development of monitoring protocols, to ensure the protection of environmental values. However in the NT, with the securing of $20 million of funding for the IMMRP over 40 years, as part of an offset agreement between INPEX Corporation and the NT Government – the IMMRP has evolved to become the NT Government's 'de facto' long-term marine monitoring program for Darwin Harbour. With very minimal investment in critical research, knowledge, modelling and monitoring gaps to underpin an integrated monitoring program. The NT Government's low level of investment and commitment to supporting integrated marine monitoring in Darwin Harbour is clearly highlighted by inspection of the INPEX website for IMMRP and comparing it with the DEPWS website for the IMMRP (which was last updated in March 2016): • INPEX - https://www.inpex.com.au/projects/ichthys-lng/our-commitments/darwin-harbourintegrated-marine-monitoring-and-research-program/ • DEPWS - https://depws.nt.gov.au/water/water-management/darwin-harbour/darwin-harbourintegrated-marine-monitoring-and-research-program	Darwin Harbour baseline
Karen Edyvane - Australian National University	311	6	3. The Darwin Harbour IMMRP does not meet international, national or industry 'best practice' As highlighted in the national review by Hallett et al (2016), the Territory's monitoring encompass a range of limitations, including: *"a continuing lack of ecologically-relevant indicators of habitat, floral and faunal condition, and a failure to ensure that declining estuarine condition triggers practical management interventions. Common limitations include (i) over-reliance on physico-chemical elements of estuarine condition, and primarily water quality, (ii) failure to quantify pressures across varied and appropriate spatial scales, and (iii) dramatic inconsistencies in the spatio-temporal coverage of monitoring."* Significantly, the IMMRP and Northern Terrritory fail to incorporate or adopt nationally-agreed standards for assessing and monitoring coastal, estuarine and marine conditions eg. ECAF (Arundal and Mount 2008), as developed under the NLWRA and CRC Coasts or the MACC R&D Working Group (2010). And more recently, specific WQ guidelines and monitoring under ANZG (2018), developed for the North Marine Region - https://www.waterquality.gov.au/anz-guidelines/your-location/australia-marineregions/north-marine-region	IMMRP

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Karen Edyvane - Australian National University	311	7	4. Sedimentation impacts and the lack of a Dredging Strategy and Plan for Darwin Harbour Of major concern in the Santos Referral Report is the failure of the DPD and IMMRP WQ to tackle the high-priority and potential major sediment impacts in the harbour. This includes the failure to incorporate any 'predictive sediment impact modelling' (an industry standard for major coastal projects in other States). Further the new Australia & NZ WQ Framework (ANZG 2018) provides national recommended protocols/approaches to sediment assessment/monitoring - https://www.waterquality.gov.au/anzguidelines/resources/guidance/biological-assessment - which should as a priority be considered for Darwin Harbour. Particularly the recommended monitoring protocols and assessing sedimentation impacts, particularly 'multiple lines of evidence' (Simon & Batley 2016). None of this included in the DPD Referral Report or the IMMRP WQ. Significantly, Darwin Harbour Integrated Report Card 2021 also highlight the *"need for Dredging Strategy and Plan as a key priority item for water quality in Darwin Harbour in accordance with work currently being conducted by NT Department of Infrastructure, Planning and Logistics". Aswell as the "need to adjust sampling locations for sediment metals to include more sites in Buffalo and Myrmidon Creeks. Investigate source of elevated metals identified at sites in East Arm."*	Sediment / plume modelling
Karen Edyvane - Australian National University	311	7	5. Significant Impacts on Marine Megafauna The Barossa Offshore Gas Project is in close proximity to the Timor Trough, one of the three major outflow channels of the Indonesian Throughflow, and one of the most important 'marine megafauna migration corridors' in the Western Indo-Pacific. Within the project area, an EPBC Protected Matters search has identified 18 listed threatened fauna species and 29 listed migratory species (17 of which are also listed as threatened species) that may occur or have habitat in the area. This includes four threatened and 12 migratory cetaceans. Appendix H – the 'likelihood of occurrence assessment' - is used to discount species from the PMST (protected matters search tool) list and reduce assessment of listed marine threatened species (just 7 species) and listed migratory species (just 2, ie. turtles). Significantly, the omission of listed migratory and threatened species is primarily based on the lack of site records and relies heavily on government data which often is dated ie. NT List of Marine Protected Species (2006). Importantly there has no attempt to access data/information/advice from non-government sources, marine species experts or data from major NESP Hub activities (eg. sawfishes, sharks). Importantly, the lack of studies and therefore information/records specifically for Darwin Harbour should not be the reason to discount critical marine species and potential marine impacts - particularly formally listed threatened and migratory species which are known to occur in the broader region. The precautionary principle should apply in all 'data-poor' assessments, with biological surveys undertaken to ensure that listed species do not occur or have habitat in the area.	Marine megafauna

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Karen Edyvane - Australian National University	311	7	6. Reliance on INPEX Ichthys Project and the IMMRP As mentioned previously, the DPD and Referral Report relies very heavily on the INPEX Ichthys Project and the NT Government Darwin Harbour Integrated Marine Monitoring and Research Program (IMMRP). *"When evaluating the potential Project impacts, consideration was given to the extensive studies and monitoring conducted for similar projects in Darwin Harbour. These include the original Bayu-Undan to Darwin pipeline and DLNG Facility, and the more recent INPEX Ichthys project. In particular, the INPEX Ichthys project has been utilised as a proxy to assess impacts on the basis that it undertook similar work activities within a similar area (including spoil disposal) but on a greater spatial and temporal extent." (pp 122)* *"INPEX's Ichthys nearshore environmental monitoring program was extensive and continues to be undertaken as part of the NT Government Darwin Harbour Integrated Marine Monitoring and Research Program (IMMRP). The monitoring data provide valuable insight into 'if' and 'how' observations in the natural environmental variability within Darwin Harbour changed as a result of its activities. " (pp 123)* *"The key findings from the Ichthys monitoring program (as reported by INPEX Browse, Ltd, 2014) were: — Upon completion of dredging activities, the turbidity concentrations at the monitoring sites closest to the dredging (i.e. Northeast Wickham Point and South Shell Island) had returned to natural conditions within a single spring-neap cycle following the completion of dredging;* *— No detectable dredging-related impacts to corals were observed at monitoring sites outside of East Arm;* *— No dredging-related impacts to seagrass habitats were observed and turbidity measured at seagrass monitoring sites were within the general range of natural variation;* *— Measurements of sedimentation levels in mangrove assemblages were below the level considered to potentially impact mangrove health;* *— No evidence of dredging-related impacts to fish health and catches;* *— No noticeable changes to the distribution of turtles and dugongs within Darwin Harbour that would indicate a potential influence of dredging; and*	IMMRP
Karen Edyvane - Australian National University	311		7. Lack of a Strategic Environmental Assessment of Darwin Harbour Darwin Harbour is currently facing major and rapid industrialization – particularly for the developing and growing oil/gas industry. However, unlike the Bonaparte Basin, Browse Basin, Exmouth Gulf, Gladstone Harbour – Darwin Harbour has NEVER been subject to a detailed formal 'strategic environmental assessment' (by the EPA) to consider cumulative impacts, and protect the key values and uses of the harbour - only 'activity-based' environmental assessments. In this regard, the recent strategic environmental assessment of Exmouth Gulf by the WA EPA (2021) – 'Potential cumulative impacts of proposed activities and developments on the environmental, social and cultural values of Exmouth Gulf in accordance with section 16(e) of the Environmental Protection Act 1986' - EPA s.16e Report -Exmouth Gulf.pdf – provides an invaluable case study and useful template for a regulator to design an impact assessment framework to protect the environmental, social and cultural values of Darwin Harbour. Significantly, any strategic environmental assess must be based on knowledge of both ecosystems and human impacts and also, current and future uses. For Exmouth Gulf, for delivery of this strategic advice, the EPA and the Department of Water and Environmental Regulation partnered with the Western Australian Marine Science Institution (WAMSI), who contributed technical and expert support on the values and pressures associated with Exmouth Gulf. The WAMSI report provides information on: • The key values (environmental, social and cultural) of Exmouth Gulf – including current state of the values, and level of confidence pertaining to the values – in the form of a literature review aligned with the EPA's environmental themes of sea, land, water, air and people. • The current and forecasted uses of Exmouth Gulf. • A qualitative risk assessment using a consequence versus likelihood approach to evaluate the impact or risk of a pressure against a key value. A detailed list of key values was consolidated at a high-level, prior to consideration in the qualitative risk assessment. • The relationship between key values and environmental pressures of Exmouth Gulf, derived from the qualitative risk assessment process. • Knowledge gaps that require further consideration to improve our understanding of Exmouth Gulf, identified against each EPA theme. The WAMSI report forms the	Project Assessment

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Karen Edyvane - Australian National University	311	9	8. Poor Data Access & Selective Use of Supporting Technical Information In assessing the Referral Report, it is essential that critical and relevant DENR and IMMRP-related and INPEX Icthys and Barossa technical and baseline reports for Darwin Harbour (and offshore) are made easily accessible and available to the public, relevant organisations, and key stakeholders. This iscurrently NOT the case – with many of the Barossa, INPEX Icthys, IMMRP and Darwin Harbour survey, monitoring and assessment reports currently not available or scattered across many organizational websites or scientific journals and difficult to access or find. For some key long-term DENR monitoring activities of the IMMRP – particularly marine biodiversity monitoring - some monitoring has been extensive and well-reported, such as the coastal dolphin and dugong monitoring - https://www.inpex.com.au/projects/ichthys-lng/our-commitments/long-termmonitoring-of-coastal-dolphins-in-darwin-harbour-and-the-abundance-and-distribution-of-dugongs-inthe-northern-territory/. How for other monitoring activities, publications could not be found at all. For example, for seagrass surveys and seagrass monitoring of Darwin Harbour since 2011 using the SeagrassWatch global monitoring protocol - https://depws.nt.gov.au/news/2016/darwin-harbourseagrass-surveys. Further, when the SeagrassWatch site is examined - https://www.seagrasswatch.org/northernterritory/ - its very clear that the program only ran for 3 years, and was suspended in 2013. Further, the Referral Report, has also engaged in the selective use of supporting technical information – while omitting key information. For instance, the marine habitat map in the Referral Report (Figure 7.3, page 77) gives a significant under-estimate of the level of coral habitat and hard substrata in Darwin Harbour. And while it cites AIMS (2016) it is not clear where this figure has come from. Further, while the Referral Report cites the latest habitat mapping report by AIMS (Galaduik etal (2019) - it does not use the latest maps, figures and best estimates for the extent of coral reef in the Darwin Harbour (contained in Galaduik et al (2019). For a comparison of coral habitat map in the Referral Report (Figure 7.3) and Galaduik et al (2019 – see Annex 1. Indeed, none of the excellent marine habitat maps (corals, seagrasses, mixed communities) for Darwin Harbour from the AIMS 2019 report are used in the Referral Report. Even the maps from 2015 GeoScience Australia report – which clearly defined the 'hard substrata' in Darwin Harbour using acoustic mapping - are not included.	IMMRP
Karen Edyvane - Australian National University	311	9	9. Other Considerations • 7.8.1 - maritime heritage – there are many shipwrecks in Darwin Harbour – many of which have both, significant cultural and marine biodiversity and fisheries values.	Cultural heritage
Karen Edyvane - Australian National University	311	9	7.8.3 – Indigenous values - no mention of the significant Indigenous shell mounds in Darwin Harbour (Hiscock & Hughes 2001)	Cultural heritage
Karen Edyvane - Australian National University	311	9	Appendix D – the baseline survey is completed restricted to the pipeline only (Project Area) – no references at all to the excellent marine habitat studies of Darwin Harbour or Outer Darwin Harbour.	General marine
Karen Edyvane - Australian National University	311	10	Recommendations for the NT EPA In considering the DPD Project for an environmental assessment – I strongly recommend that the NT EPA give this activity the highest level of assessment – an Inquiry. Specifically, that the NT EPA should undertake a formal, detailed, 'strategic environment assessment' prior to any consideration of the DPD activity - or indeed, any other major infrastructure development activity within the harbour. The primary objective of the strategic assessment should be the design of an environmental assessment impact framework for Darwin Habour to: (i) identify the key environmental, social and cultural values of Darwin Harbour, (ii) identify and assess the current and projected threats and pressures (iii) consider the cumulative impacts of current and proposed projects within the harbour, and (iv) provide advice/recommendations on conservation of values, compatibility of uses/activities and the integration of land-sea management. In undertaking this strategic environmental assessment - critical reviews/analyses, additional field research/studies, modelling and major risk assessments will likely need to be undertaken, in addition to the review, collection and collation of all relevant existing technical information. As with other strategic assessments (conducted in other jurisdictions), this information and technical advice should be provided to the EPA, to inform the design of a robust monitoring and environmental impact assessment framework that will protect significant ecosystems and values of Darwin Harbour. The reviews and assessments should also take account of the following specific issues and challenges relevant to Darwin Harbour:	Project Assessment

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Karen Edyvane - Australian National University	311	10	1. Need for independent expert-based review of coastal, estuarine and marine conservation, monitoring and management in Darwin Harbour – particularly in light of the NT Government's inadequate IMMRP program and proposed major infrastructure developments (ie. DPD Project, Middle Arm Industrial Precinct) – including identifying indicators and monitoring protocols that meet current recommended national and industry 'best practice' standards. 2. The potential to learn major lessons from the WA and Queensland – regulating, assessing, monitoring impacts of major oil/gas industry, including the best practice monitoring and assessment protocols. 3. The critical need to identify the critical and essential science and knowledge/information requirements for ensuring a robust environmental monitoring and assessment program in Darwin Harbour, including exploring financing and governance options to promote greater public and industry partnerships and investment in monitoring and critical baseline research (eg. Exmouth Gulf - WAMSI model, Gladstone Healthy Harbour Partnership). 4. The major value and benefit of the collation/integration of all relevant Darwin Harbour technical studies. Including publicly releasing relevant past industry and government studies on Darwin Harbour - and also, relevant NT and Commonwealth-funded, coastal, estuarine and marine assessment, monitoring/reporting studies. 5. The urgent need to improve the IMMRP, particularly the lack of ecological monitoring and integrated ecosystem modelling to enable the assessment of ecosystem condition and health. 6. The urgent need to finalize and implement a Dredging Strategy and Plan for Darwin Harbour, undertake predictive sediment impact modelling – and adopt provides national recommended protocols/approaches to sediment assessment/monitoring (ANZG 2018, Simon & Batley 2016).	
Dina Rui - Jubilee Australia Research Centre	4		First, Jubilee Australia is concerned about the greenhouse gas emissions associated with this project. Although Santos claims that such emissions are irrelevant for the purposes of this referral, we strongly disagree. The Project is part of Santos' proposed Barossa gas project, which could be the most carbon-intensive gas project in the world.	GHG emissions / AQ
Dina Rui - Jubilee Australia Research Centre	4		Second, despite Santos' claiming that Carbon Capture and Storage (CCs) will reduce this project's carbon footprint, Santos has no comprehensive plan in place to capture the very high CO2 content of the gas. Even if the CCS project was successful, it would fail to offset the Barossa project's emissions. In no scenario is the Barossa project compatible with keeping global warming below 1.5 degrees and avoiding the worst impacts of the ongoing climate crisis.	Broader project
Dina Rui - Jubilee Australia Research Centre	4		Third, we are worried about the local social and environmental risks that the Project could have on Darwin Harbour and the local communities. The marine environment outside of Darwin is already under pressure due to the ongoing industrialisation of Darwin Harbour (e.g. the Inpex LNG plant), and the Darwin Pipeline Duplication Project would add to this.	General marine
Dina Rui - Jubilee Australia Research Centre	4		Fourth, the Barossa project as a whole could have severe environmental and social impacts, beyond that of the Project. It could put local livelihoods and Australia's fish supply at risk and the pipeline could destroy the habitats of dozens of threatened species including whales, dugongs and turtles. Of particular concern is that the pipeline will run for 70km along the Tiwi Islands' coastal lines and come within 6km of the southwestern corner of Bathurst Island (Cape Fourcroy), which is a crucial internesting area for the threatened Olive Ridley Turtle.	Threatened species
Dina Rui - Jubilee Australia Research Centre	4		Fifth, the planned pipeline clearly violates Tiwi interests and rights. The pipeline's closeness to the Tiwi Islands contradicts the national recovery plan for marine turtles in Australia for Olive Ridley turtles, which defines an internesting buffer zone around the Tiwi Islands as being 20km.1 Further, the Tiwi people are planning for a sea country Indigenous Protected Area (IPA), which will be formally recognised as part of Australia's network of protected areas and is partially funded by the Australian government. The Barossa gas pipeline will traverse this IPA, making it impossible to manage this sea country for conservation under International Union for Conservation of Nature (IUCN) category VI. Despite these risks, the consultation process with the impacted communities – the Tiwi people and the wider Northern Territory community – appears to be lacking.	Consultation

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Dina Rui - Jubilee Australia Research Centre	4		Sixth, we have assessed the Offshore Project Proposal and are concerned that the project proponents have underestimated the potential environmental damages from oil and gas spills and leakage. We have identified gaps in three areas: the potential underestimation of stochastic modelling scenarios, the lack of evidence regarding the environmental impacts of condensate and other pollutants and that the transboundary damage could be significant.	Spills
Bruce Robertson - Institute for Energy Economics and Financial Analysis	5	2	The project does not dimension its purpose. On page 3 of Santos's Referral Report1, the proponent states: "Importantly, executing the DPD Project in a timely manner preserves the existing Santos Bayu-Undan to Darwin pipeline for re-purposing opportunities into the future, including carrying carbon dioxide for offshore carbon capture and storage (CCS). This opportunity will help Santos meet its emission reduction targets and achieve net-zero Scope 1 and 2 absolute emissions by 2040." The NT EPA is being asked to approve a pipeline that facilitates a project (CCS at Bayu-Undan) that is not dimensioned in any way.	Broader project
Bruce Robertson - Institute for Energy Economics and Financial Analysis	5	2	Ill-defined Carbon Capture and Storage project may not lower emissions John Robert, a guest contributor with IEEFA, has attempted to interpret Santos' incomplete plans for a CCS project in a recent report.2 Robert concludes that the CCS project may not significantly lower emissions: "Santos now has an application for approval for a new Darwin Harbour pipeline for its Barossa gas – potentially enabling a carbon capture and storage (CCS) scheme in an attempt to reduce the very high emissions from the development. But uniquely, despite the new application, Santos' project would still actually produce more carbon dioxide emissions offshore and onshore than its production of liquefied natural gas (LNG) – even with CCS implemented successfully – making it one of the more expensive and dirtiest gas projects in the world."3 IEEFA acknowledges that the NT EPA does not approve offshore projects. The Darwin Pipeline Duplication Project facilitates CCS offshore at Bayu-Undan, and that will substantially increase the Northern Territory's onshore emissions – at the Darwin LNG plant (DLNG). The carbon dioxide (CO2) removal facilities at DLNG will have to be trebled, producing more vented CO2 and more emissions from combustion of (then 18%CO2) fuel gas at greater rates. Also, the separated CO2 will have to be compressed onshore to send it 500km down the pipe to Bayu-Undan, producing significant emissions (of both greenhouse gases and other pollutants) onshore that have not been specified by the proponent or assessed by the NT EPA.	Broader project
Bruce Robertson - Institute for Energy Economics and Financial Analysis	5	3	The Project is not consistent with Northern Territory Government Policy The Darwin Pipeline Duplication Project facilitates the Barossa gas project. The Barossa project runs contrary to the stated Northern Territory policy target of net zero by 20504.5 The International Energy Agency (IEA) has clearly stated that no new natural gas fields are needed globally in the Net Zero Emissions by 2050 Roadmap, beyond those already under development. Many of the LNG liquefaction facilities currently under construction or at the planning stage are not needed.6	GHG emissions / AQ
Bruce Robertson - Institute for Energy Economics and Financial Analysis	5	3	There appears to be no firm decommissioning plan or bond Given the uncertain future for gas in a net-zero world (see point 5), the NT EPA needs to ensure a robust decommissioning plan for the pipeline with a bond paid up front to cover the decommissioning costs. Without such a regime, it is likely that the Northern Territory taxpayer will have to pick up the bill for decommissioning costs.	Project description

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Bruce Robertson - Institute for Energy Economics and Financial Analysis	5	3	Santos dramatically overstates the role of gas in a low emissions future Santos is attempting to downplay the role of gas in global warming by consistently quoting figures that do not apply to the Barossa gas/Darwin LNG project. Santos have stated that its "role in low-carbon future is built around natural gas, which produces half the greenhouse gas emissions of coal when used to generate electricity. It is the perfect partner for renewable energy sources and can be made even cleaner with carbon capture and storage (CCS)."21 This statement is simply not true in the case of the Barossa LNG project that the Darwin Pipeline Duplication Project facilitates. Santos quotes the wrong figure for renewable-rich grids. Barossa is not an average gas field, but rather one high in CO2. The Barossa gas and LNG project is an export operation and uses gas in both the energy intensive LNG process and the shipping process. The Santos referral tatement excludes the effect of fugitive emissions and venting/flaring that occur with all gas projects to a greater or lesser degree. The CCS project will not significantly lower emissions. In summary, it is likely that the Barossa gas/LNG project produces marginal benefits over coal in the generation of greenhouse gases when burned for power in a gas peaking plant. The Barossa gas/Darwin LNG project is inconsistent with the Net Zero by 2050 stated target of the Northern Territory government. A full lifecycle analysis of the greenhouse gas emissions from the Barossa gas/Darwin LNG export project needs to be independently undertaken prior to approval of the Darwin Pipeline Duplication Project. Santos has not been truthful about the greenhouse gas effects of the project in the Darwin Pipeline Duplication Project NT EPA Referral paper.	GHG emissions / AQ
Bruce Robertson - Institute for Energy Economics and Financial Analysis	5	1	IEEFA calls for: 1.An independent review of the lifecycle emissions of the Barossa/Darwin LNG project. 2.A full environmental impact statement (EIS) for the Darwin Pipeline Duplication Project. 3.A full EIS for the Bayu-Undan CCS project that the Darwin Pipeline Duplication Project so clearly facilitate s.	Project Assessment
Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis	6	1	Relationships across the Timor Sea As you know, Timor-Leste and Australia have had a troubled history for most of the last half-century. We believe that the Maritime Boundary Treaty signed in 2018 marks a change to a more respectful and considerate relationship, which we are confident that your oversight of this DPD project will exemplify. Like the Northern Territory and the entire Commonwealth, Timor-Leste has received substantial benefits from the Bayu-Undan oil and gas field and the Wickham Point LNG plant, which we appreciate. Nevertheless, we cannot forget that Australia took about $6 billion worth of revenues from oil and gas fields that your government now agrees are in Timor-Leste's territory, and that Australia continues to persecute 'Witness K' and Bernard Collaery for trying to make the negotiations between our countries less unfair. However, we would like to move forward.	Social impacts
Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis	6	2	This project will impact yourselves, your neighbours and the world Our submission is written from a Timor-Leste perspective, and we don't presume to speak for the people of the Northern Territory. We encourage you to carefully consider issues raised by people there, including by Aboriginal and environmental organizations. The NTEPA should not look at the part of this project that falls within the Northern Territory in isolation, as it affects your neighbours and the global climate. Environmental risks don't stop at the three-mile limit; they are not constrained by the 200-mile EEZ. Gas extraction from Barossa and carbon storage at Bayu-Undan may be outside your territorial jurisdiction, but they are intrinsic elements of the proposed DPD project. Please consider effects outside the Northern Territory, some of which could endure for centuries, while you look into the local impacts of this project. A piecemeal approach to a project which straddles multiple jurisdictions may not adequately protect our common welfare. Overarching issues might fall outside of each authority's localized mandate and be overlooked – there is more to this project than the pipelines currently before you. Furthermore, if some regulators are less experienced or are overly influenced by corporate pressure, others, including yourselves, need to step up and exercise their responsibilities effectively. It is unfortunate that the NTEPA did not assess the nearly two-decade-old Darwin LNG plant before authorizing extending its use with a different operator for a different gas field. However, the proposed DPD project provides another opportunity to review this project. Please assess it at the highest level by holding a public inquiry.	Project Assessment

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Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis	6	2	Carbon Capture and Storage is not a solution Santos disingenuously wrote that its September 2021 MOU with Timor-Leste's National Petroleum and Minerals Authority (ANPM) is "to pursue Carbon Capture and Storage (CCS) by the Bayu-Undan Joint Venture."1 However, people in ANPM and elsewhere in TL understand that this MOU is only the beginning of a conversation, not a decision to go ahead with the project. In fact, the MOU itself states that the Bayu-Undan joint venture and ANPM "agree to cooperate in good faith to assess the feasibility of pursuing this opportunity," and the matters listed in the MOU involve "assessing" various items and "establishing a clear and reasonable timeline for decisions on whether to pursue this CCS project." antos floated the idea of Carbon Capture and Storage (CCS) at Bayu-Undan to enable them to develop the carbon-intensive Barossa gas field, a greenwashing strategy to confuse the public about the damage they will inflict on the global climate. CCS is not a proven technology. Santos' statement that "CCS is recognised as a safe, well established solution for permanent, large-scale emissions reduction and clean energy production, being the keys to economy-wide decarbonisation2" may be true for oil companies such as themselves who have a vested interest, but it is far from universally recognised, and nearly all CCS projects have sequestered far less carbon than their proponents promised.3 Please do not be taken in by Santos' assertions, and do your own objective, environmentally-focussed research. NTEPA's mandate is to protect the environment, not to facilitate public relations efforts intended to prolong the operations (and profits) of the globally-environmentally-destructive fossil fuel industry. "Net Zero" is a misleading concept. Even if the CCS project at Bayu-Undan works as Santos hopes, it may not reduce the overall carbon dioxide emissions from extracting and liquefying the natural gas from Barossa, which is one of the dirtiest gas fields in the world.4 Furthermore, inevitable leaks of methane from the wells, pipelines and LNG and regasification facilities, as well as the CO2 released by burning Barossa-sourced gas elsewhere on our planet, will significantly exacerbate the risk of serious consequences of global climate change.	GHG emissions / AQ
Charles Scheiner - La'o Hamutuk - Timor-Leste Institute for Development Monitoring and Analysis	6	3	Climate Change is real Please do not contribute to the destruction of human life on earth to enable short-term financial gains by Santos and their partners. Although we are not knowledgeable about the impacts of climate change on the Northern Territory, we know only too well the calamities it has already brought to Timor-Leste, including last April's floods which killed more than 40 people and displaced 15,000. The future will be far worse if environmental regulators like yourselves lack the courage to take serious action. Each person in Timor-Leste is responsible for about 0.5 tons of CO2 emissions per year. Each Australian is responsible for 30 times that much, not counting the emissions where each of our fuel exports are burned. Why should Timor-Leste be saddled with the responsibility, and the risks, of Barossa's CO2 so that Australian companies can extract and export more fossil fuels from deposits in Australia?	GHG emissions / AQ
Jorgen Doyle - Central Australian Frack Free Alliance	7	1	The Project is a new component of Santos' proposed Barossa gas project. The Barossa gas project, if it goes ahead, will be the dirtiest gas project in the world. The Barossa gas field has the highest carbon dioxide (CO2) content of any gas field, and this CO2 will be vented into the atmosphere before the gas is transported to Darwin. The life cycle greenhouse gas emissions of the Barossa project will be 15mtpa, producing more CO2 than LNG. The proponent's claim that GHG emissions are not a key factor for this referral should be rejected; it would be unacceptable if emissions from the world's most carbon-intensive gas field escaped assessment by the NTEPA under the Environment Protection Act 2019 (NT). I therefore urge the NTEPA to consider the significant emissions that would result from this project when making their decision.	GHG emissions / AQ
Jorgen Doyle - Central Australian Frack Free Alliance	7	1	The proponent has stated in the referral document that undertaking the Project will allow the existing Bayu-Undan to Darwin pipeline to be used for Carbon Capture and Storage (CCS). The proponent makes a number of misleading claims about CCS in the referral document. CCS is an unproven technology that has a track record of failure. It is untested in an offshore gas reservoir such as Bayu-Undan. Any risk mitigation strategy that is premised on the viable functioning of CCS is inadequate. As such, the emissions profile of the project constitutes a significant impact that requires assessment at the highest possible level.	Broader project
Jorgen Doyle - Central Australian Frack Free Alliance	7	1	The Barossa project as a whole should be called in for a referral under s53 (1) of the Environment Protection Act. At the very minimum, this Darwin Pipeline Duplication Project must be assessed by the NTEPA and must be assessed at the highest possible level. I would like to see a public inquiry.	Project Assessment

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Julie Fraser - Australian Services Union	8	1	The Australian Services Union SA+NT Branch submit that the NTEPA should proceed with an assessment of the Darwin Pipeline Duplication Project through a public inquiry. We are concerned about a number of significant impacts that could result from the proposed Project and believe that these impacts constitute a considerable environmental risk that warrants stringent assessment.	Project Assessment
Julie Fraser - Australian Services Union	8	1	Emissions from the project will have a substantial impact on the Territory's ability to meet its emissions reductions targets. We note that the current Darwin LNG facility has approvals to emit up to 10mtpa of greenhouse gasses (GHG), but IEEFA modeling shows that when the Barossa project lifecycle emissions are added to current Darwin LNG emissions, this 10mtpa threshold will be exceeded. This discrepancy alone justifies a full and transparent assessment of the emissions profile of the Barossa project. The risk to workers' livelihoods due to increased temperatures and wild weather events is extreme and will only be worsened by the development of new gas fields and their associated emissions. Both the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) have stated that new gas projects must not go ahead if catastrophic global warming is to be avoided. Increased temperatures at work are emerging as one of the major occupational health and safety hazards for workers, particularly in tropical locations such as the Northern Territory.	GHG emissions / AQ
Julie Fraser - Australian Services Union	8	1	We are also concerned about this Project being used to facilitate Carbon Capture and Storage (CCS) in the Bayu-Undan gas field. CCS is unproven, unreliable, and has a track record of failing to meet targets. There are specific problems with the Bayu-Undan CCS proposal, not the least of which is the injustice of saddling Timor-Leste with carbon pollution and the uncertainty of how this carbon will be stored and regulated into the future. The high CO2 content of gas from the Barossa field (18%) adds a range of complications to the CCS process. The impacts of this project must be assessed in a full public inquiry so the risks can be examined.	Broader project
Julie Fraser - Australian Services Union	8	2	Workers in a range of industries stand to lose from the further industrialisation of Darwin Harbour. The impacts will be directly and obviously felt on.the tourism industry, but reduced air quality, increased pollution, warmer temperatures, and petrochemical development will heavily impact the entire Darwin and Palmerston region and surrounds. Workers deserve long-term, sustainable jobs in industries that are socially beneficial, not in polluting industries that create little jobs and contribute to the risk of climate change.	Social impacts
Brooke Ah Shay - Doctors for the Environment Australia	10	1	Fossil fuel use is the primary cause of anthropogenic climate change The evidence is clear that the main cause of climate change is the burning of fossil fuels, such as gas, oil, and coal. The Barossa project will produce significant global greenhouse gas (GHG) emissions at a time when significant reduction in emissions is imperative for the adequate mitigation of global warming and climate change.1 The project could produce the most carbon intensive LNG in Australia, being potentially among the most polluting LNG projects in the world.2 n addition to GHG emissions from burning methane, and fugitive methane emissions which are increasing world-wide and are usually underestimated,3 the Barossa gas field has very high levels of CO2 (16-20%), which would be vented into the atmosphere. Life cycle emissions could be in the vicinity of 15 million tonnes per annum.4 Carbon capture and storage has been proposed to capture these emissions but an economic process at scale has defied development.5 Moreover, the referral document contains no figures or estimates for GHG emissions associated with the pipeline and broader Barossa project and does not make any reference to the emissions from combustion of produced LNG. This is unacceptable and must be part of any assessment of the project.6	GHG emissions / AQ
Brooke Ah Shay - Doctors for the Environment Australia	10	2	Climate change is a public health emergency There is global scientific consensus that climate change is an emergency and has many known serious health risks. Climate change will cause, for instance, higher mortality and morbidity from heat stress, increasingly severe weather events, the increased transmission of vector-borne diseases, food production and livelihood (<already edited), and a higher incidence of mental ill health.7 The health of Australians is already negatively impacted by climate change – impacts that will become more severe and create a greater health burden over the coming years. One cannot overemphasise the enormity of health, economic, security and environmental costs of an inadequate response to climate change.8	GHG emissions / AQ

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Brooke Ah Shay - Doctors for the Environment Australia	10	2	Natural gas processing poses health risks The extraction and processing of natural gas is known to have adverse public health consequences. For instance, in 2016-17, the LNG plants Woodside proposed to use for the Burrup Hub project were among the highest industrial point source polluters of harmful air pollutants in Western Australia. Those LNG facilities released 8,000 tonnes of nitrogen dioxide, 97 tonnes of sulphur dioxide and 16,000 tonnes of volatile organic compounds, in addition to other heavy metals, into the atmosphere.9 These pollutants are similar to those from burning other fossil fuels and can contribute to a range of health issues, including exacerbation of asthma, respiratory and cardiac disease, lung cancer and stroke.10 Natural gas operations may have long-term health effects that are not immediately expressed.11	Social impacts
Brooke Ah Shay - Doctors for the Environment Australia	10	2	Biodiversity loss ultimately affects human health Biodiversity helps to regulate climate, filters air and water, enables soil formation and mitigates the impact of natural disasters. It also provides timber, fish, crops, pollination, ecotourism, medicines, and physical and mental health benefits (UN 2019)12 The Darwin Pipeline Duplication Project will establish a third significant pipeline in Darwin Harbour, which will have many impacts on marine ecosystems that are already under pressure from existing gas developments. The number of resident dolphins in Darwin Harbour, for instance, has almost halved since construction of the Inpex gas plant and shipping channel in 2011.13 The dredging operation requires 750,000m3 of the seafloor in Darwin Harbour to be removed and dumped off Lee Point in an operation which will further damage delicate marine plants and creatures and interfere with feeding and breeding grounds.	General marine
Brooke Ah Shay - Doctors for the Environment Australia	10	3	This project contravenes the NT government's commitment to net zero emissions The NT government has acknowledged that climate change is an issue of critical significance. This proposal is in direct contravention to the government's stated goals of working towards net zero emissions.14,15 '	GHG emissions / AQ
Brooke Ah Shay - Doctors for the Environment Australia	10	3	DEA therefore opposes the development of this pipeline and the Darwin LNG plant. DEA suggests that the NTEPA call in a referral under s53(1) of the Environment Protection Act of the broader Barossa Project as a whole. If, however, the NTEPA does not call in the proposal, DEA urges that the Project be assessed at the highest level, in the form of a public Inquiry.	Project Assessment
The Australian Institute	11		This consultation is calling for feedback into the new proposed pipeline by Santos and whether the proposal requires environmental impact assessment. We urge the NTEPA to require a full assessment.	Project Assessment
The Australian Institute	11	1	The presentation of the project as a duplication aimed at facilitating carbon capture and storage (CCS) is misleading. When seen in wider context, the aims of the project appear to be to increase gas exports through the Barossa Project and to delay the $1.1 billion decommissioning costs estimated for the Bayu Undan field.1	Project description
The Australian Institute	11	1	Santos' describes Bayu Undan CCS as an "opportunity". This is unusual. Santos do not refer to it as a project, or even a proposal, but simply as a potential future opportunity. There is no public documentation around how this non-project would work, what its environmental impacts might be, or how much it might cost.	Project description

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The Australian Institute	11	1	Even if Santos were to progress CSS in Bayu Undan, there is little evidence it would succeed. CCS has failed to date, despite decades of effort and billions in public funding. The global capacity of genuine CCS projects (projects that are not aimed at enhancing oil recovery) is just 10 million tonnes per year.2 The largest by far of these is Chevron's Gorgon project in Western Australia, which has been beset by delay and technical failure.3 It injected only 30 percent of promised emissions in its first 5-year reporting period,4 and only 50 percent last year.5 Analysis shows that even if carbon dioxide could be successfully permanently stored in the Bayu Undan fields, the emissions required for processing, compression and transport of the CO2 would be approximately equivalent to the amount injected, meaning that there would be no net reduction in the projects very high emissions.6 Regardless of its lack of substance or low prospects of success, the promotion of CCS at Bayu Undan facilitates the greenwashing of the Barossa LNG Project. If it proceeds, Barossa would be, by far, the most emissions intensive LNG project in Australia.7 It would extend the life of Darwin LNG by a least 20 years. The gas from the Barossa fields will result in around 3.4 million tonnes of emissions within Australia annually,8 and a further 10.5 million tonnes of emissions when the gas is burned overseas.9 Worse still, Santos proposes a tie in point to the pipeline that will allow gas from other fields around Barossa to be developed. Some of these fields have an even higher CO2 content than Barossa, notably the enormous Evans Shoal field which reportedly has a 30 percent CO2 content.10 This is unacceptable from a climate perspective, particularly in the light of the IEA's recent statement that in order to achieve net zero by 2050, no new coal and gas projects should be approved,11 and the IPCC issuing a "code red for humanity".12 Santos has virtually ignored the emissions impact of the full Barossa project in its proposal to the NTEPA. Instead, the proposal considers the "duplicate" pipeline within NT waters in isolation from the overall project, with vague assertions that some of the emissions will be sequestered.	GHG emissions / AQ
The Australian Institute	11	2	The Australia Institute strongly recommends that Santos' DPD Referral undergo environmental assessment in the form of an inquiry, as set out in the Environmental Protection Regulations 2020 (NT) which considers the full climate implications of Santos's related Barossa project.	Project Assessment
Grusha Leeman	12		Carbon "storage" is a downright dangerous pipedream Carbon capture and storage (CCS) is simply a licence to pollute and is an excuse to ramp up emissions. Santos is pushing to duplicate this pipeline and is spinning the line it has plans to produce clean energy so it has a licence to keep its polluting projects going, not because it wants to cut emissions. Don't be duped. CCS is a temporary dump, at best. Yet to be proven, the most advanced Aussie project is Gorgon. As of July 2021, the Gorgon experiment has reached a milestone with five years of failure10, falling millions of tonnes short of its emissions capture promises. If Chevron is required to make good on its failed promises using carbon credits, this will cost the company nearly $100 million11. CCS is incapable of tackling the pollution needed to diminish our climate crisis. When attached to fossil fuel developments, especially like those of the really dirty Barossa field, carbon storage is not a climate solution, as digging up and burning fossil fuels only adds to the problem. Global temperatures do not stop increasing until emissions reach or go beyond net zero12. To achieve that we must stop digging up and burning fossil fuels. CCS is extremely expensive and cannot deliver zero emissions. The only solution is to stop mining and burning fossil fuels. Pumping dangerous concentrations of carbon dioxide into crevices under the sea as in this project's associated projected plan, has no guarantee it will stay there. Any crack may see it seep out: we've all seen the CO2 bubbles. But also there are such things as earthquakes that will render such deposits free to rise and pollute our planet's precious climate. Recommendation: It is far better and cheaper to avoid carbon emissions in the first place, rather than try to capture them after they've been released. Rather than wasting money on something that's expensive, ineffective, and likely downright dangerous, Australia should be investing in the things we know can cut emissions quickly and bring down power prices, like renewables backed by storage.	GHG emissions / AQ

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Grusha Leeman	12		Smashing another pipeline through our Harbour and sea Darwin was once, not long ago, the envy of the world, a happy city with a LIVING HARBOUR. Since then it has been smashed and dredged by fossil fools. We want our dolphins whales back. Plans for sonar to identify seafloor debris and seabed profile with pulses at high frequencies are an anathema to our saltwater friends who depend on their senses. In shallower waters, the Project pipeline may require stabilisation due to exposure to waves, currents and tidal movement. Surely anchoring devices will suffice and trenching along with the associated blasting and dredging can be abandoned. These activities are severely detrimental to the environs under the sea and should never be condoned. Dumping sludge in a six kilometre area back of Lee Point is a huge ruination of seagrass and other vital seabed biodiversity. The project's proximity to the near pristine Tiwi Islands and the Oceanic Shoals Marine Park is a concern as if this project is given the go ahead, it will have devastating impacts on biodiversity in the region, including on critical habitat for the threatened Flatback and Olive Ridley turtles13. Recommendation: Adding yet another destructive development to the seafloor is unnecessary and detrimental to the environment so reject the plan. It’s a duplication, if they must, use the pipeline that is there.	General marine
Grusha Leeman	12		Gas is not even safe to use in our kitchens Although Santos likes to inform us all that gas is safe it is not. Beyond contributing to global warming, gas stoves emit unhealthy levels of nitrogen oxide14, which can trigger breathing problems for people with asthma or chronic obstructive pulmonary disease, even in low concentrations. Recommendation: As the gases from Barossa are not safe, not in the kitchen, not in production and not in our atmosphere, ensure the wells are plugged and the gases left in situ.	Social impacts
Grusha Leeman	12		Accepted Accepted Accepted Accepted Accepted… Wonder if any proposals15 are ever rejected or is the Government just a rubber stamper? Does the $1.8 million in donations that Santos has handed over to the Coalition in the last 20 years make a difference?16 As we do not seem to have a mechanism to deny outrageous proposals like this one from the outset, it is vital that the NT EPA decides the proposed action requires the maximum environmental impact assessment. Recommendation: Reject this plan.	Project Assessment
Julie Fraser	13		Firstly, emissions from the project will have a substantial impact on the Territory’s ability to meet its emissions reductions targets. I note that the current Darwin LNG facility has approvals to emit up to 10mtpa of greenhouse gasses (GHG), but IEEFA modeling shows that when the Barossa project lifecycle emissions are added to current Darwin LNG emissions, this 10mtpa threshold will be exceeded. This discrepancy alone justifies a full and transparent assessment of the emissions profile of the Barossa project. The risk to workers’ livelihoods due to increased temperatures and wild weather events is extreme and will only be worsened by the development of new gas fields and their associated emissions. Both the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) have stated that new gas projects must not go ahead if catastrophic global warming is to be avoided. Increased temperatures at work are emerging as one of the major occupational health and safety hazards for workers, particularly in tropical locations such as the Northern Territory.	GHG emissions / AQ
Julie Fraser	13		I am also concerned about this Project being used to facilitate Carbon Capture and Storage (CCS) in the Bayu-Undan gas field. CCS is unproven, unreliable, and has a record of failing to meet targets. There are specific problems with the Bayu-Undan CCS proposal, not the least of which is the injustice of saddling Timor-Leste with carbon pollution and the uncertainty of how this carbon will be stored and regulated. The high CO_2 content of gas from the Barossa field (18%) adds a range of complications to the CCS process- which has failed, as in the case of the Gorgon CCS project, in less complex circumstances. The DPDP facilitates the development of this CCS project and as such the impacts must be assessed in a full public inquiry so the risks can be examined.	Broader project

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Julie Fraser	13		Workers in a range of industries stand to lose from the further industrialisation of Darwin Harbour. The impacts will be directly and obviously felt on the tourism industry, but reduced air quality, increased pollution, warmer temperatures, and petrochemical development will heavily impact the entire Darwin and Palmerston region and surrounds. Workers deserve long-term, sustainable jobs in industries that are socially beneficial, not in polluting industries that create limited jobs and contribute to the risk of climate catastrophe.	Social impacts
Identity removed	14		I believe the Darwin Pipeline Duplication Project (DPDP) should be assessed at the highest level of environmental assessment - an inquiry. As recreational fisho in Darwin who regularly fishes Darwin harbour, and as someone who cares about the greenhouse emissions of fossil fuel projects, the DPDP concerns me greatly.	Project Assessment
Identity removed	14		The dredging required to facilitate this new proposed pipeline is immense, and it upsets me greatly that it would go straight through the Charles Point reef protection zone - a zone that Darwin fishers have (for six-odd years now) been prohibited from fishing explicitly for the protection of marine ecosystems, namely key fish species (golden snapper and black jewfish). This project would have an effect on a key habitat of these species (both of which are crucial to rec fishing in the Territory). Also, anecdotally - from seasoned Darwin fishos - it's not only the dolphin population that suffered after the dredging for the Inpex shipping channel. The threadfin salmon population inside the harbour has also taken a hit.	Charles Point RPA
Identity removed	14		The proposed dumping of the dredged seafloor at Lee Point is unacceptable - this being an area that has substantial areas of bottom structure where reef and pelagic species dwell.	Spoil disposal ground
Identity removed	14		This mass dredging over 15 months and its attendant potential consequences for fish populations and marine habitats need to be scrutinised extremely highly - especially so given fishing is such an important part of Darwin's identity and economy. There is much at stake when it comes to the impacts of this projedct on recreational fishing.	General marine
Identity removed	14		But it's not just these significant direct and indirect effects on local marine environments. The Barossa project as a whole is expected to be up to 15 million tonnes per annum of greenhouse gases over its lifetime. Given the juncture the world is at regarding the recognised need to mitigate the impacts of climate change, and the effect climate change is already having on ecosystems in the NT (mangrove dieback in Darwin harbour being just one example) these emissions need to be considered, whether the gas is extracted in NT waters or not. The pipeline will run through NT waters, and the gas processed in the NT. It is wilful blindness to not take these and the project's indirect emissions into account.	GHG emissions / AQ

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Identity removed	15		Emissions from the project with CCS and without - not much difference Based on the NOPSEMA-approved Offshore Project Proposal by ConocoPhillips of March 2018, and adding the emissions at Darwin LNG plant produces total emissions of 5.4million tonnes of CO2 per year to produce 3.7Mt/year of LNG. That represents an emissions intensity of 1.47 tCO2/tLNG - twice the Australian LNG industry average, based on EIS data. Now it seems that the Barossa to Darwin LNG project, even with a CCS element, would still produce more carbon dioxide emissions offshore and onshore than it will produce LNG. I base this on the research I have done recently on data contained in project EISs, OPPs and similar documents that has led me to write several papers which have been published and quoted in the media. The table (refer Attachment 3) shows the basis of the above statements, based on the Barossa OPP and Darwin LNG information (Case A) and as deduced for the case with CCS added (Case B). The emissions figures are not calculated in detail but directionally correct. I have done this work in the public interest because I am concerned that emissions from the Australian LNG industry have grown disproportionately higher than the growth in L NG capacity. as inferior quality gas reserves have ben developed. Barossa is a leading example of this alarming trend.	GHG emissions / AQ
Alice Nagy	16		My two key concerns relating to this project are the huge Green House Gas (GHG) emissions it will generate, and the impact it will have on sensitive marine ecosystems and vulnerable species such as Olive Ridley turtles. As I understand, the Gas extraction site for this project lies outside the NTs jurisdiction and so will not be subject to any Environmental Assessment Scrutiny. However, I strongly believe the NTG has a responsibility to consider the emissions that will be generated as a result of the project as a whole given the gas will be transported and processed in the NT. This is the responsible and reasonable approach to take. Furthermore, it has been well established that there are significant fugitive emissions released through the transportation of gas and there is a potential for leakages along the pipeline. Therefore, I urge the NTEPA to closely consider the predicted GHG emissions from the entire project - which could be as much as 15million tonnes annually. This is a huge emission load to add to the atmosphere when we are already seeing the devastating impacts of global warming on our ecosystems and communities.	GHG emissions / AQ
Alice Nagy	16		In the NT we have been seeing dieback of mangrove forests caused by marine heat waves. These kinds of dieback events are environmental disasters as well as social, cultural and economic disasters, and they are caused by global warming which is caused by the perpetuation of fossil fuel extraction and consumption like the Santos' Barossa project.	General marine
Alice Nagy	16		Given the likely impacts from this project - both the direct and tangible threat that the pipeline will pose to NT marine habitats during construction and the threat to our climate by increasing GHG emissions - are so great, I strongly urge the EPA to apply the most rigorous and highest standard of assessment to this proposal.	Project Assessment
Identity removed	17		The Barossa Gas Project which is the reason for needing this new pipeline, is potentially the dirtiest most carbon polluting gas project in the world. Santos have not consulted with the NT people, nor the Aboriginal communities who will be most affected by the impact of this project. They have a record of riding roughshod over people's rights and regard for environmental regulation as evidenced by the recent Rallen vs Santos case. Should this pipeline project be assessed? The NTEPA exists to protect the environment, it is our agent to protect us from the damaging effects of development. In this case, nothing less than a full inquiry will suffice – for both the pipeline project and the whole Barossa gas project that it will support. I understand that this is enabled by s53(1) of the Environment Protection Act. The Darwin Pipeline Duplication Project and the broader Barossa Project must be assessed at the highest level – a public inquiry. The impact on carbon emissions by the pipeline and Barossa Gas proposal will threaten achievement of the Northern Territory's carbon emission targets and obviously contribute significantly to climate change. The carbon emissions for the pipeline must be assessed as part of the whole Barossa Gas project to obtain the real impact and must not be assessed in a piecemeal manner.	Project Assessment

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Identity removed	17		Darwin harbour is a pristine environment which supports extensive breeding grounds for survival of many varieties of fish and other sea creatures that underpin our lifestyle, tourism and amenity. Dugongs feed on the sea grass. Hard corals, where golden snapper and jewfish breed, are not clearly identified in the mapping of the Santos proposal. These will all suffer from dumping of tons of dredged harbour mud. THese species must be protected from months of dredging that will risk their destruction. Monitoring but not protecting the dolphin population in Darwin Harbour has seen it nearly halve since the Inpex development.	General marine
Identity removed	17		But not just Darwin harbour is at risk. The pipeline will pass through the Oceanic Shoals Marine Park, through the Charles point reef fish protection zone and within 6 km of the Tiwi Islands' western coast. It will pass through Tiwi country, which is subject to native title rights and interests, but the Tiwi have not given their free, prior and informed consent to the Project. The Tiwi Islands's western coastline is a biologically significant area for Olive Ridley turtles and green turtles.	Charles Point RPA
Identity removed	17		The proposed pipeline will also facilitate transport of gas that poses a risk for explosion if leaked into the Harbour. The NTEPA needs to protect Darwin against this risk. The last environmental impact assessment for the existing Darwin LNG (and hence ongoing regulation requirements for) occured in 2002. Times have changed, scientific knowledge has advanced and our climate has changed. This previous assessment is now irrelevant. A now and thorough NTEPA assessment is required. Only a 100 km section of the proposed 260 km pipeline is being assessed which does not include the Darwin LNG facility at Wickham point. THis is also an oversight that needs to be addressed.	Project Assessment
Identity removed	17		Carbon emissions both direct and indirect related to the pipeline must be taken into account. Barossa gas contains high levels of CO2 (16-20%) which will result in release of world leading levels of CO2 by this project and the pipeline. These emissions must be assessed as part of the pipeline project for Barossa Gas and not separated out to minimise the apparent impact. Carbon capture and Storage (CCS) is proposed to be facilitated. It is proposed to use this pipeline project to facilitate CCS at Bayu-Undan in the Timor Sea. This requires capturing the CO2, drying it, cleaning it and then piping it 100 km out to Bayu-Undan through the aging existing infrastructure and burying it 3.5 km under the sea. This alone is a massively energy intensive project, but unfortunately CCS has not been proven to be effective. THis technology is a smokescreen to reduce public concerns about carbon dioxide emissions. The technology has niot been proven to work at scale anywhere in the world. Despite millions of taxpayer funded dollars invested in the Gorgon state-of-the-art CCS project, it has achieved appallingly low rates of carbon capture. The Australiasian Centre for Corporate Responsibility recently pointed out that "the rate of CCS project is striking: a recent study of all CCS developments in the United States of America (home to a significant majority of the world's CCS capacity) found that more than 80 % had ended in failure".	GHG emissions / AQ
Identity removed	302	1	Santos has prepared a case for the DPDP which it describes as a 'robust self-assessment' and concluded that 'most impacts during the construction phase would be temporary and localised and can be readily managed with little to no environmental impact' (Darwin Pipeline Duplication (DPD) Project NT EPA Referral, page 190). Santos' DPDP is an integral part of a much larger project, the development of the Barossa gas field. My strong view is that large projects such as this should be considered as a whole. They should not be assessed in small segments as presented by this proponent, under some misapprehension that the environment is made up of discrete, unrelated elements and with cumulative effects that have minimal impact on the environment. A terrestrial example of this principle is the loss of habitat. Recent news that koalas are officially endangered is not because of a single land-clearing event. Instead, it is due to many land-clearing events, fire, water mismanagement, and degradation of habitat along with many other factors that result in poor health or death of animals. The stark outcome is the status of the koala today. Similarly, marine and coastal environments are being assaulted by piecemeal development approvals and the water quality of our seas and rivers is at risk.	Broader project
Identity removed	302		Darwin Harbour is a Northern Territory Site of Conservation Significance and home to a number of endangered species of marine life. Santos contends that with good management, the proposed DPDP will not adversely impact on these values or species. While the risks associated with marine-related hydrocarbon spills, high levels of underwater noise and acid sulphate soils may be low, if the Barossa gas field does not go ahead then there is no risk at all.	Conservation areas

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Identity removed	302	1	The project proposal refers to the possibility of re-purposing the existing Santos Bayu-Undan pipeline for offshore Carbon Capture and Storage (CCS) (page 3); however, the technology for such a strategy is still in the early stages. As CCS is part of the reason for the DPDP, the whole project should be carefully examined considering the environmental values that are at stake.	Broader project
Identity removed	302	2	The estimates of carbon dioxide emissions from the proposed Barossa gas field are very high. As the DPDP is part of the Barossa gas field the emissions need to be considered in line with principles of ecologically sustainable development. New industry should enhance rather than undermine the Northern Territory's ability to meet its commitments to reduce greenhouse gas emissions.	GHG emissions / AQ
Identity removed	302	2	It is in the long-term interests of the Territory's economy and environment that Santos' Barossa gas field, including its DPDP be considered at a public inquiry. The community should be satisfied that a major project such as this will proceed only on the basis that there is minimal environmental impact and risk and that it is ecologically sustainable.	Project Assessment
Robin Knox	303		Darwin's healthy environment supports enormous numbers of jobs in tourism, fishing, life style activities and food production and all this could be lost if more destruction of our harbour occurs. The Barossa Gas Field is a small, poor quality project on the world scale and will create long term destruction for a very short term project. It will leave damage for many future generations that may never repair and leave toxins in our environment.	Social impacts
Robin Knox	303		The construction of the pipeline in Darwin Harbour will be highly destructive to the sea bed and the animals and creatures that are living in and on our harbour floor. The works will be highly disturbing to marine life such as migrating crayfish, fish, shell life, dolphins, turtles and dugongs. The movement and breeding patterns of these creatures in the harbour is little known so the consequences of the disturbances cannot be foreseen. The potential for accidents is high and the consequences can last for hundreds of years.	General marine
Robin Knox	303		The inquiry should also look at the proposal for carbon sequestration and storage (CCS), a process that is costly and unproven. Another justification for the pipeline is the remove emissions for possible sequestration so this proposal needs to be publicly scrutinised too. The CCS proposal is just a distraction to make the gas industry sound like it can manage its emissions. Gas industry evidence shows that it is releasing large amounts of emissions into the environment in the extraction and production of gas, even before burning the gas.	Broader project
Robin Knox	303		The NTEPA needs to hold a public enquiry at the highest level so the effected population can hear the details of the project proposal.	Project Assessment
Identity removed	304		The fossil fuel industry is trying to con governments, and the public, in many countries into accepting CCS technology as a viable means of addressing climate change - though research has indicated it is not. However it does help investors in the fossil fuel industries to continue with business as usual. Please be guided by credible science! Please don't be a bad example for the World by lending credibility to this deceitful process, as the Liberal govt. in Canada recently did. I wrote the following 3 paragraphs for a citizen's campaign in Canada to protest this deceitful pro-fossil fuel CCS scam here, but they are applicable to your situation as well: Its disgusting that our government plans a tax credit in the upcoming federal budget to support Big Oil investments in Carbon Capture and Storage (CCS). We need a well-funded just transition to renewable energy, not more green-washed bailouts for the fossil fuel profiteers that have already done so very much harm to life on Earth in a multitude of ways. Analysts have long warned that CCS would be a false, ineffective, and risky 'solution.' Rather than moving us away from fossil fuels, it would drive up greenhouse gas emissions - as demonstrated by Shell's CCS facility in Alberta, which is currently emitting more than it captures. Recently, more than 400 scientists, academics, and energy experts wrote an open letter to the federal government warning against a CCS tax credit, which they said would constitute "a substantial new fossil fuel subsidy."	Broader project

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Identity removed	304		PLEASE conduct a sincere holistic environmental assessment of Darwin Pipeline Duplication Project, and ensure it is undertaken at the highest level - public inquiry.	Broader project
Identity removed	304		The Project not only poses significant environmental, economic, cultural, and health risks for Darwin and surrounding areas, but will also greatly increase the release of greenhouse gases into the atmosphere - and hence would accelerate climate change around the planet, and violate Australian claims to be legitimately trying to diminish its climate-related toxic output.	GHG emissions / AQ
Identity removed	305	1	As a component of Santos' proposed Barossa gas project it is part of what will be the dirtiest gas project in the world, should it be allowed to go ahead. The Barossa gas field has the highest carbon dioxide (CO2) content of any gas field, and this CO2 will be vented into the atmosphere before the gas is transported to Darwin. The life cycle greenhouse gas emissions of the Barossa project will be 15mtpa, producing more CO2 than LNG. The proponent's claim that GHG emissions are not a key factor for this referral should be rejected; it would be unacceptable if emissions from the world's most carbon-intensive gas field escaped assessment by the NTEPA under the Environment Protection Act 2019 (NT). I therefore urge the NTEPA to please consider the significant emissions that would result from this project when making their decision.	GHG emissions / AQ
Identity removed	305	1	The proponent has stated in the referral document that undertaking the Project will allow the existing Bayu-Undan to Darwin pipeline to be used for Carbon Capture and Storage (CCS). The proponent makes a number of misleading claims about CCS in the referral document. CCS is an unproven technology that has a track record of failure. It is untested in an offshore gas reservoir such as Bayu-Undan. Any risk mitigation strategy that is premised on the viable functioning of CCS is inadequate. As such, the emissions profile of the project constitutes a significant impact that requires assessment at the highest possible level.	GHG emissions / AQ
Identity removed	305	1	The Project is part of the intensified industrialisation of Darwin Harbour, with the transported gas to be used as a feedstock for petrochemical industries in the Harbour. This poses immense environmental, economic, cultural, and health risks for Darwin and surrounding areas and must be considered relevant to any assessment of the Project's impacts.	cumulative impacts
Identity removed	305	1	The Barossa project as a whole should be called in for a referral under s53 (1) of the Environment Protection Act. At the very minimum, this Darwin Pipeline Duplication Project must be assessed by the NTEPA and must be assessed at the highest possible level. I would like to see a public Inquiry.	Project Assessment
Peta Baillie	306	1	The Santos Darwin Pipeline Duplication Project requires an environmental impact assessment, and this assessment must be undertaken at the level of a public inquiry. The scope of inquiry should include the entire Barossa Gas Project and proposed Carbon Capture and Storage development.	Project Assessment
Peta Baillie	306	1	The proposed project will generate significant global greenhouse gas emissions at a point in history where all fronts are demanding that we cease greenhouse gas production. Carbon Capture and Storage is an unproven technology and hitherto has failed to perform effectively at scale. A project of this scale and level of risk must be assessed at the greatest level of rigour	GHG emissions / AQ
Identity removed	307	1	I urge the NTEPA to conduct a detailed environmental assessment of the Darwin Pipeline Duplication Project at the highest level possible, for the following reasons: *A stated in the referral document itself the project has been considered against the principles of ecologically sustainable development.	Project Assessment
Identity removed	307	1	* The indicated carbon capture and storage function of The pipeline contradicts (rather than ameliorates) The anticipated emissions profile of broader Barossa gas project.G164	GHG emissions / AQ

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Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Identity removed	307	1	*Numerous threats to threatened marine fauna are acknowledged but merely dismissed with little to no supporting documentation. * Indication of intention to carry out marine fauna management actions is not corroborated with any indicated intention for active protection of fauna which does fall under threat.	General marine
Identity removed	307	1	* The project is part of the intensified industrialisation of Darwin Harbour, which in turn poses environmental, economic, cultural, and health risks for Darwin and surrounding areas and must be considered relevant to any assessment of the Project's impact	cumulative impacts
Identity removed	308	1	Thank you for the opportunity to make a submission on the Darwin Duplication Pipeline Project. This project should be assessed at the highest level of assessment (an Inquiry) for the following reasons: This project will generate significant global greenhouse gas emissions at a time when the IPCC report has issued Code Red for humanity and the International Energy Agency has said no new fossil fuel projects; CCS is unproven technology to reduce greenhouse gas emissions and the feasibility of the project should be further investigated; The project will have significant environmental impacts on Darwin Harbour which is unlikely to be supported by the community and must be subjected to the most rigorous assessment.	Project Assessment
Kelly Lee Hickey	309	1	I am deeply concerned about the impacts of dredging on the harbour. We've already seen the significant negative impacts of dredging on marine flora and fauna and I can't bear the thought of our ocean floor being ripped up further. I am deeply concerned that the maps provided by Santos don't show areas of hard coral, such as those in the reserve in East Point that can clearly be seen from a boat and that the pipeline will cut through important marine protected areas.	Benthic habitats
Kelly Lee Hickey	309	1	Furthermore the dredging of the harbour will visually pollute our beautiful harbour with ugly ships on the horizon of Mindil Beach markets.	Social impacts
Kelly Lee Hickey	309	1	The Barossa gas project, if it goes ahead, may be the dirtiest gas project in the world. The offshore Barossa gas field in the Timor Sea, north of the Tiwi Islands, has the highest carbon dioxide (CO2) content of any gas field. The life cycle greenhouse gas emissions of the Barossa project will be 15mtpa, producing more CO2 than LNG. We are already experiencing the extreme impacts of climate change in the Northern Territory, and this will blow the goverments 2030 decarbonisation plans. Economist John Robert has called the project a "carbon dioxide factory with an LNG by product".	GHG emissions / AQ
Kelly Lee Hickey	309	1	The Barossa is thus a significant, controversial and high risk project, and ECNT believes its impacts should be rigorously assessed and reviewed by the NTEPA. Our harbour is a vital source of life and a national assset. We desperately need a proper review of this project to protect the livelihoods of our tourism and fisheries industries, as well as our precious Territorian lifestyle. I believe that the NTEPA should: (a)call in a referral under s53(1) of the Environment Protection Act of the broader Barossa Project as a whole; (b)if, the NTEPA does not call in the proposal, the Darwin Pipeline Duplication Project and the broader Barossa Project must be assessed at the highest level - a public inquiry	Project Assessment
Identity removed	310	1	I have no objection to this project	Not Applicable
Naish Gawen (on behalf of many)	18-301		The proponent's claim that GHG emissions are not a key factor for this referral should be rejected; it would be unacceptable if emissions from the world's most carbon-intensive gas field escaped assessment by the NTEPA under the Environment Protection Act 2019 (NT). I therefore urge the NTEPA to consider the significant emissions that would result from this project when making their decision.	GHG emissions / AQ

This table provides a summary of the Public Submissions received for the referral. Each submission has been assigned a number from 1-311.

Stakeholder	Submission No.	Pg number	Public Submission / Key Issues	Topic category
Naish Gawen (on behalf of many)	18-301		The proponent has stated in the referral document that undertaking the Project will allow the existing Bayu-Undan to Darwin pipeline to be used for Carbon Capture and Storage (CCS). The proponent makes a number of misleading claims about CCS in the referral document. CCS is an unproven technology that has a track record of failure. It is untested in an offshore gas reservoir such as Bayu-Undan. Any risk mitigation strategy that is premised on the viable functioning of CCS is inadequate. As such, the emissions profile of the project constitutes a significant impact that requires assessment at the highest possible level.	Broader project
Naish Gawen (on behalf of many)	18-301		The Project is part of the intensified industrialisation of Darwin Harbour, with the transported gas to be used as a feedstock for petrochemical industries in the Harbour. This poses immense environmental, economic, cultural, and health risks for Darwin and surrounding areas and must be considered relevant to any assessment of the Project's impacts.	cumulative impacts
Naish Gawen (on behalf of many)	18-301		The Barossa project as a whole should be called in for a referral under s53 (1) of the Environment Protection Act. At the very minimum, this Darwin Pipeline Duplication Project must be assessed by the NTEPA and must be assessed at the highest possible level. I would like to see a public inquiry.	Project Assessment

Appendix 3: Sediment Dispersion Modelling Report

SANTOS BAROSSA DPD STUDIES

Sediment Dispersion Modelling

MAW1077J.001
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23 February 2023

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
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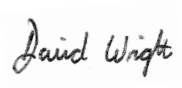
David Wright		23 February 2023

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Contents

1 INTRODUCTION 1
1.1 Background 1
1.2 Modelling Scope 3
1.3 Definition of Relevant Terms and Abbreviations 3

2 REGIONAL METOCEAN CONDITIONS 5
2.1 Climate 5
2.2 Wind Climate 5
2.3 Hydrodynamics: Currents and Water Levels 5
2.4 Waves 6

3 MODEL SKILL MEASURES 7
3.1 Statistical Analysis 7
3.2 Time Series Analysis 7

4 HYDRODYNAMIC AND WAVE MODELLING 8
4.1 Hydrodynamic Model (D-FLOW) 8
4.1.1 Model Description 8
4.1.2 Bathymetry and Domain Definition 9
4.1.3 Boundary and Initial Conditions 12
4.1.4 Model Validation 15
4.2 Wave Model (D-WAVE) 17
4.2.1 Model Description 17
4.2.2 Model Implementation 17
4.2.3 Model Validation 17

5 APPROACH TO SEDIMENT FATE MODELLING 20
5.1 Model Description 20
5.2 Model Limitations 22
5.3 Model Domain and Bathymetry 23
5.4 Trenching Project Description and Model Operational Assumptions 25
5.4.1 Overview 25
5.4.2 Methods and Equipment 25
5.4.3 Quantities and Production Rates 27
5.4.4 Schedules 28
5.4.5 Scenario Summary 30
5.5 Geotechnical Information 30
5.6 Model Sediment Sources 34
5.6.1 Overview 34
5.6.2 Representation of BHD Trenching 34
5.6.3 Representation of Disposal of BHD-Trenched Material 36
5.6.4 Representation of TSHD Trenching 38
5.6.5 Representation of Disposal of TSHD-Trenched Material 43
5.6.6 Representation of CSD Trenching 46
5.6.7 Representation of SHB/TSHD Propeller-Wash 47
5.6.8 Summary of Source Rates 49

6 ENVIRONMENTAL THRESHOLD ANALYSIS 50
6.1 Thresholds 50
6.2 Management Zones 52
6.2.1 Zone of High Impact 52
6.2.2 Zone of Moderate Impact 52
6.2.3 Zone of Influence 52

7 RESULTS OF SEDIMENT FATE MODELLING 54

7.1 General Plume Movement 54
7.1.1 Summary 54
7.1.2 Plume Movement over the Spring and Neap Tide 54
7.1.3 Plume Movement at the Disposal Ground 59
7.2 Spatial and Temporal Characteristics of SSC 64
7.2.1 Spatial Distribution of SSC 64
7.2.2 Temporal Variability of SSC 73
7.3 Spatial and Temporal Characteristics of Sedimentation 87
7.3.1 Spatial Distribution of Sedimentation 87
7.3.2 Temporal Variability of Sedimentation 94
7.4 Prediction of Management Zone Extents 99

8 CONCLUSIONS 104
8.1 General Plume Movement 104
8.2 Spatial and Temporal Distributions of SSC 104
8.3 Spatial and Temporal Distributions of Sedimentation 104
8.4 Management Zone Extents 104

9 REFERENCES 106

APPENDIX A – EXPERT REVIEW OF SEDIMENT DISPERSION MODELLING ASSESSMENT REPORT

APPENDIX B – EXPERT REVIEW AIMS COMMENTS AND RPS RESPONSE TABLE REV 1

Tables

Table 4.1 Statistical summary of quality of agreement between measured and modelled wind velocity components at the NRSDAR station over the period 1 January 2019 to 1 June 2022. 15
Table 4.2 Statistical summary of quality of agreement between measured and modelled water level and current velocity components at the NRSDAR station over the period 1 to 31 January 2019. 15
Table 4.3 Statistical summary of quality of agreement between measured and modelled significant wave height, peak period and peak direction at the NRSDAR station over the period 1 January 2019 to 1 March 2019. 18
Table 5.1 Material size classes used in SSFATE. 20
Table 5.2 Typical values of coefficients for calculating settling velocities in SSFATE. 21
Table 5.3 Provisional outline of proposed pipeline trenching and disposal activities. 26
Table 5.4 Estimated cycle times for each pipeline section where the BHD will be operating. 26
Table 5.5 Estimated cycle times for each pipeline section where the TSHD will be operating. 26
Table 5.6 Relevant vessel specifications for propeller wash assessment. 26
Table 5.7 Modelled trench depths, quantities of material type, and production rates by material type for trenching of each pipeline section. 28
Table 5.8 Modelled durations of trenching and disposal operations by material type for each pipeline section. 29
Table 5.9 Modelled sequencing of trenching and disposal operations assuming concurrent TSHD, CSD and BHD operation (worst case). 29
Table 5.10 Summary of geotechnical data used in the derivation of model PSDs for each pipeline section. 31
Table 5.11 *In situ* PSDs broken down into DREDGEMAP material classes for each pipeline section to be dredged, derived from available geotechnical information. 33
Table 5.12 *In situ* wet bulk densities and estimated dry bulk densities, based on the available wet bulk density and voids ratio data. 33
Table 5.13 Assumed PSDs of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is not dewatering. 35
Table 5.14 Assumed PSDs of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is dewatering. 35
Table 5.15 Assumed vertical distribution of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is not dewatering. 35
Table 5.16 Assumed vertical distribution of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is dewatering. 36
Table 5.17 Assumed PSDs of sediments initially suspended into the water column during SHB disposal operations at the offshore spoil ground. 37
Table 5.18 Assumed vertical distribution of sediments initially suspended into the water column during SHB disposal operations at the offshore spoil ground. 37
Table 5.19 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for pre-sweep of sediment while the hopper is not overflowing. 40
Table 5.20 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for pre-sweep of sediment while the hopper is overflowing. 40
Table 5.21 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for post-sweep of material that has been crushed by CSD while the hopper is not overflowing. 41
Table 5.22 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for post-sweep of material that has been crushed by CSD while the hopper is overflowing. 41

Table 5.23 Assumed vertical distribution of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route while the hopper is not overflowing. 41
Table 5.24 Assumed vertical distribution of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route while the hopper is overflowing 41
Table 5.25 Calculated source rates of sediments initially suspended into the water column during TSHD hopper overflow for pre-sweep sediment and post-sweep CSD-crushed material, using the methodology outlined in Becker *et al.* (2015). 43
Table 5.26 Assumed PSDs of sediments initially suspended into the water column during TSHD hopper disposal operations at spoil ground for the pre-sweep material. 45
Table 5.27 Assumed PSDs of sediments initially suspended into the water column during TSHD hopper disposal operations at spoil ground for the post-sweep of CSD-crushed material. 45
Table 5.28 Assumed vertical distribution of sediments initially suspended into the water column during TSHD hopper disposal operations at the offshore spoil ground. 46
Table 5.29 Assumed PSDs of sediments initially suspended into the water column during CSD trenching operations along the pipeline route for crushing and casting of material. 47
Table 5.30 Assumed vertical distribution of sediments initially suspended into the water column during CSD trenching operations along the pipeline route for crushing and casting of material. 47
Table 5.31 Summary of sediment sources applied in the model. 49
Table 5.32 Sediment source rates applied in the model for the TSHD while overflowing. 49
Table 6.1 Tolerance limits for excess SSC and sedimentation (INPEX, 2018). 50

Figures

Figure 1.1 Route of the nearshore section (KP78 to KP122.5) of the proposed DPD project pipeline in Darwin Harbour, showing trenching, pre-sweep and sand wave sections and the location of the proposed offshore spoil ground that will be utilised during disposal activities. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 2

Figure 4.1 Hydrodynamic grid setup showing the domain decomposition scheme applied and the model bathymetry. 10

Figure 4.2 Hydrodynamic grid setup showing the domain decomposition scheme applied and the model bathymetry, focusing on the innermost grids. 11

Figure 4.3 Time series comparisons of wind speed, direction, U and V components as measured at the NRSDAR station and as extracted at the closest grid point in the CFSR model over the wave and hydrodynamic model validation period (1 January 2019 to 1 March 2019). 13

Figure 4.4 Time series comparisons of wind speed, direction, U and V components as measured at the NRSDAR station and as extracted at the closest grid point in the CFSR model over the winter/dry season sediment dispersion model scenario period (1 April 2019 to 10 July 2019). 14

Figure 4.5 Time series comparisons of water level, current speed, direction, U and V components as measured at the NRSDAR station and as extracted at the closest grid point in the hydrodynamic model over the period 1 to 31 January 2019. 16

Figure 4.6 Time series comparisons of significant wave height, peak period and peak direction as measured at the NRSDAR station and as extracted at the closest grid point in the wave model over the period 1 January 2019 to 1 March 2019. 19

Figure 5.1 DREDGEMAP model domain and bathymetry (m MSL). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 24

Figure 5.2 PSD sediment sample locations, with blue dots representing the 2021 survey and green dots representing the January 2022 survey. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 32

Figure 5.3 Conceptual diagram showing the general behaviour of sediments dumped from a barge/SHB in open water and the vertical distribution of material set up by entrainment and billowing (Source: Moritz & Randall, 1992). 38

Figure 5.4 Two-dimensional view of a propeller-induced velocity profile. 48

Figure 6.1 Delineation of the proposed trenching impact reporting zones (East Arm, Middle Arm, Mid Harbour and Offshore) based on INPEX, 2010. Thresholds used to define the management zones will vary in magnitude between the trenching impact reporting zones. 51

Figure 7.1 Example two-hourly snapshots of modelled sediment plume movement during a nominal spring tide cycle in the winter/dry season scenario (based on 21 April 2019 6am to 2pm, flooding to ebbing tide). At this point in the simulation the TSHD is working near the northern end of Trench Zone 6, the CSD is working near the southern end of Trench Zone 6, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 55

Figure 7.2 Example two-hourly snapshots of modelled sediment plume movement during a nominal neap tide cycle in the winter/dry season scenario (based on 15-16 April 2019 8pm to 6am, ebbing to flooding tide). At this point in the simulation the TSHD is working in Trench Zone 6, the CSD is working in Trench Zone 5, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 56

Figure 7.3 Example two-hourly snapshots of modelled sediment plume movement during a nominal spring tide cycle in the summer/wet season scenario (based on 18 October 2019 1pm to 11pm, from high tide ebb to slack tide to high tide flood). At this point in the simulation the TSHD is working in Trench Zone 6, the CSD is working in Trench Zone 5, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 57

Figure 7.4 Example two-hourly snapshots of modelled sediment plume movement during a nominal neap tide cycle in the summer/wet season scenario (based on 22-23 October 2019 6pm to 4am, ebbing to slack tide to flooding). At this point in the simulation the TSHD is working in Trench Zone 7, the CSD is working in Trench Zone 6, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 58
Figure 7.5 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal spring tide cycle in the winter/dry season scenario (based on 21 April 2019 6am to 11am, flooding to start of ebbing tide). At this point in the simulation, disposals from the TSHD occur at 5:10am, first seen in the 6am snapshot (dashed circle 1) and at 9:40am, first seen in the 10am snapshot (dashed circle 3), and a disposal from the BHD occurs at 6:10am, first seen in the 7am snapshot (dashed circle 2). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear. 60
Figure 7.6 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal spring tide cycle in the winter/dry season scenario (based on 21 April 2019 12pm to 5pm, ebbing tide). At this point in the simulation, a disposal from the TSHD occurs at 2:05pm, first seen in the 3pm snapshot (dashed circle 5), and a disposal from the BHD occurs at 12:30pm, first seen in the 1pm snapshot (dashed circle 4). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear. 61
Figure 7.7 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal neap tide cycle in the winter/dry season scenario (based on 15-16 April 2019 9pm to 2am, ebbing tide). At this point in the simulation, disposals from the TSHD occur at 8:10pm, first seen on the 9pm snapshot (dashed circle 6) and at 12:36am, first seen on the 1am snapshot (dashed circle 8), and a disposal from the BHD occurs at 10:10pm, first seen on 11pm snapshot (dashed circle 7). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear. 62
Figure 7.8 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal neap tide cycle in the winter/dry season scenario (based on 16 April 2019 3am to 8am, flooding tide). At this point in the simulation, disposals from the TSHD occur at 4:55am, first seen on the 5am snapshot (dashed circle 9) and BHD occur at 4:35 am, first seen on the 5am snapshot (dashed circle 10). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear. 63
Figure 7.9 Predicted 90th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 65
Figure 7.10 Predicted 95th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 66
Figure 7.11 Predicted 90th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 67
Figure 7.12 Predicted 95th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 68

Figure 7.13 Predicted 90th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 69
Figure 7.14 Predicted 95th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 70
Figure 7.15 Predicted 90th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 71
Figure 7.16 Predicted 95th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 72
Figure 7.17 Time series analysis point locations. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 74
Figure 7.18 Time series of predicted trenching-excess SSC at the *WI_S*, *WED1* and *CHI* sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 77
Figure 7.19 Time series of predicted trenching-excess SSC at the *WI_S*, *WED1* and *CHI* sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 78
Figure 7.20 Time series of predicted trenching-excess SSC at the *CPW1*, *MAN* and *CHP* sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 79
Figure 7.21 Time series of predicted trenching-excess SSC at the *CPW1*, *MAN* and *CHP* sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 80
Figure 7.22 Time series of predicted trenching-excess SSC at the *VI_S* and *VI_E* sites throughout the entire trenching program and run-on period in the winter/dry season scenario....................... 81
Figure 7.23 Time series of predicted trenching-excess SSC at the *VI_S* and *VI_E* sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 82
Figure 7.24 Time series of predicted trenching-excess SSC at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the winter/dry season scenario....................... 83
Figure 7.25 Time series of predicted trenching-excess SSC at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 84
Figure 7.26 Time series of predicted trenching-excess SSC at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 85
Figure 7.27 Time series of predicted trenching-excess SSC at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 86
Figure 7.28 Predicted maximum trenching-excess bottom thickness (mm) throughout the entire trenching program for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 88
Figure 7.29 Predicted trenching-excess bottom thickness (mm) at the last time step of the trenching program (not including run-on period) for the winter/dry season scenario (based on 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation... 89

Figure 7.30 Predicted trenching-excess bottom thickness (mm) at the last time step of the simulation (end of run-on period) for the winter/dry season scenario (based on 10 July 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 90

Figure 7.31 Predicted maximum trenching-excess bottom thickness (mm) throughout the entire trenching program for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 91

Figure 7.32 Predicted trenching-excess bottom thickness (mm) at the last time step of the trenching program (not including run-on period) for the summer/wet season scenario (based on 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 92

Figure 7.33 Predicted trenching-excess bottom thickness (mm) at the last time step of the simulation (end of run-on period) for the summer/wet season scenario (based on 9 January 2020). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 93

Figure 7.34 Time series of predicted trenching-excess bottom thickness at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 95

Figure 7.35 Time series of predicted trenching-excess bottom thickness at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 96

Figure 7.36 Time series of predicted trenching-excess bottom thickness at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 97

Figure 7.37 Time series of predicted trenching-excess bottom thickness at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 98

Figure 7.38 Predicted Zone of Influence following application of the appropriate spatial thresholds in Table 6.1 to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 100

Figure 7.39 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in Table 6.1 to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 101

Figure 7.40 Predicted Zone of Influence following application of the appropriate spatial thresholds in Table 6.1 to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 102

Figure 7.41 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in Table 6.1 to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 103

1 INTRODUCTION

1.1 Background

Santos is exploring options for the Darwin pipeline duplication (DPD) project associated with development of the Barossa gas field in northern Australia. The proposed pipeline would run from the offshore point where the Barossa gas export pipeline (GEP) reaches the existing Bayu-Undan pipeline to the Darwin LNG (DLNG) plant at Wickham Point in Darwin Harbour. Sections making up approximately 16 km of the proposed pipeline within the harbour will require trenching using dredge vessels, with the remaining sections – including the section offshore from the harbour –, laid on the seabed. Trenched material is proposed to be disposed of at an offshore disposal site adjacent to the existing INPEX spoil ground (Figure 1.1). Pipeline burial where required is proposed using quarry rock material that contains minimal fines; as such, this activity is not expected to represent a significant source of suspended sediment. Suspended sediment generated during the trenching and disposal activities has a potential to cause environmental impacts which must be identified, quantified, mitigated and managed to acceptable levels.

RPS was commissioned by Santos to undertake sediment dispersion modelling of the trenching and disposal operations associated with the Barossa DPD project in support of environmental approvals documentation and the development of the trenching and spoil disposal monitoring and management plan (TSDMMP) for the project. The sediment dispersion modelling has quantified the potential magnitude, intensity and spatial distribution of suspended sediment concentrations (SSC) and sedimentation that would be expected for the trenching and disposal operations proposed for the project. The predicted outcomes are to be used to inform the assessment of the potential for influence or impact upon water quality and benthic habitats in the region.

This technical report contains a summary of the sediment fate model inputs, methodologies and assumptions, and the model outcomes following analysis of specified threshold criteria. This report has been improved through updates made in response to a third-party expert review by the Australian Institute of Marine Science (AIMS) (AIMS, 2022; Appendix A). The review comments and subsequent changes made in response to these comments are summarised in Appendix B.

Subsequent to the sediment and spoil disposal modelling presented in this report, and in response to feedback from the Northern Territory (NT) Department of Environment Parks and Water Security (DEPWS) and an expert peer review report from AIMS (Appendix A), an additional spoil ground stability assessment study was conducted and has been presented in a separate addendum to this report (*Santos Barossa DPD Studies: Sediment Dispersion Modelling Addendum 1 - Spoil Stability Assessment*).

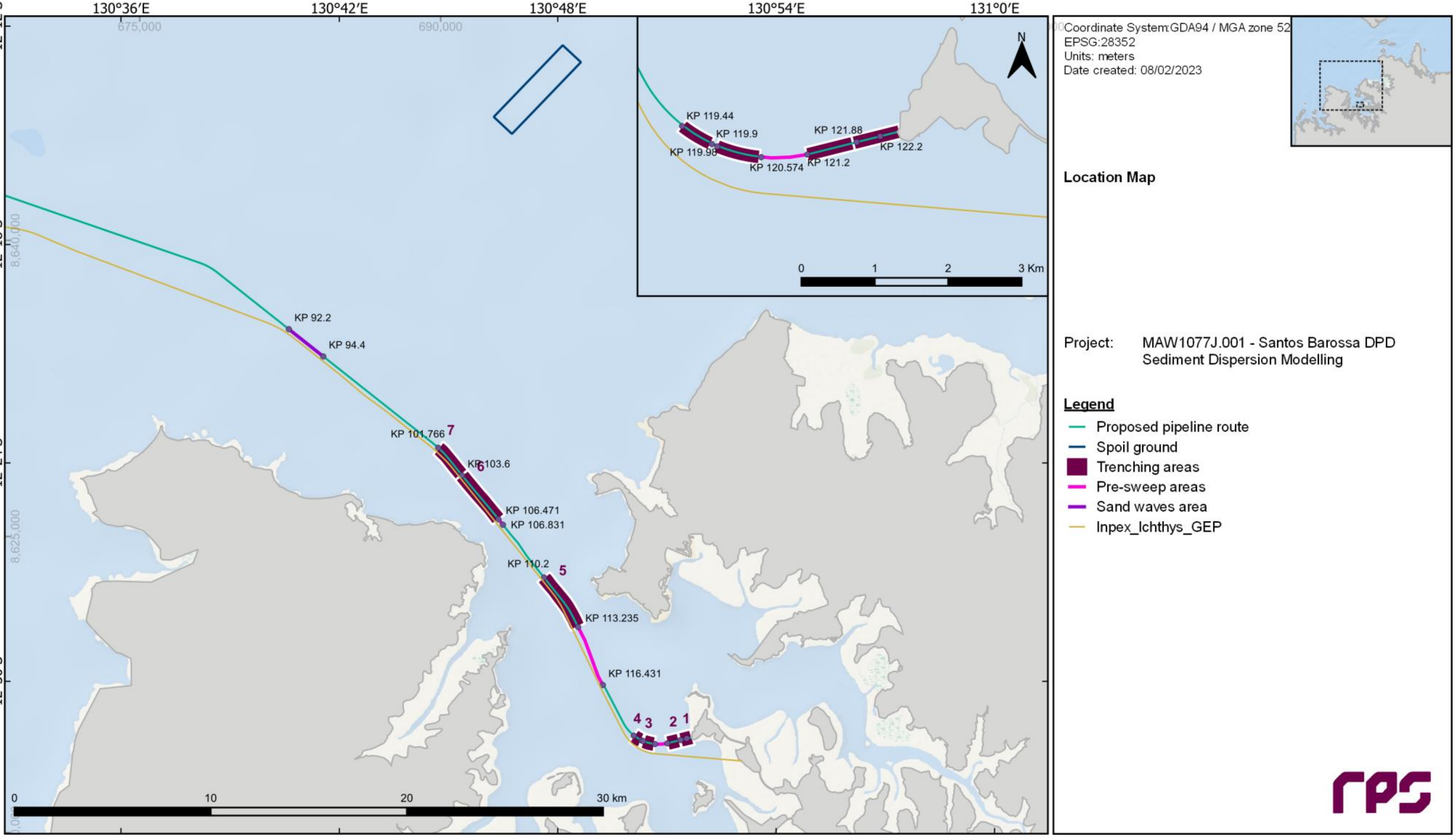

Figure 1.1 **Route of the nearshore section (KP78 to KP122.5) of the proposed DPD project pipeline in Darwin Harbour, showing trenching, pre-sweep and sand wave sections and the location of the proposed offshore spoil ground that will be utilised during disposal activities. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

1.2 Modelling Scope

RPS was commissioned to conduct sediment dispersion modelling for the following activities:

- The fate of the suspended material generated during trenching along the pipeline route.
- The fate of the material that is relocated to the nominated spoil grounds.

The scope of work required to complete the sediment dispersion modelling included:

1. Hydrodynamic and Wave Modelling.
   a. An initial assessment of the existing D-FLOW hydrodynamic and D-WAVE wave model frameworks in Darwin Harbour determined that refinements were necessary to suit the requirements of this scope of work. Reconfiguration of the models was conducted, to increase resolution within the harbour and update the model with the latest bathymetric data. This was followed by re-validation of the model predictions against available measurements of water levels, currents and waves.
   b. Two years (2019-2020) of hydrodynamic and wave simulation data was produced for use as input to the sediment dispersion model.
2. Sediment Dispersion Modelling.
   a. Inputs for the trenching program were prepared for the DREDGEMAP model, accounting for all potential concurrent sources of sediment characterised by location, intensity, particle size distribution, vertical distribution in the water column, and levels of cohesivity.
   b. Two trenching and disposal scenarios were simulated: (i) trenching commencing in winter/dry season; and (ii) trenching commencing in summer/wet season. The two scenarios simulated the ongoing sequence of all sediment-disturbing operations, along with simulation of a suitable post-trenching period to account for the fate of loosely consolidated material disturbed by the trenching and sediment placement.
   c. Simulation outputs from each separate trenching and disposal activity were post-processed, combined and analysed to determine outcomes including zones of impact and influence for each scenario based on specified threshold criteria.
   d. Key model outcomes were provided as spatial datasets in GIS shapefile format.
3. Reporting. This technical report detailing the sediment fate model inputs, methodologies, assumptions and model outcomes following analysis of specified threshold criteria was provided.

1.3 Definition of Relevant Terms and Abbreviations

BHD:

Backhoe Dredge. A pontoon equipped with a hydraulic excavator. The pontoon is stabilised and secured by three spuds. The excavator uses a large arm fitted with a bucket to excavate material from the seabed and discharge it into (typically) a split hopper barge moored alongside. BHDs are mainly used for dredging or breaking up the sedimentary rock below a layer of unconsolidated sediments, or for dredging in areas inaccessible to larger self-propelled vessels.

CSD:

Cutter Suction Dredge. A stationary (or self-propelled) vessel that is secured by a spud. The vessel is equipped with a rotating cutterhead, controlled via means of winches and anchors, that is used to cut and fragment material on the seabed. The vessel has a powerful pump system that sucks up a mixture of sediment and water and discharges it into a split hopper barge moored alongside or to a disposal zone via a pipeline. CSDs are mainly used for dredging hard soils and sedimentary rock.

Dewatering:

Draining of excess water from a split hopper barge using its drainage system.

Overflow:

Excess water and suspended solids that leave a trailing suction hopper dredge and are discharged to the water column via a weir and discharge pipe located at the base of the vessel.

Resuspension:

Removal of deposited material from the seabed to the water column as a result of natural or artificial agitation.

Sedimentation rate:

Rate of sediment accumulation on the seabed following deposition of SSC from the water column.

SHB:

Split Hopper Barge: Vessel with a large open hold used to load and transport dredged material. The unloading is performed by splitting the two halves of the hull to release the material towards the seabed.

SSC:

Suspended Solids Concentration (or Suspended Sediment Concentration). The concentration of sediment material in the water column following natural or artificial resuspension from the seabed.

TSHD:

Trailing Suction Hopper Dredge. A self-propelled vessel with one or two suction tubes/arms, equipped with dragheads that are lowered to the seabed and trailed over the bottom. The vessel has a powerful pump system that sucks up a mixture of sediment and water and discharges it in the hopper (hold) of the vessel. TSHDs are mainly used for dredging loose and soft soils such as sand, gravel, silt or clay.

2 REGIONAL METOCEAN CONDITIONS

The trenching and disposal operations for the DPD project will be conducted within Darwin Harbour and the area just offshore of the Harbour entrance, with the spoil ground located approximately 20 km to the north-east of the Harbour in Beagle Gulf (Figure 1.1). Knowledge of the metocean conditions in this region is necessary for prediction of the dispersion and sedimentation of any suspended sediment generated by the trenching and disposal operations associated with the project. Details of the regional climate and metocean conditions in the project area were outlined in the DPD Project NT EPA Referral (CDM Smith, 2022), and the following sections summarise the metocean conditions relevant to the trenching and disposal operation locations.

2.1 Climate

The project area is characterised by a tropical monsoonal climate with a distinct dry season (May to September) and wet season (October to March), separated by a relatively short transition period. The dry season is dominated by dry, cool weather with little rain, low humidity and wide-ranging temperatures. The onset and duration of the wet season varies between years; however, most rainfall in the Northern Territory is associated with monsoonal troughs and/or from isolated convective storms (BoM, 2021). High precipitation rates are commonly experienced during storm events in the wet season.

Tropical cyclones occur in the project area on average about once per year, typically occurring between November to April. The strongest winds and heaviest rainfall are associated with the passage of tropical cyclones.

2.2 Wind Climate

Synoptic winds during the dry season tend to be dominated by the south-east trade winds, while light west to north-westerlies predominate during the wet season. Sea breezes from the north-west occur on most afternoons throughout the year.

Mean afternoon wind speeds tend to be stronger than morning wind speeds all year round. Morning wind speed is typically stronger during the dry season, whereas the afternoon wind speed increases during the late dry, build-up and wet season periods which is most likely associated with the formation of mid-to-late afternoon storm cells during this time of the year. Strong wind gusts can be experienced at any time throughout the year.

2.3 Hydrodynamics: Currents and Water Levels

While oceanic currents in the region offshore of Beagle Gulf are influenced by the Indonesian Throughflow and South Equatorial Current, the Beagle Gulf is dominated by strong internal circulation and experiences only minor oceanic interaction. In the dry season there is a general south-westerly drift while wet season circulation is dominated by a north-easterly drift, generated by north-west monsoonal winds. The drift currents are often less than 0.5 knots (0.26 m/s; Smit *et al.*, 2000). Tidal ranges in this region are 6 m to 8 m (ConocoPhillips, 2019).

INPEX (2010) deployed a bottom mounted Acoustic Doppler Current Profiler (ADCP) in the vicinity of the proposed offshore spoil ground in Beagle Gulf. Measurements showed currents flowed over a tidal axis oriented approximately east-west at speeds up to 1 m/s. The data showed marginally larger variations at the surface indicating increased influence of wind forcing on the currents.

Darwin Harbour experiences regular and rapid exchange of water with Beagle Gulf as large tidal movements, and to a lesser extent winds, drive the exchange of large volumes of water between inner Darwin Harbour and the Beagle Gulf each day. The macro-tidal regime of the harbour is the dominant influence on currents which are strongly correlated with the rise and fall of the tide. Currents in the harbour can peak at speeds of up to 2-2.5 m/s (Williams *et al.*, 2006).

The macro-tidal regime of Darwin Harbour has a maximum range of 8.1 m (Harper, 2010) with predominantly semidiurnal tides (two highs and two lows per day), with a slight diurnal inequality. The mean neap tidal range is 1.9 m and mean spring tidal range is 5.5 m (NT Government, 2011).

2.4 Waves

The wave climate in Beagle Gulf exhibits a strong seasonality associated with the tropical north-west monsoon that occurs between November and March. The monsoon's north westerly winds blow over the uninterrupted fetch of the Timor Sea, increasing incident wave energy in Beagle Gulf and at the entrance to Darwin Harbour. During the months of April to October, south-easterly trade winds blow across a limited fetch and generate a low energy local wave climate, with wave heights generally below 1.0 m for 90% of the time, and peak wave energy periods of about 3-5 seconds (Nicholas *et al.*, 2019).

Darwin Harbour is well sheltered from long period tsunami and ocean swell waves by the Tiwi Islands and the harbour's orientation, shallow bathymetry and coastline configuration. The energy of long period waves entering the harbour quickly dissipates and wave heights decrease significantly. Waves within the harbour are generally of short (3-5 seconds) mean periods with heights well below 1.0 m under non-cyclone conditions (INPEX, 2010).

Tropical cyclones can cause extreme wave conditions with significant wave height of 4.5 m and mean wave period of 7.5 seconds at the harbour entrance, which reduces in height down to 0.7 m inside the harbour (Makarynska, 2019a, 2019b). Wave height measurements from Australia's Integrated Marine Observing System (IMOS) national reference station at the entrance to Darwin Harbour recorded significant wave heights exceeding 3.5 m during the passage of tropical lows in 2012 with peak periods of wave energy also increasing to between about 6-8 seconds (Nicholas *et al.*, 2019).

3 MODEL SKILL MEASURES

The predictive capabilities of the hydrodynamic and wave models under development were validated through quantitative and visual comparisons of measured and modelled data.

3.1 Statistical Analysis

To provide a quantitative measure of model performance, analyses of the Index of Agreement (IOA; Willmott, 1981) and the Mean Absolute Error (MAE; Willmott, 1982; Willmott & Matsuura, 2005) were conducted. Although other traditional error estimates – such as the correlation coefficient and the root mean square error (RMSE) – are problematic and prone to ambiguities and bias (Willmott, 1982; Willmott & Matsuura, 2005), they are presented in some instances to provide better context for the IOA and MAE estimates.

The IOA is determined using the following formula:

$$\text{IOA} = 1 - \frac{\sum |X_{\text{model}} - X_{\text{obs}}|^2}{\sum \left(|X_{\text{model}} - \overline{X_{\text{obs}}}| + |X_{\text{obs}} - \overline{X_{\text{obs}}}| \right)^2}$$

In this equation, X represents the variable being compared and $\bar{X}$ represents the mean of that variable over time.

A perfect agreement can be said to exist between field observations and model predictions if the IOA gives a measure of unity (1), while complete disagreement will produce an IOA measure of zero (Willmott, 1981). Although there are no definitive guidelines for what IOA values might represent a good agreement, Willmott *et al.* (1985) suggests that values meaningfully larger than 0.5 represent good model performance.

The MAE is simply the average of the absolute differences between observed and modelled values. As a more natural measure of average error (Willmott & Matsuura, 2005) it is more readily understood than the IOA. In common with the RMSE, a lower MAE implies better model performance.

An important point to note regarding both the IOA and MAE, and in fact most measures of model performance, is that slight phase differences between two data sets can result in a seemingly poor statistical comparison – particularly in rapidly-changing data such as tidal direction or water elevation where the tidal range is large. It is therefore always important to consider both the statistics and a visual representation of the comparison (Willmott *et al.*, 1985).

Another potential source of misleading statistical comparisons is that directional fluctuations across the 0/360° compass point can bias the skill measures of current direction. Therefore, this study has based the quantitative assessment of model skill on the separate U (east-west) and V (north-south) components of the wind or current vectors rather than on the derived products of magnitude and direction.

3.2 Time Series Analysis

In addition to bulk statistical measures, model performance for the validation periods was assessed visually with the aid of time series plots of wind speed and direction for the wind field input, water level, current speed and current direction data for the hydrodynamic model, and time series plots of wave height, wave period and wave direction for the wave model. This approach is particularly valuable for the hydrodynamic model because statistical measures of model skill can heavily penalise errors in phase (i.e. time lags) even when the dynamics of flow are broadly reproduced.

4 HYDRODYNAMIC AND WAVE MODELLING

Modelling of the potential sediment dispersion from the trenching and disposal activities associated with the Barossa DPD project required temporal and spatial representation of the hydrodynamic and wave conditions within the project area. A hydrodynamic and wave model framework of the Beagle Gulf area centred and refined in Darwin Harbour was constructed, calibrated and validated for a past marine modelling study of dredging and spoil disposal for INPEX (RPS, 2009). This model framework has been redeveloped for the Barossa DPD project scope of work and is described in the following sections.

The hydrodynamic and wave modelling for the project was conducted using the Delft3D suite of software. The Delft3D suite is a fully integrated computer software package composed of several modules (e.g. flow, waves, sediment, water quality, and ecology) grouped around a common interface. This software suite has been developed to carry out studies with a multi-disciplinary approach and multi-dimensional calculations (e.g. 2-D and 3-D) for a range of systems, such as oceanic, coastal, estuarine and river environments. It can simulate the interaction of flows, waves, sediment transport, morphological developments, water quality and aquatic ecology. Specific modules of the Delft3D suite are referenced in this report, following the convention of the software developers, with the suffix D- (e.g. D-FLOW for the Delft3D Hydrodynamics module and D-WAVE for the Delft3D Spectral Wave module).

The Delft3D suite has been developed by Deltares, an independent institute for applied research on water with over 30 years of experience in modelling aquatic systems (http://www.deltares.nl/en). The Delft3D suite of models adheres to the International Association for Hydro-Environment Engineering and Research guidelines for documenting the validity of computational modelling software, closely replicating an array of analytical, laboratory, schematic and real-world data.

The configuration of the hydrodynamic and wave models is in line with recommendations of best practice for sediment dispersion modelling as outlined by WAMSI Dredging Science Node guidance (Sun *et al.*, 2016). Inclusion of mesoscale ocean currents is recommended, as these currents have a significant influence on the net drift of suspended material over the time scales of trenching operations (days to weeks) and are therefore important to predictions of sediment transport. The use of three-dimensional current modelling with a series of interconnected grids of progressively finer resolution is also recommended, as are coupling of the hydrodynamic and wave models and validation of current predictions against measured data.

4.1 Hydrodynamic Model (D-FLOW)

4.1.1 Model Description

To simulate the hydrodynamics within Darwin Harbour, Beagle Gulf and the surrounding area, a three-dimensional model with accurate representations of the bathymetry, bottom roughness and spatially-varying wind stress was utilised for the region. The model framework was developed through the combination of a large-scale regional model with smaller refined regions, or sub-domains.

The D-FLOW model is ideally suited to represent the hydrodynamics of complex coastal waters, including regions where the tidal range creates large intertidal zones. RPS has applied the model for numerous studies in the region.

D-FLOW is a multi-dimensional (2-D or 3-D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena that result from tidal, meteorological and baroclinic forcing on a rectilinear or a curvilinear, boundary-fitted grid. In three-dimensional simulations, the vertical grid can be defined following the sigma-coordinate approach, where the local water depth is divided into a series of layers with thickness at a set proportion of the depth.

D-FLOW allows for the establishment of a series of interconnected (two-way, dynamically-nested) curvilinear grids of varying resolution; a technique referred to as “domain decomposition”. This allows for the generation of a series of grids with progressively increasing spatial resolution, down to an appropriate scale for accurate resolution of the hydrodynamics associated with features such as dredged channels. The main advantage of domain decomposition over traditional one-way, or static, nesting systems is that the model domains interact seamlessly, allowing transport and feedback between the regions of different scales. The ability to dynamically couple multiple model domains offers a flexible framework for hydrodynamic model development. This modelling method was applied in this study.

Inputs to the model, as discussed in the following sections, included:

- Bathymetry of the study area, including shipping channels, islands, and adjacent features. The wetting and drying of the intertidal zones was simulated in applicable areas.
- Boundary elevation forcing data.
- Spatially-varying surface wind and pressure data.

4.1.2 Bathymetry and Domain Definition

The hydrodynamic model was established over the domain shown in Figure 4.1. Accurate bathymetry is a significant factor in development of a model framework required to resolve highly variable current conditions. The bathymetry was developed using Geoscience Australia lidar data, as well as project specific multibeam bathymetry data within Darwin Harbour provided by Santos, supplemented with GEBCO (General Bathymetric Chart of the Oceans) data (GEBCO, 2021) and the C-MAP electronic chart database in the broader area where relevant and required.

The composite bathymetric data was interpolated onto the D-FLOW Cartesian grid. The resultant bathymetry is shown in Figure 4.2. The extent and shape of the model coastline will change as water levels rise and fall with tidal movements due to the inclusion of wetting and drying within the model system.

The vertical grid of the model comprised five layers of varying thickness, depending on location, throughout the domain. Five layers were found to be enough to resolve the circulation and provide suitable bed-level currents without overly compromising model performance. As the model was set up as a proportional sigma-grid in the vertical dimension, these layers therefore represented a terrain-following arrangement with a layer thickness of 20% of the total local water depth.

To offset the computational effort required for a large, multi-layered model domain, and to achieve adequate horizontal and temporal resolution, a multiple-grid (domain-decomposition) strategy was applied using five sub-domains of varying horizontal grid cell size (Figure 4.1 and Figure 4.2). Horizontal resolutions within each sub-domain were 80 m for the Darwin Harbour area (sub-grid 4), 240 m for the region from Gunn Point to Dundee Beach (sub-grid 3), 720 m for the Beagle Gulf and Clarence Strait region (sub-grid 2), 2.2 km for the Van Diemen Gulf and Tiwi Island region (sub-grid 1), and 6.5 km for the outer domain (sub-grid 0).

Each sub-domain is an individual hydrodynamic model simulated in parallel with the others, with dynamic coupling at the shared boundaries between sub-domains. The outermost sub-domains captured large-scale oceanographic phenomena which progressively fed into the finer-resolution domains representing the area of interest. The resolution of the innermost sub-domain was specified after assessment of the requirement to adequately resolve the variation in current fields, and in turn the sediment dynamics.

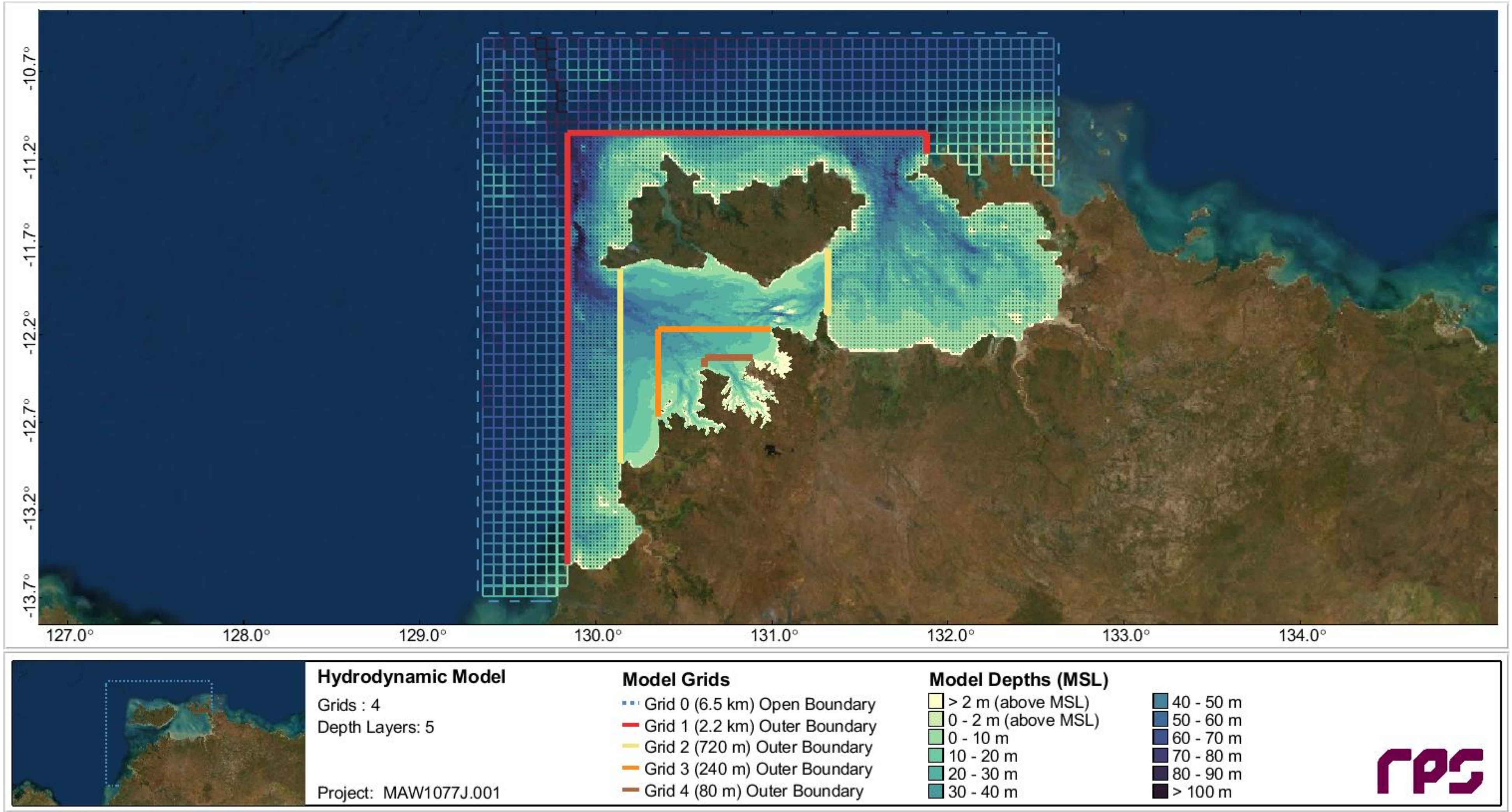

Figure 4.1 Hydrodynamic grid setup showing the domain decomposition scheme applied and the model bathymetry.

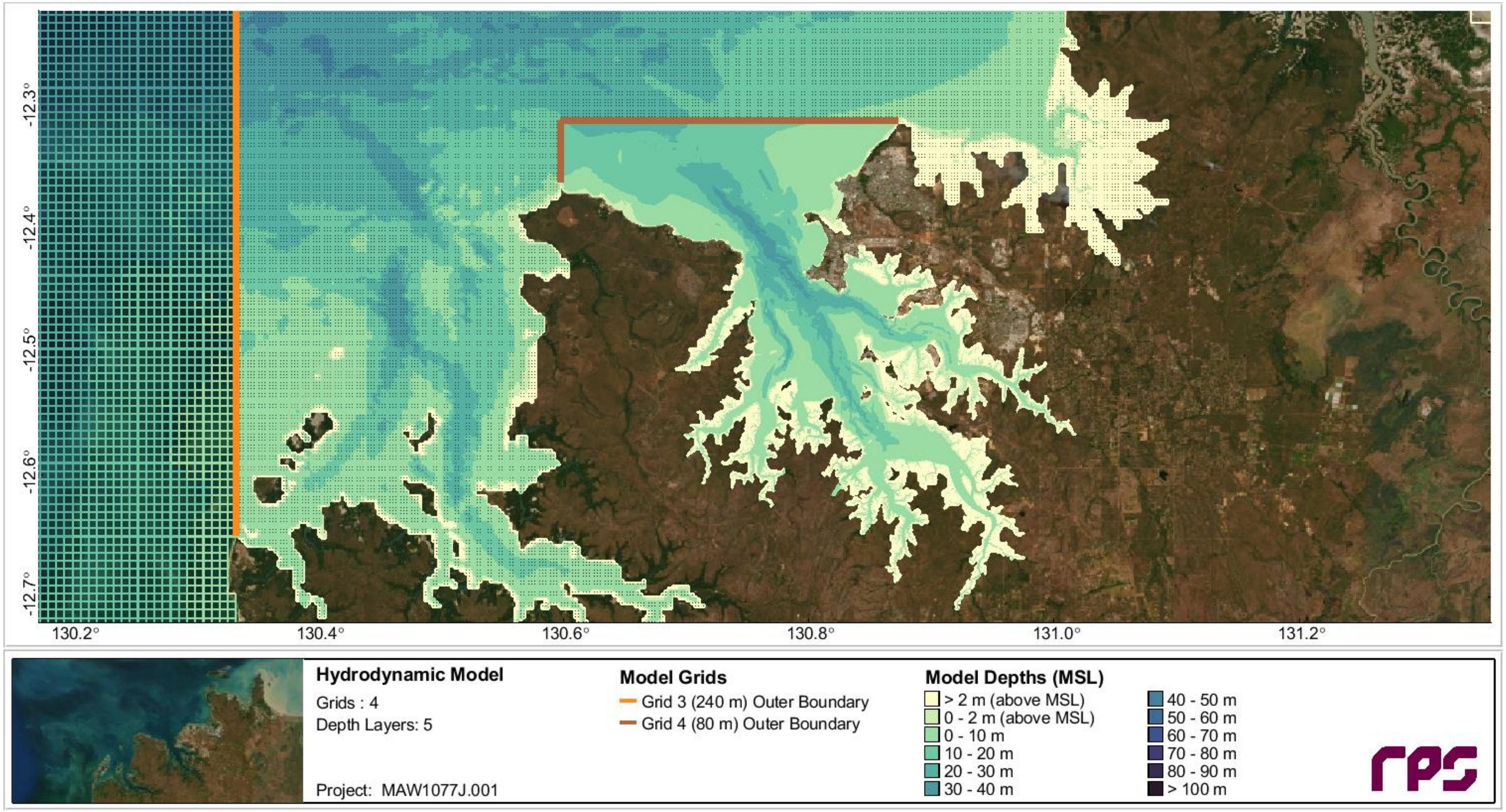

Figure 4.2 Hydrodynamic grid setup showing the domain decomposition scheme applied and the model bathymetry, focusing on the innermost grids.

4.1.3 Boundary and Initial Conditions

4.1.3.1 Overview

As the hydrodynamics in the study area are controlled primarily by tidal flows and wind forcing, these processes were explicitly included in the developed model.

The model was forced on the open boundaries of the outer sub-domain with time series of water elevation obtained for the chosen simulation period. Spatially-varying wind speed and wind direction data was used to force the model across the entire domain.

4.1.3.2 Water Elevation

Water elevations at hourly intervals were obtained from the TPXO8.0 database (Egbert & Erofeeva, 2002), which is a recent iteration of a global model of ocean tides derived from measurements of sea-surface topography by the TOPEX/Poseidon satellite-borne radar altimeters. Tides are provided as complex amplitudes of earth-relative sea-surface elevation for eight primary (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1), two long-period (M_f, M_m) and three non-linear (M_4, MS_4, MN_4) harmonic constituents at a spatial resolution of 0.25°.

The tidal sea level data was augmented with non-tidal sea level elevation data from the global Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet *et al.*, 2003; Halliwell, 2004), created by the USA's National Ocean Partnership Program (NOPP) as part of the Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite instrumentation, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density, sea height variations and the rotation of the Earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (z-levels), density (isopycnal layers), and terrain-following (σ-levels). HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics than non-hybrid models. The model has global coverage with a horizontal resolution of $1/12^{th}$ of a degree (~7 km at mid-latitudes) and a temporal resolution of 24 hours.

4.1.3.3 Wind Forcing

Spatially-variable wind data was sourced from the Global Data Assimilation System (GDAS), which is used by the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) model to place observations into a gridded model space for the purpose of starting, or initializing, weather forecasts with observed data. The GFS Forecasts model variant used has a horizontal resolution of $1/12^{th}$ of a degree and a temporal resolution of 6 hours (NCEP, 2016).

Measured wind data sourced from Australia's IMOS national reference station Darwin (NSRDAR) was analysed and compared with the closest CFSR model hindcast data point to provide confirmation of the accuracy of CFSR winds in the project area. Time series comparisons of the measured and modelled wind data at the NRSDAR location are shown in Figure 4.3 for the validation period (1 January to 1 March 2019). Given the measured data had significant gaps during the validation period, an additional comparison is provided in Figure 4.4 for the winter/dry season sediment dispersion model scenario period (1 April 2019 to 10 July 2019). The visual comparisons of the measured and modelled wind parameters show the overall patterns and ranges of the wind parameters are well matched at the NRSDAR location.

A statistical summary of CFSR model skill at the NRSDAR location for the period 1 January 2019 to 1 June 2022 is presented in Table 4.1. The statistical summary confirms that the CFSR model performance is strong for all parameters at the NRSDAR location. The good agreement between CFSR-modelled and NRSDAR-measured winds provides confidence in the use of CFSR wind data as a forcing input to both the hydrodynamic and wave models.

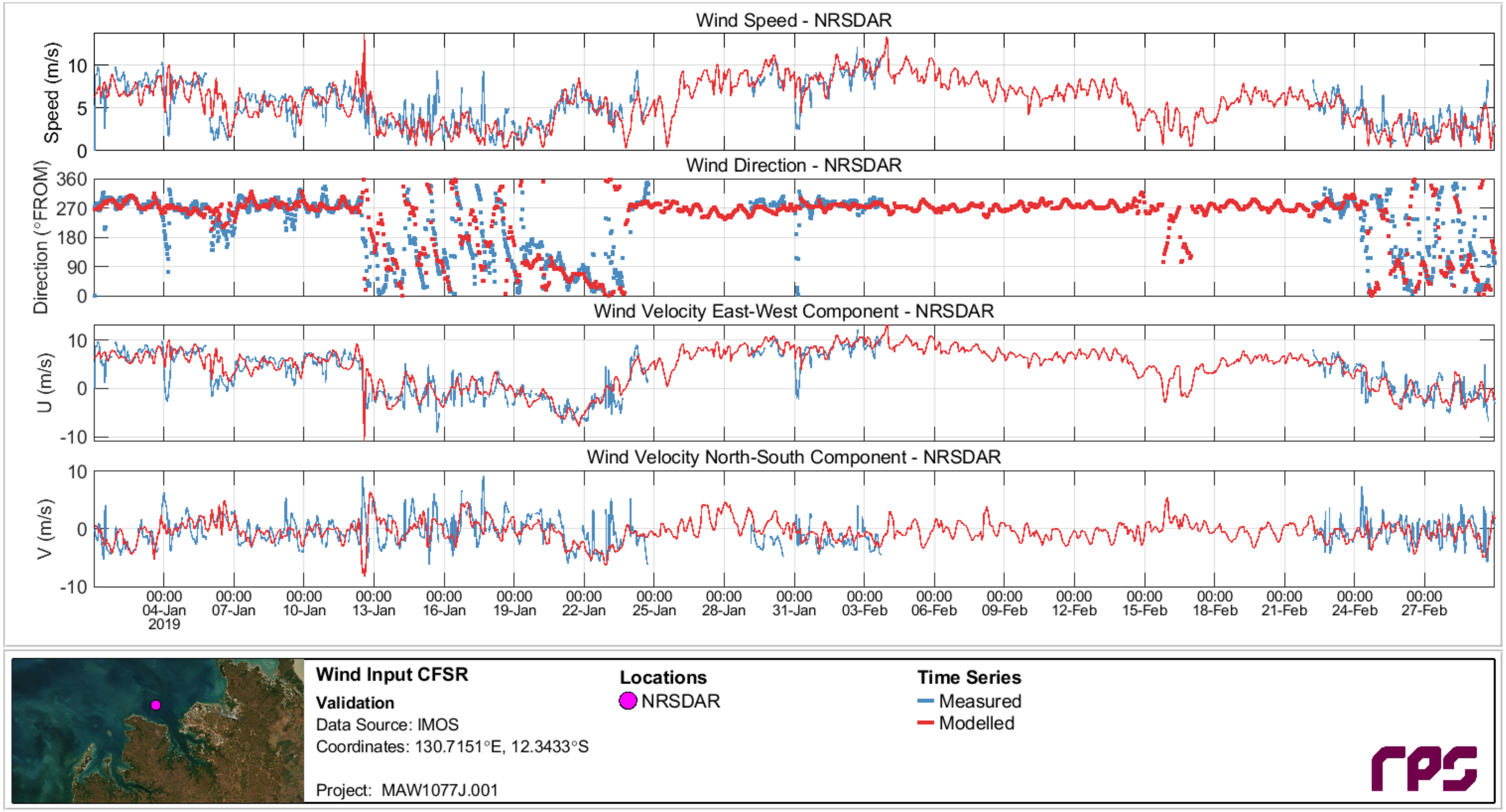

Figure 4.3 **Time series comparisons of wind speed, direction, U and V components as measured at the NRSDAR station and as extracted at the closest grid point in the CFSR model over the wave and hydrodynamic model validation period (1 January 2019 to 1 March 2019).**

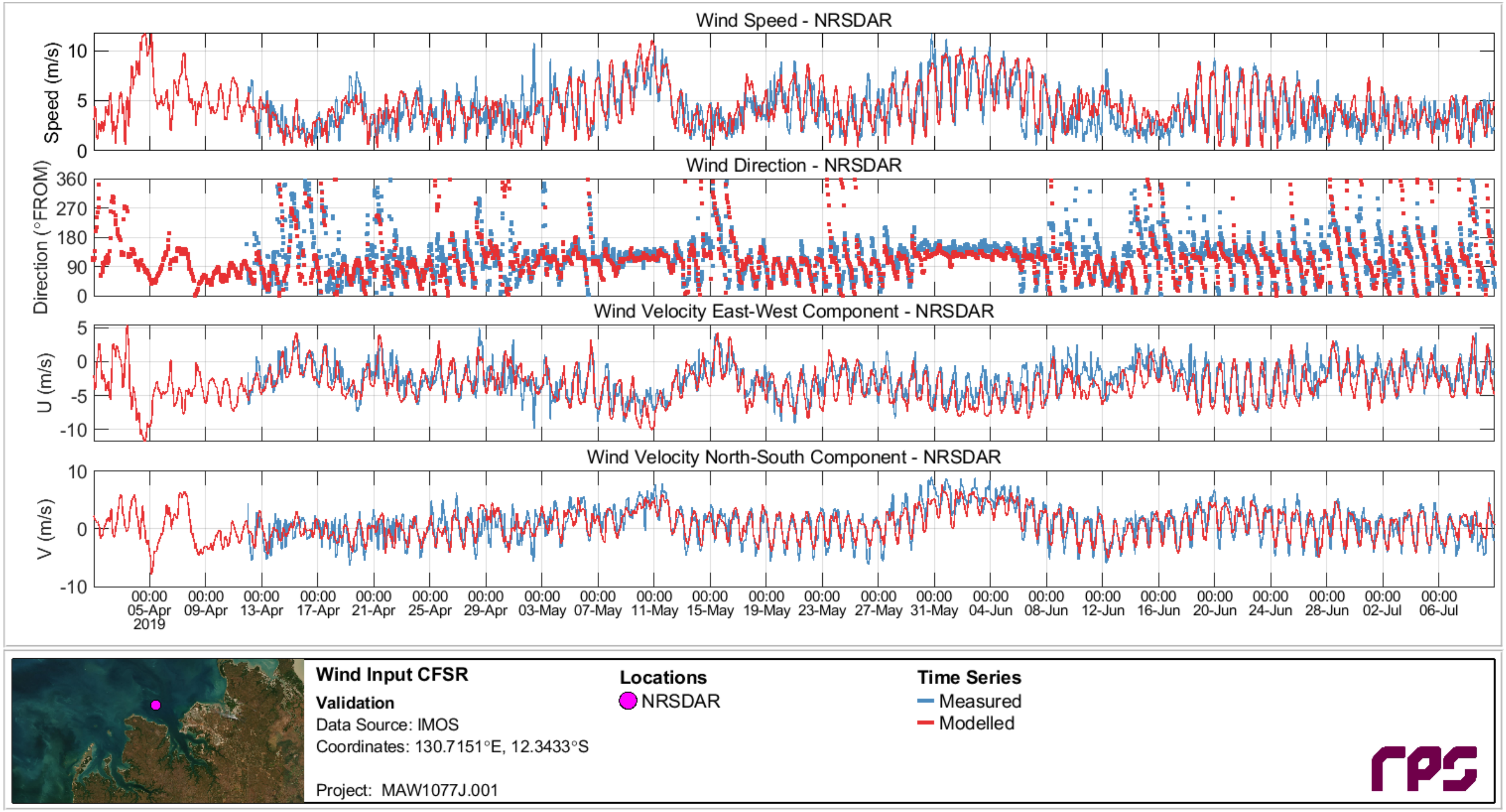

Figure 4.4 **Time series comparisons of wind speed, direction, U and V components as measured at the NRSDAR station and as extracted at the closest grid point in the CFSR model over the winter/dry season sediment dispersion model scenario period (1 April 2019 to 10 July 2019).**

Table 4.1 Statistical summary of quality of agreement between measured and modelled wind velocity components at the NRSDAR station over the period 1 January 2019 to 1 June 2022.

Wind Component	Skill Measure		
	IOA *	MAE †	RMSE †
U (east-west) (m/s)	0.90	1.82	2.39
V (north-south) (m/s)	0.77	1.67	2.17

* IOA values closer to 1 indicate higher model skill.

† MAE/RMSE values closer to 0 indicate higher model skill.

Spatial wind fields were prepared and used as forcing inputs across the model domains for both the Delft3D hydrodynamic and wave model. Winds covering the relevant periods were extracted from the Climate Forecast System Reanalysis (CFSR) hindcast data set. The CFSRv2 Reanalysis (Saha *et al.*, 2014) data product features output at spatial resolution of 0.2° at hourly intervals, contains 64 vertical levels in the atmosphere, and is coupled with ocean circulation and sea ice models.

4.1.4 Model Validation

4.1.4.1 Measured Data Source

Validation data was sourced from Australia's Integrated Marine Observing System (IMOS), enabled by the National Collaborative Research Infrastructure Strategy (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent.

4.1.4.2 Comparison of Modelled and Measured Currents

The first months of 2019 were selected as the candidate validation period for the hydrodynamic model. Results presented here for a one-month validation period demonstrate the model performance under spring and neap tides, and given the dominant influence of tidal forcing this period captures most of the expected range for current speeds.

The time series comparison of measured and modelled data (Figure 4.5) shows excellent agreement between modelled and measured currents and water levels. A statistical summary of the hydrodynamic model skill at the NRSDAR location for the period 1 to 31 January 2019 is presented in Table 4.2. The statistical summary confirms that the hydrodynamic model performance is excellent for all parameters at the NRSDAR location.

Table 4.2 Statistical summary of quality of agreement between measured and modelled water level and current velocity components at the NRSDAR station over the period 1 to 31 January 2019.

Hydrodynamic Parameter	Skill Measure		
	IOA *	MAE †	RMSE †
Water level	0.99	0.17	0.23
U (east-west) (m/s)	0.98	0.08	0.11
V (north-south) (m/s)	0.98	0.05	0.08

* IOA values closer to 1 indicate higher model skill.

† MAE/RMSE values closer to 0 indicate higher model skill.

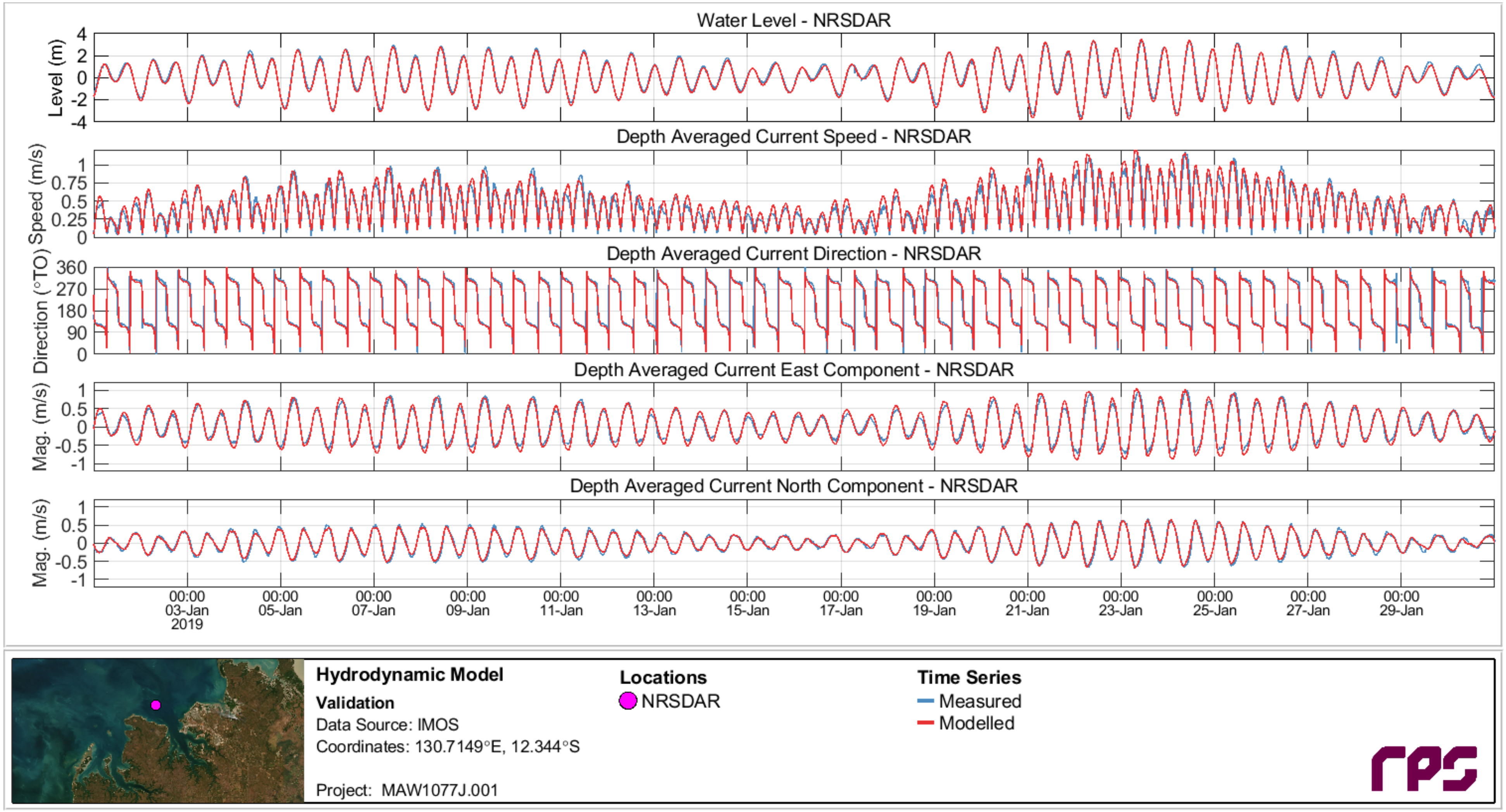

Figure 4.5 **Time series comparisons of water level, current speed, direction, U and V components as measured at the NRSDAR station and as extracted at the closest grid point in the hydrodynamic model over the period 1 to 31 January 2019.**

4.2 Wave Model (D-WAVE)

4.2.1 Model Description

Reliable forecasting for the fate of fine sediments in the study location required the input of wave spectra information to calculate the shear stress and orbital velocities imposed by waves which will affect the settlement and resuspension of fine material that is initially suspended by trenching and related operations. D-WAVE is a variant of the well-known SWAN wave model that has been customised for compatibility with the Delft3D software suite.

The D-WAVE model is a spectral phase-averaging wave model originally developed by the Delft University of Technology. D-WAVE, a third-generation model based on the energy balance equation, is a numerical model for simulating realistic estimates of wave parameters in coastal areas for given wind, bottom and current conditions.

D-WAVE includes algorithms for the following wave propagation processes: propagation through geographic space; refraction and shoaling due to bottom and current variations; blocking and reflections by opposing currents; and transmission through or blockage by obstacles. The model also accounts for dissipation effects due to white-capping, bottom friction and wave breaking as well as non-linear wave-wave interactions. D-WAVE is fully spectral (in all directions and frequencies) and computes the evolution of wind waves in coastal regions with shallow water depths and ambient currents.

4.2.2 Model Implementation

The D-WAVE model was developed to cover the same grid regions defined by the hydrodynamic model (Figure 4.1 and Figure 4.2). The bathymetry and wind data input to the wave model was the same as used for the hydrodynamic model. Time-varying water level information for each grid node in the wave model was provided by the output of the hydrodynamic model.

CAWCR (Centre for Australian Weather and Climate Research) Wave Hindcast data (Durrant *et al.*, 2020) was used to create boundary conditions as forcing input to the wave model. Wave parameters covering the relevant periods were extracted from the CAWCR model at 20 km intervals and used to generate parametric spectral inputs along each of the wave model open boundaries.

The global resolution of the CAWCR Wave Hindcast is 0.4°, with a resolution of 4 arc-minutes (up to 7 km) in the Australasian and central and south-west Pacific region. The increased coastal resolution near land masses in this region provides better representation of geometry, an important consideration for sheltering effects around islands. High spatial resolution also enables improved representation of bathymetry near coastlines, which in turn results in a more accurate computation of the influence of bottom friction, depth-induced wave breaking and improved modelled intensity of storm systems that can be significantly underestimated in terms of wave height at coarser resolutions (Cavaleri, 2009).

The numerical model underpinning the CAWCR Wave Hindcast is WAVEWATCH III (WW3; Tolman, 1991). WW3 is a third-generation wave model and is widely used in forecasting centres.

The D-WAVE model was configured as three one-way nested cartesian grids, with resolutions of 7 km, 800 m and 250 m, respectively. The outer boundaries of these nested grids correspond with those of Grid 0, Grid 2 and Grid 4 in the hydrodynamic model (Figure 4.1).

The wave model was run in a coupled mode with the hydrodynamic model for the years of 2019 and 2020. The model results were independently validated by comparison to IMOS measured wave data for the Darwin Harbour region. Given the purpose of the wave model is to provide bottom shear stresses and orbital velocities for settlement and resuspension calculations across a large domain in the sediment dispersion model, rather than a more site-specific application such as the design of a structure, it is believed this is an acceptable level of validation.

4.2.3 Model Validation

The first two months of 2019 were selected as the candidate validation period for the wave model because this period included relatively large wave events in comparison to the remainder of 2019. During the validation period, significant wave heights reached up to 2 m for a sustained period towards the end of January, supported by consistent westerly wind forcing. Outside of the validation period the wave heights at the measurement location tended to be less than 0.75 m.

The wave heights and directions were well reproduced by the wave model, as shown in the time series comparisons (Figure 4.6) and as reinforced by the statistical comparisons (Table 4.3) which have high IOAs of 0.95 and 0.89, respectively. The time series comparison for peak period shows a model underprediction throughout the validation period. This is reflected in the statistical comparison where there is a moderate IOA value of 0.67, however the MAE is less than 1 s. A literature review revealed that other modelling studies using the D-WAVE (SWAN) model had encountered similar underestimation of wave period values – most notably Rogers *et al.* (2003) who investigated methods for improving predictions and found, as did we, that only a limited level of improvement could be achieved.

Given the primary role of the wave model data is to predict seabed shear velocities for sediment transport, this level of error in the wave period is considered acceptable. At the ranges of the significant wave heights (relatively small) and wave periods seen in the project area, the impact on the near-bed orbital velocities is small – in the order of several cm/s. Changes in the order of cm/s are not significant when compared against the magnitudes of the tidal current velocities which range to greater than 1 m/s (Figure 4.5).

Table 4.3 Statistical summary of quality of agreement between measured and modelled significant wave height, peak period and peak direction at the NRSDAR station over the period 1 January 2019 to 1 March 2019.

Wave Parameter	Skill Measure		
	IOA *	MAE †	RMSE †
Significant height (m)	0.95	0.15	0.19
Peak period (s)	0.67	0.94	1.11
Peak direction (° from)	0.89	20.8	36.7

* IOA values closer to 1 indicate higher model skill.

† MAE/RMSE values closer to 0 indicate higher model skill.

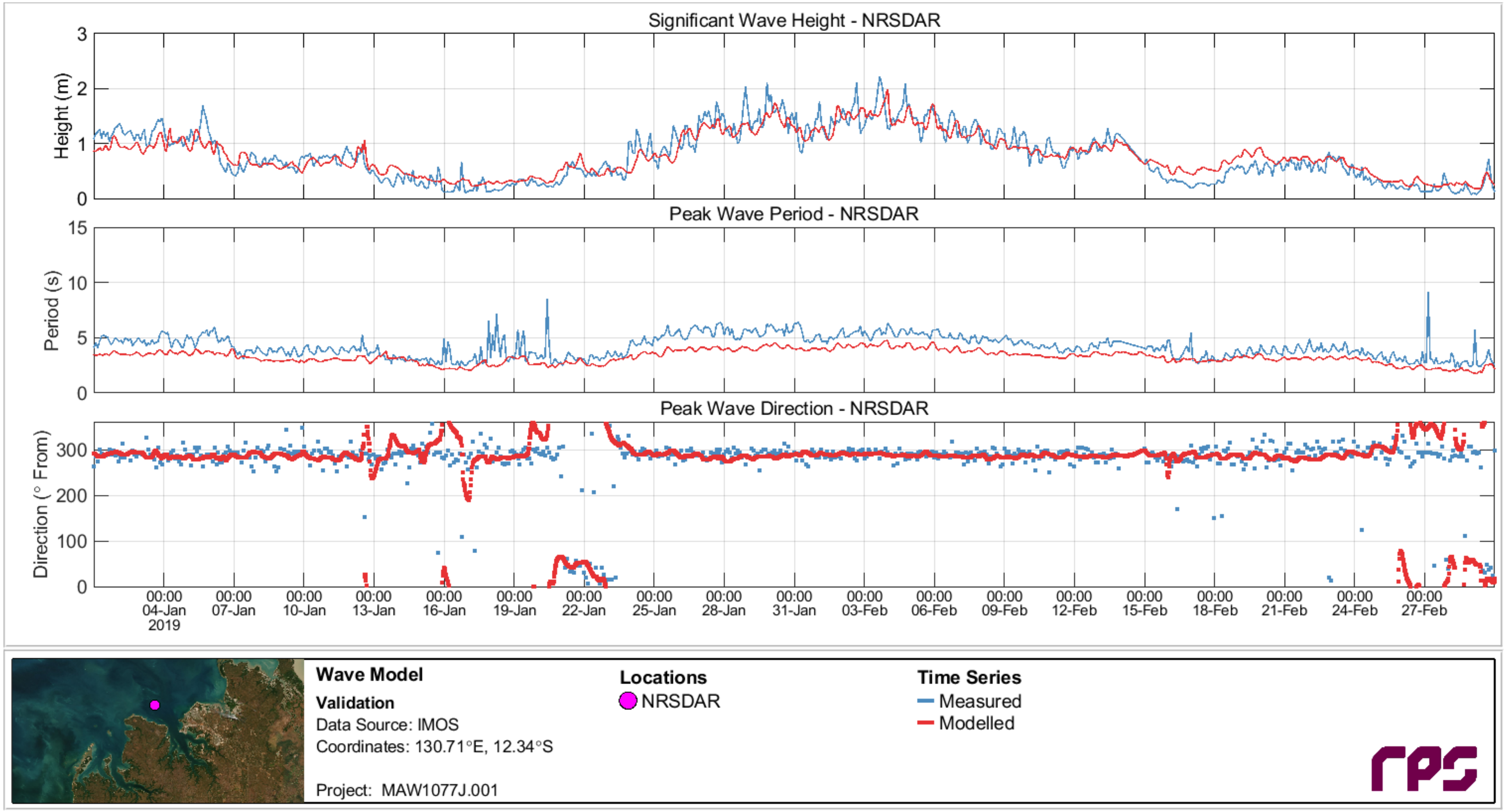

Figure 4.6 Time series comparisons of significant wave height, peak period and peak direction as measured at the NRSDAR station and as extracted at the closest grid point in the wave model over the period 1 January 2019 to 1 March 2019.

5 APPROACH TO SEDIMENT FATE MODELLING

Estimates for the three-dimensional distribution of sediments suspended by trenching and disposal operations have been derived for the full duration of the pipeline trenching and disposal program using numerical modelling. The approach of modelling operations in full and in three dimensions is in line with best practice for sediment dispersion modelling as outlined by WAMSI Dredging Science Node guidance (Sun *et al.*, 2016).

This modelling relied upon specification of sediment discharges over time for each of the expected sources of sediment suspension and predicted the evolution of the combined sediment plumes via current transport, dispersion, sinking and sedimentation. The model allowed for the subsequent resuspension of settling sediments due to the erosive effects of currents and waves. Thus, the fate of sediments was assessed beyond their initial settling.

Forcing was provided using predictions of three-dimensional current fields and two-dimensional wave fields for the study area, which are described in Section 2.

5.1 Model Description

Modelling of the dispersion of suspended sediment resulting from the various trenching and disposal operations was undertaken using an advanced sediment fate model, Suspended Sediment FATE (SSFATE), operating within the RPS DREDGEMAP model framework. This model computes the advection, dispersion, differential sinking, settlement and resuspension of sediment particles. The model can be used to represent inputs from a wide range of suspension sources, producing predictions of sediment fate both over the short-term (minutes to days following a discharge source) and longer term (days to years following a discharge source).

SSFATE allows the three-dimensional predictions of SSC and seabed sedimentation to be assessed against allowable exposure thresholds. Sedimentation thresholds often relate to burial depths or rates, while SSC thresholds are usually more complicated, involving tiered exposure duration and intensities. As a result, assessing the project-generated sediment distributions against these thresholds in both three-dimensional space and time is a computationally intensive task. A variety of SSC threshold formulations have recently been applied in Australian coastal waters and at present there are no general guidelines.

SSFATE is a computer model originally developed jointly by the US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) and RPS to estimate SSC generated in the water column and deposition patterns generated due to dredging operations in a current-dominated environment, such as a river (Johnson *et al.*, 2000; Swanson *et al.*, 2000, 2004). RPS has significantly enhanced the capability of SSFATE to allow the prediction of sediment fate in marine and coastal environments where wave forcing becomes important for reworking the distribution of sediments (Swanson *et al.*, 2007).

SSFATE is formulated to simulate far-field effects (~25 m or larger scale) in which the mean transport and turbulence associated with ambient currents are dominant over the initial turbulence generated at the discharge point. A five-class particle-based model predicts the transport and dispersion of the suspended material. The classes include the 0-130 µm range of sediment grain sizes that typically result in plumes. Heavier sediments tend to settle very rapidly, remain more stable over time and are not relevant over the longer durations (>1 hour) and larger spatial scales (>25 m) of interest here. Table 5.1 shows the standard material classes used in SSFATE for suspended sediment.

Table 5.1 Material size classes used in SSFATE.

Material Class Description	Particle Size Range (µm)
Clay	<7
Fine Silt	7-34
Coarse Silt	35-74
Fine Sand	75-130
Coarse Sand	>130

Particle advection is calculated using three-dimensional current fields, obtained from hydrodynamic modelling, thus the model can account for vertical changes in the currents within the water column. For example, as particles sink towards the seabed they will tend to be moved at slower speeds due to the slowing of currents by friction at the seabed. Particle diffusion is assumed to follow a random walk process using a Lagrangian approach of calculating transport, which uses a grid-less space to remove limitations of grid resolution, artefacts due to grid boundaries, and also maintain a high degree of mass conservation.

Following release into the model space, the sediment cloud evolves according to the following processes:

- Advection due to the three-dimensional current field.
- Diffusion by a random walk model with the mass diffusion rate specified, ideally, from measurements at the site. As particles represent an ensemble of real particles, each particle in the model has an associated Gaussian distribution governed by particle age and the mass diffusion properties of the surrounding water.
- Settlement or sinking of the sediment due to buoyancy forces. Settlement rates are determined from the particle class sizes and include allowance for flocculation and other concentration-dependent behaviour, following the model of Teeter (2000). The SSFATE model calculates the settling velocity for four of the five classes, with a settling velocity of 0.1 m/s assumed for coarse sand (Teeter, 2000; Swanson, 2007). The settling velocities are calculated from typical values of coefficients within SSFATE. The formulas used to calculate settling velocities, and the typical values of coefficients from the formulas, are presented below.

$$If\ \bar{C}_{ll} \leq C \leq \bar{C}_{ul}\ then$$

$$Ws_i = a\left(\frac{C}{\bar{\bar{C}}_{ul}}\right)^{n_i}$$

$$If\ C \geq \bar{C}_{ul}\ then$$

$$Ws_i = a$$

$$If\ C \leq \bar{C}_{ll}$$

$$Ws_i = a\left(\frac{\bar{C}_{ll}}{\bar{\bar{C}}_{ul}}\right)^{n_i}$$

Where:

$$a = \frac{1}{C}\sum_i a_i C_i \qquad \bar{C}_{ul} = \frac{1}{C}\sum_i C_{ul_i} C_i \qquad \bar{C}_{ll} = \frac{1}{C}\sum_i C_{ll_i} C_i$$

- C_{uli} and C_{lli} are the nominal upper and lower concentration limits, respectively, for enhanced settling of grain class *i*, and *C* is the total concentration for all grain size classes (except coarse sand).
- a_i is a grain-size class average maximum floc settling velocity.
- n_i is a grain-size dependent exponent.

Table 5.2 Typical values of coefficients for calculating settling velocities in SSFATE.

Sediment Grain Size Class	Size Range (µm)	C_{lli} (mg/L)	C_{uli} (mg/L)	a_i (m/s)	n_i
Clay	<7	50	1,000	0.0008	1.33
Fine Silt	7-34	150	3,000	0.0023	1.10
Coarse Silt	35-74	250	5,000	0.0038	0.90
Fine Sand	75-130	400	8,000	0.0106	0.80

- Potential deposition to the seabed determined using a model that couples the deposition across particle classes (Teeter, 2000). The likelihood and rate of deposition depends on the shear stress at the seabed. High shear inhibits deposition, and in some cases excludes it altogether with sediment remaining in suspension. The model allows for partial deposition of individual particles according to a practical deposition rate, thereby allowing the bulk sediment mass to be represented by fewer particles.
- Potential resuspension from the seabed, if previously deposited, at a rate governed by exceedance of a shear stress threshold at the seabed due to the combined action of waves and currents. Different thresholds are applied for resuspension depending upon the size of the particle and the duration of sedimentation, based on empirical studies that have demonstrated that newly-settled sediments will have higher water content and are more easily resuspended by lower shear stresses (Swanson *et al.*, 2007). The resuspension flux calculation also accounts for armouring of fine particles within the interstitial spaces of larger particles. Thus, the model can indicate whether deposits will stabilise or continue to erode over time given the shear forces that occur at the site. Resuspended material is released back into the water column to be affected by the processes defined above.

SSFATE formulations and proof of performance have been documented in a series of USACE Dredging Operations and Environmental Research (DOER) Program technical notes (Johnson *et al.*, 2000; Swanson *et al.*, 2000), and published in the peer-reviewed literature (Andersen *et al.*, 2001; Swanson *et al.*, 2004; Swanson *et al.*, 2007). SSFATE has been applied and validated by RPS against observations of sedimentation and suspended sediments at multiple locations in Australia, notably Cockburn Sound for Fremantle Ports and Mermaid Sound for the LNG Foundation Project dredging program.

5.2 Model Limitations

There are inherent limitations to the accuracy of numerical models. The possible sources of uncertainty within the modelling conducted for the sediment fate assessment of the DPD project include:

- *The equations and algorithms applied in the model*. The formulations included in the model, as discussed in Section 5.1, were selected to achieve the best possible representation of the relevant processes and have been proven to be valid over a range of projects.
- *The accuracy of the physical (current and wave) inputs to the model*. Current and wave forcing inputs were provided from validated hydrodynamic and wave models created and customised for the study area. The accuracy of these models is suitable, as good correlations with field measurements have been achieved, with the uncertainties minimised and quantifiable. The hydrodynamic and wave models are described in Section 2. It should be noted that the model inputs are a hindcast of past metocean conditions; the overall trends reflected in this data will be broadly reflected in future conditions, but conditions on any given day during the actual trenching operations may be quite different.
- *The accuracy of trenching methodology inputs to the model*. Specification of the proposed trenching and disposal methodologies was provided by Santos after consultation with the trenching contractors tendering to perform the work. Any assumptions made to achieve a realistic representation of the trenching and disposal activities are outlined in Section 5.6 and were based on extensive past project experience.
- *The accuracy of the material properties input to the model*. Geotechnical information obtained by RPS during the benthic/environmental survey investigations for the DPD project (RPS, 2022) and during previous site investigations for the Bayu-Undan Pipeline Project (Santos, 2022e, 2022f) was provided by Santos and is discussed in Section 5.5. From this data, the properties of the *in situ* material to be trenched are reasonably well-known. However, it is not possible to determine how the material properties will be changed by the action of the dredges, particularly the CSD cutting rock and the mixing of the material with seawater in the process of pumping it to the hopper/SHB. Therefore, assumptions were made in the model with regard to the material that is released into the water column from trenching and the material properties of the sediments that are to be placed at the proposed spoil ground.
- *The accuracy of the trenching and disposal sediment source terms input to the model*. The source definition in the model is flexible and can be applied to any sediment source by specifying the time-varying flux rate, particle size distribution (PSD) and vertical profile in the water column. This information will be specific to the equipment used and the material encountered at the site, and therefore can only be determined with confidence from a pilot study at the site or field measurements during trenching. In the absence of such data, conservative assumptions were made with regard to these parameters. The

assumptions are outlined in Section 5.6 and were based on literature review, including the recent WAMSI Dredging Science Node reports, and extensive past project experience.

The major sources of uncertainty for the sediment fate modelling are the modelled trenching methodology and sediment source inputs to the model. The assumptions made were based on literature review and experience and aimed to give a good representation of the sources of suspended sediment that will result from the proposed trenching and disposal activities. However, as there were uncertainties in the inputs to the model, the results should be considered as indicative of the expected ranges in magnitude and distribution of suspended sediments and sedimentation, rather than an exact prediction.

5.3 Model Domain and Bathymetry

The DREDGEMAP model domain established for the Barossa DPD project trenching works extended approximately 100 km north-south by 100 km east-west (Figure 5.1). The model grid covers the section of the Northern Territory coastline from Dundee Beach in the west to Cape Hotham in the east and offshore to the Tiwi Islands. The offshore boundaries of the domain were imposed at a reasonable distance from the proposed trenching areas, to allow potential sediment drift patterns in offshore directions to be adequately captured.

This region lies within the model domain of the Delft3D hydrodynamic and wave models that provide the current and wave inputs to DREDGEMAP (see Section 2). A grid resolution of 100 m by 100 m was selected to ensure that existing features in the domain, including the many bays, islands, channels and passages of Darwin Harbour and Beagle Gulf, were adequately defined.

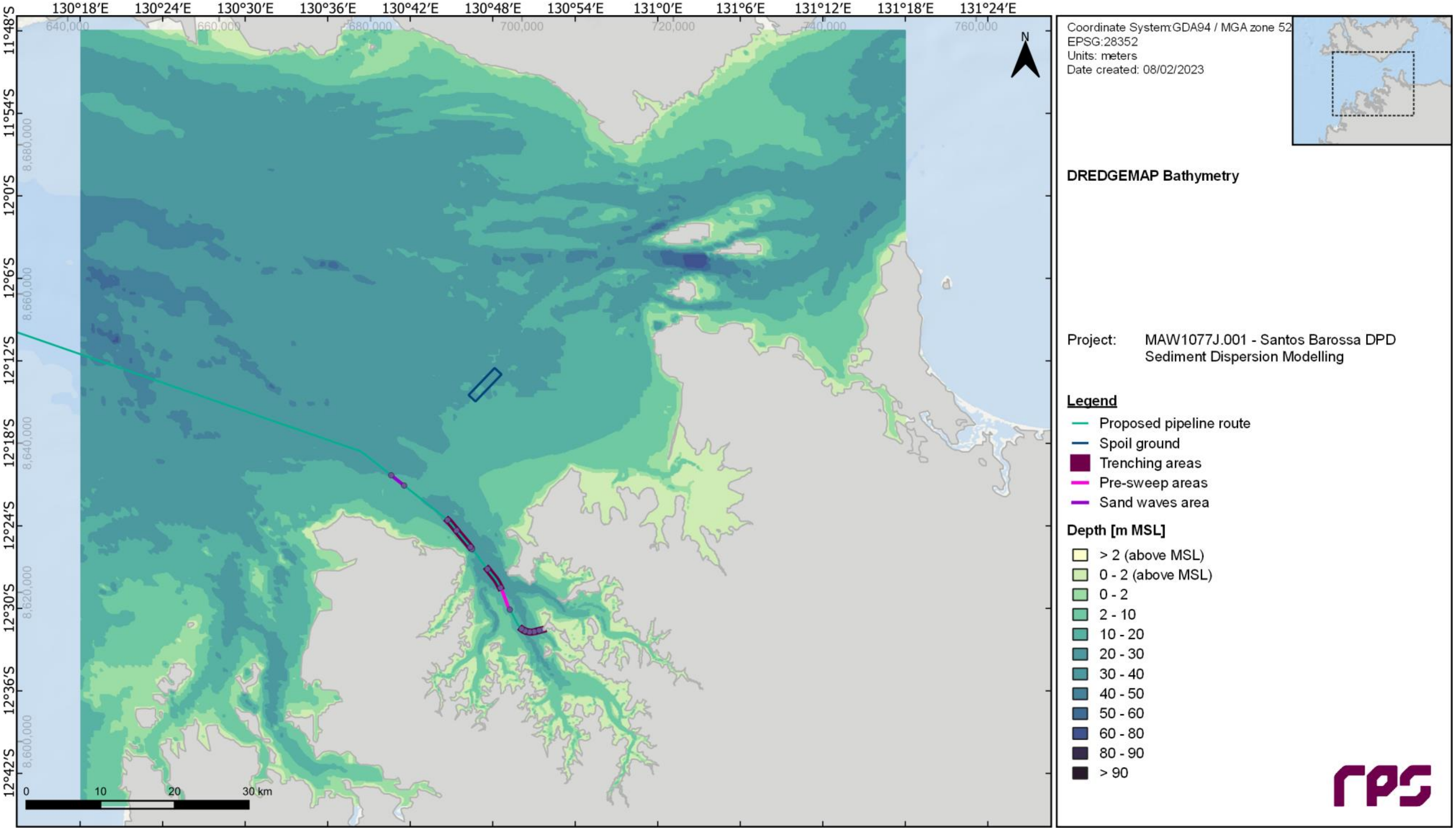

Figure 5.1 **DREDGEMAP model domain and bathymetry (m MSL). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

5.4 Trenching Project Description and Model Operational Assumptions

5.4.1 Overview

Information outlining the proposed trenching and disposal operations for the Barossa DPD project has been drawn from input data provided by Santos and its potential trenching contractors, and subsequent meetings and email discussions (Santos, 2022a-f; RPS, 2022), including feedback from AIMS (Physical Oceanographer Dr Hemerson Tonin). At the time of commencement of modelling, the collated information represented the best available data with regard to geotechnical properties of the project areas, the trenching and construction methodologies expected to be used within these areas, and the characteristics of vessels planned to be engaged for the work.

The operations requiring modelling have been broken into two main activities:

- Trenching of sediment and rock along the pipeline route.
- Disposal of trenched sediment and rock at the nominated spoil ground.

It should be noted that the proposed backfill and stabilisation of the pipeline will use quarry rock material, and this activity has not been modelled because the methods as currently understood will not represent a significant source of suspended sediment.

The pipeline route trenching areas and spoil ground are all within NT waters (Figure 1.1).

The following sections outline the details of the operations for each of these activities and highlight any assumptions that were made.

5.4.2 Methods and Equipment

5.4.2.1 Pipeline Route Trenching

The material to be trenched from the pipeline route will consist mainly of marine sediments (approximately 209,000 m^3) and rock material (approximately 97,000 m^3).

The trenching operations for the pipeline route have been divided into eleven sections as outlined in Table 5.3, with the three pre-sweep areas and the sand wave area only requiring sediments to be removed and the other seven trenching sections requiring removal of both sediment and rock material.

The breakdown of the proposed trenching activities, including the locations of the pipeline KPs and spoil grounds, are shown in Figure 1.1. The trenching in each of the seven trenching sections was assumed to be completed with either: a backhoe dredge (BHD; Trench Zones 1 and 2); or a trailing suction hopper dredge (TSHD) conducting a pre-sweep to remove surface sediments, followed by a cutter suction dredge (CSD) crushing harder material, and a post-sweep with the TSHD to remove the CSD-crushed material. Trenching of the pre-sweep and sand wave sections is assumed to only require the TSHD.

Typically, a TSHD will remove the sediments or material that has been previously crushed by a CSD while a BHD or CSD will remove rock, and the quantities of each material type assumed in this case are detailed in Section 5.4.3. The assumed BHD has a bucket size up to 16 m^3 and total installed power of 2416 kW, while the TSHD hopper size was assumed to be 15,000 m^3 and the CSD was assumed to have a total installed power of 28,200 kW. It has been specified that overflow of fines from the TSHD hopper will be permitted, with a ‘green valve’ incorporated into the overflow system, and that dewatering of the split hopper barges (SHBs) that accompany the BHD will also occur.

The estimated cycle times for trenching within each pipeline section where the BHD will operate are presented in Table 5.4, and those for each pipeline section where the TSHD will operate are presented in Table 5.5.

The potential for sediment mobilisation by TSHD propeller-wash effects has been considered along all relevant pipeline sections. This has been done using supplied data on vessel characteristics, and local depth and seabed composition. For the purposes of the modelling assessment, the relevant vessel specifications are as outlined in Table 5.6.

Table 5.3 Provisional outline of proposed pipeline trenching and disposal activities.

Pipeline Zone	Pipeline Location Start KP	Pipeline Location End KP	Vessel	Task Description	Disposal Location
Trench Zone 1	122.2	121.88	BHD & 2 SHBs	-	Spoil ground
Trench Zone 2	121.88	121.2	BHD & 2 SHBs	-	Spoil ground
Pre-Sweep Area 1	121.2	120.574	TSHD	-	Spoil ground
Trench Zone 3	120.574	119.98	TSHD (pre/post-sweep) & CSD	TSHD pre-sweep - CSD crush - TSHD post-sweep	Spoil ground
Trench Zone 4	119.9	119.44	TSHD (pre/post -sweep) & CSD	TSHD pre-sweep - CSD crush - TSHD post-sweep	Spoil ground
Pre-Sweep Area 2	116.431	113.235	TSHD	-	Spoil ground
Trench Zone 5	113.235	110.2	TSHD (pre/post -sweep) & CSD	TSHD pre-sweep - CSD crush - TSHD post-sweep	Spoil ground
Pre-Sweep Area 3	106.831	106.471	TSHD	-	Spoil ground
Trench Zone 6	106.471	103.6	TSHD (pre/post -sweep) & CSD	TSHD pre-sweep - CSD crush - TSHD post-sweep	Spoil ground
Trench Zone 7	103.6	101.766	TSHD (pre/post -sweep) & CSD	TSHD pre-sweep - CSD crush - TSHD post-sweep	Spoil ground
Sand Waves Area	94.4	92.2	TSHD	-	Spoil ground

Table 5.4 Estimated cycle times for each pipeline section where the BHD will be operating.

Pipeline Zone	Non-Dewatering Time (min)	Dewatering Time (min)	Disposal Time (min)	Sailing Time (min)	Total Cycle Time (min)
Trench Zone 1	108	217	15	250	590
Trench Zone 2	108	217	15	250	590

Table 5.5 Estimated cycle times for each pipeline section where the TSHD will be operating.

Pipeline Zone	Non-Overflow Time (min)	Overflow Time (min)	Disposal Time (min)	Sailing Time (min)	Total Cycle Time (min)
Pre-Sweep Area 1	20	160	15	140	335
Trench Zones 3-4	20	160	15	132	327
Pre-Sweep Area 2	20	160	15	132	327
Trench Zone 5	20	160	15	96	291
Pre-Sweep Area 3	20	160	15	80	275
Trench Zones 6-7	20	160	15	72	267
Sand Waves Area	20	160	15	64	259

Table 5.6 Relevant vessel specifications for propeller wash assessment.

Item	TSHD	SHB
Vessel draft (loaded/empty)	10 m / 3 m	5 m / 2 m
Number of propellers, type	Two, ducted	Two, ducted
Diameter of propellers	4 m	1.5 m
Thrust power (kW per propeller)	8,000 kW	1,150 kW

5.4.2.2 Spoil Ground Disposal

As outlined in Table 5.3, it was assumed that all material removed by the BHD will be placed into one of two waiting SHBs and transported to the offshore disposal area (shown in Figure 1.1). All material removed by the TSHD will be transported directly to the offshore disposal area.

It was assumed that the BHD will be accompanied by two SHBs, each assumed to be approximately 2,700 m^3 in capacity, to be used for disposal of trenched material. Material discharges from the SHBs were assumed to occur between depths of 5 m and 2 m below mean sea level.

The TSHD hopper doors, from which discharge will occur, were assumed to be opened at a depth of 10 m below sea level. The modelled vessel draft was reduced as spoil is discharged to a minimum depth of 5 m below sea level when empty.

The SHBs will be self-propelled and the potential for sediment mobilisation by propeller-wash effects has been considered along all relevant pipeline sections. This has been done using supplied data on vessel characteristics, and local depth and seabed composition. For the purposes of the modelling assessment, the relevant specifications were as outlined in Table 5.6.

It was assumed that the broad aim of the spoil disposal patterns will be to evenly distribute the total volume of allocated material across the entire spoil ground area by the conclusion of all activities, so the spacing of individual disposal operations (which are restricted to a comparatively small area within the spoil ground) was designed to achieve this. The surface area of the proposed spoil grounds is approximately 6,290,000 m^2; given the volume of material to be placed in the spoil ground, a theoretical thickness of 5-10 cm is expected if the spoil is evenly distributed.

5.4.3 Quantities and Production Rates

For trenching of each section along the pipeline route, the proposed trench depths and quantities for each material type were specified for input to the modelling (Table 5.7). The stated quantities include allowances for contingency; hence, they are conservative volume estimates. The table has two material categories, defined as “sediments” (sand/silt/clay/gravel) assumed to be able to be removed by a TSHD and “rock” (siltstone/claystone/sandstone/phyllite) assumed to require a CSD to remove. Some of the weaker rock may be able to be removed by the TSHD; however, to err on the side of conservatism it was assumed that all the rock material would require cutting by CSD.

It is understood that:

- The estimated material quantities were based on the latest surveyed bathymetry and a geotechnical model based on seismic refraction survey data.
- The estimated production rates were averages based on trench contractor estimated durations for each equipment type and the material volume for each zone.
- The estimated production rates were average values inclusive of expected downtime estimates.

Table 5.7 Modelled trench depths, quantities of material type, and production rates by material type for trenching of each pipeline section.

Pipeline Zone	Trench Depth	Trenched Quantities (m^3)			Production Rates (m^3/week)	
	Nominal below seabed (m)	Sediment	Rock	Total	Sediment	Rock
Trench Zone 1	3.2	11,963	4,703	16,665	12,000	9,800
Trench Zone 2	1.5	3,988	1,568	5,555	12,000	9,800
Pre-Sweep Area 1	-	6,130	-	6,130	86,000	-
Trench Zone 3	2.3	7,764	14,419	22,183	86,000	27,200
Trench Zone 4	1	6,349	1,120	7,469	86,000	27,200
Pre-Sweep Area 2	-	34,840	-	34,840	86,000	-
Trench Zone 5	1	29,567	19,712	49,279	86,000	27,200
Pre-Sweep Area 3	-	2,955	-	2,955	86,000	-
Trench Zone 6	2.5	64,097	52,443	116,541	86,000	27,200
Trench Zone 7	1	26,801	2,978	29,779	86,000	27,200
Sand Waves Area	-	14,817	-	14,817	86,000	-
	Totals	**209,270**	**96,942**	**306,212**	**-**	**-**

5.4.4 Schedules

For trenching of each section along the pipeline route, the proposed duration and sequencing of operations has been specified for input to the modelling (Table 5.8 and Table 5.9). Table 5.8 has two material categories, as described in Section 5.4.3.

The modelled sequence of trenching has been specified to represent a worst-case scenario where the TSHD, CSD and BHD operate concurrently, as outlined in Table 5.9. The TSHD modelled sequence is assumed to start in Pre-Sweep Area 1, moving offshore along the pipeline route to Trench Zone 3, and then proceeding consecutively to each zone from Trench Zone 4 out to the Sand Waves Area. Once the TSHD has completed its first pass over each of the trenching sections it will begin removing the material that has been crushed by the CSD, starting at Trench Zone 3, moving offshore along the pipeline route out to Trench Zone 7.

The BHD modelled sequence starts in Trench Zone 1 then moves to Trench Zone 2, with the BHD assumed to commence work at the same time as the TSHD on day one of the dredging program.

The CSD cannot start until the TSHD has pre-swept some of the zones, and the schedule minimises the amount of time that two pieces of equipment are in the same zone at the same time. To meet this condition the CSD will start in week two of the program in Trench Zone 3 then move sequentially offshore to Trench Zone 7.

The CSD is scheduled to finish after 28 days (on day 35 of the program because it starts in week two), the BHD is scheduled to finish after 30 days, and the TSHD will finish after 40 days.

Modelling of each section involves a series of trenching and related disposal activities.

Table 5.8 Modelled durations of trenching and disposal operations by material type for each pipeline section.

<table>
<tr><th rowspan="2">Pipeline Zone</th><th colspan="3">Duration of Operations (weeks)</th><th colspan="3">Total Duration (Weeks)</th></tr>
<tr><th>Sediments (BHD/TSHD)</th><th>Rock (BHD/CSD)</th><th>Crushed Material (TSHD)</th><th>BHD</th><th>TSHD</th><th>CSD</th></tr>
<tr><td>Trench Zone 1</td><td>2.17</td><td>1.05</td><td>-</td><td rowspan="11" colspan="3">-</td></tr>
<tr><td>Trench Zone 2</td><td>0.72</td><td>0.35</td><td>-</td></tr>
<tr><td>Pre-Sweep Area 1</td><td>0.14</td><td>-</td><td>-</td></tr>
<tr><td>Trench Zone 3</td><td>0.18</td><td>0.64</td><td>0.33</td></tr>
<tr><td>Trench Zone 4</td><td>0.15</td><td>0.05</td><td>0.03</td></tr>
<tr><td>Pre-Sweep Area 2</td><td>0.80</td><td>-</td><td>-</td></tr>
<tr><td>Trench Zone 5</td><td>0.61</td><td>0.87</td><td>0.40</td></tr>
<tr><td>Pre-Sweep Area 3</td><td>0.06</td><td>-</td><td>-</td></tr>
<tr><td>Trench Zone 6</td><td>1.21</td><td>2.31</td><td>0.99</td></tr>
<tr><td>Trench Zone 7</td><td>0.50</td><td>0.13</td><td>0.06</td></tr>
<tr><td>Sand Waves Area</td><td>0.27</td><td>-</td><td>-</td></tr>
<tr><td>Totals</td><td>6.81</td><td>5.39</td><td>1.81</td><td>4.29</td><td>5.72</td><td>4.00</td></tr>
</table>

Table 5.9 Modelled sequencing of trenching and disposal operations assuming concurrent TSHD, CSD and BHD operation (worst case).

<table>
<tr><th rowspan="2">Week</th><th colspan="2">TSHD</th><th colspan="2">CSD</th><th colspan="2">BHD</th><th rowspan="2">Comments</th></tr>
<tr><th>Pipeline Zone</th><th>Duration (weeks)</th><th>Pipeline Zone</th><th>Duration (weeks)</th><th>Pipeline Zone</th><th>Duration (weeks)</th></tr>
<tr><td rowspan="4">1</td><td>Pre-Sweep Area 1</td><td>0.14</td><td rowspan="4">-</td><td rowspan="4">-</td><td rowspan="8">Trench Zone 1</td><td rowspan="8">3.22</td><td rowspan="4">TSHD and BHD begin together on Day 1 of program</td></tr>
<tr><td>Trench Zone 3</td><td>0.18</td></tr>
<tr><td>Trench Zone 4</td><td>0.15</td></tr>
<tr><td>Pre-Sweep Area 2</td><td>0.80</td></tr>
<tr><td rowspan="3">2</td><td>Trench Zone 5</td><td>0.61</td><td>Trench Zone 3</td><td>0.64</td><td rowspan="3">CSD starts in Week 2 once TSHD has pre-swept Trench Zones 3/4 and commenced Pre-Sweep Area 2</td></tr>
<tr><td rowspan="2">Pre-Sweep Area 3</td><td rowspan="2">0.06</td><td>Trench Zone 4</td><td>0.05</td></tr>
<tr><td>Trench Zone 5</td><td>0.87</td></tr>
<tr><td>3</td><td>Trench Zone 6</td><td>1.21</td><td rowspan="6">Trench Zone 6</td><td rowspan="6">2.31</td><td>-</td></tr>
<tr><td rowspan="2">4</td><td>Trench Zone 7</td><td>0.50</td><td rowspan="6">Trench Zone 2</td><td rowspan="6">1.07</td><td rowspan="2">-</td></tr>
<tr><td>Sand Waves Area</td><td>0.27</td></tr>
<tr><td rowspan="4">5</td><td>Trench Zone 3</td><td>0.33</td><td rowspan="4">TSHD begins post-sweep of CSD-crushed material</td></tr>
<tr><td>Trench Zone 4</td><td>0.03</td></tr>
<tr><td>Trench Zone 5</td><td>0.40</td></tr>
<tr><td>Trench Zone 6</td><td>0.99</td><td>Trench Zone 7</td><td>0.13</td></tr>
<tr><td>6</td><td>Trench Zone 7</td><td>0.06</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Totals</td><td>-</td><td>5.72</td><td>-</td><td>4.00</td><td>-</td><td>4.29</td><td>-</td></tr>
</table>

5.4.5 Scenario Summary

At the time of modelling commencement the high-level schedule for the trenching works indicated an April/May 2023 start for trenching of the pipeline route. Analysis of wind data in the region from 2012-2021 has shown that the period of 2019-2020 is likely to be representative of typical conditions. Thus, the sediment dispersion modelling simulations were conducted using hydrodynamic and wave data drawn from this period, with nominal start dates for model simulation purposes being chosen as 1 April 2019 (winter/dry) and 1 October 2019 (summer/wet). While trenching for the DPD project is now expected to commence in late 2023 or early 2024, the modelling scenarios are still considered representative of potential environmental conditions.

A summary of the scenarios that were modelled is as follows:

- Scenario 1: trenching works simulated to commence on 1 April 2019 (winter/dry start):
    1. TSHD trenching and disposal operations were simulated to occur between 1 April 2019 and 10 May 2019.
    2. CSD trenching and disposal operations were simulated to occur between 8 April 2019 and 5 May 2019.
    3. BHD trenching and disposal operations were simulated to occur between 1 April 2019 and 30 April 2019.
    4. A simulation run-on period was assumed to occur between 10 May 2019 and 10 July 2019. Sediments suspended in the water column during previous operations were subject to settlement and progressively-reducing levels of resuspension during this time.
- Scenario 2: trenching works simulated to commence on 1 October 2019 (summer/wet start):
    1. TSHD trenching and disposal operations were simulated to occur between 1 October 2019 and 9 November 2019.
    2. CSD trenching and disposal operations were simulated to occur between 8 October 2019 and 4 November 2019.
    3. BHD trenching and disposal operations were simulated to occur between 1 October 2019 and 30 October 2019.
    4. A simulation run-on period was assumed to occur between 9 November 2019 and 9 January 2020. Sediments suspended in the water column during previous operations were subject to settlement and progressively-reducing levels of resuspension during this time.

The outcomes of the summer/wet season-start and winter/dry season-start scenarios have been analysed and presented separately, for comparison.

5.5 Geotechnical Information

The trenched material from the pipeline route will consist mainly of marine sediments (approximately 209,000 m^3) and rock material (approximately 97,000 m^3). The critical geotechnical information required as input to the modelling is: (i) PSD data for the sediments to be trenched along the pipeline route; and (ii) *in situ* dry bulk density for the materials to be trenched along the pipeline route.

The PSD data used in the modelling was based on field data collected for the DPD project by RPS as part of the Environmental Survey during October 2021 and January 2022 along the proposed pipeline corridor and at the proposed offshore spoil ground (RPS, 2022). The specified PSD for each zone was determined based on an average of the PSD results of all samples taken within each zone during site investigations.

The geotechnical sampling points from which PSDs were acquired within each zone are summarised in Table 5.10, including the total number of PSD samples used to determine the averages. The locations of the geotechnical sampling points from the RPS October 2021 and January 2022 site investigations are shown in Figure 5.2. The resultant PSDs for each pipeline section have been redistributed to match the material size classes used in the DREDGEMAP model, as shown in Table 5.11.

Dry bulk density values were not available from current or past field investigations, but wet bulk density and voids ratio information for the project area was available from geotechnical studies conducted for the project and for the Bayu-Undan Pipeline Project (Santos, 2022e, 2022f). The wet bulk density and void ratio values were used to estimate dry bulk density for modelling purposes. The dry bulk density values applied to each zone are outlined in Table 5.12.

Table 5.10 Summary of geotechnical data used in the derivation of model PSDs for each pipeline section.

Pipeline Zone	Pipeline Location Start KP	Pipeline Location End KP	No. of PSD Samples
Trench Zone 1	122.2	121.88	2
Trench Zone 2	121.88	121.2	
Pre-Sweep Area 1	121.2	120.574	4
Trench Zone 3	120.574	119.98	4
Trench Zone 4	119.9	119.44	5
Pre-Sweep Area 2	116.431	113.235	12
Trench Zone 5	113.235	110.2	7
Pre-Sweep Area 3	106.831	106.471	3
Trench Zone 6	106.471	103.6	4
Trench Zone 7	103.6	101.766	6
Sand Waves Area	94.4	92.2	23

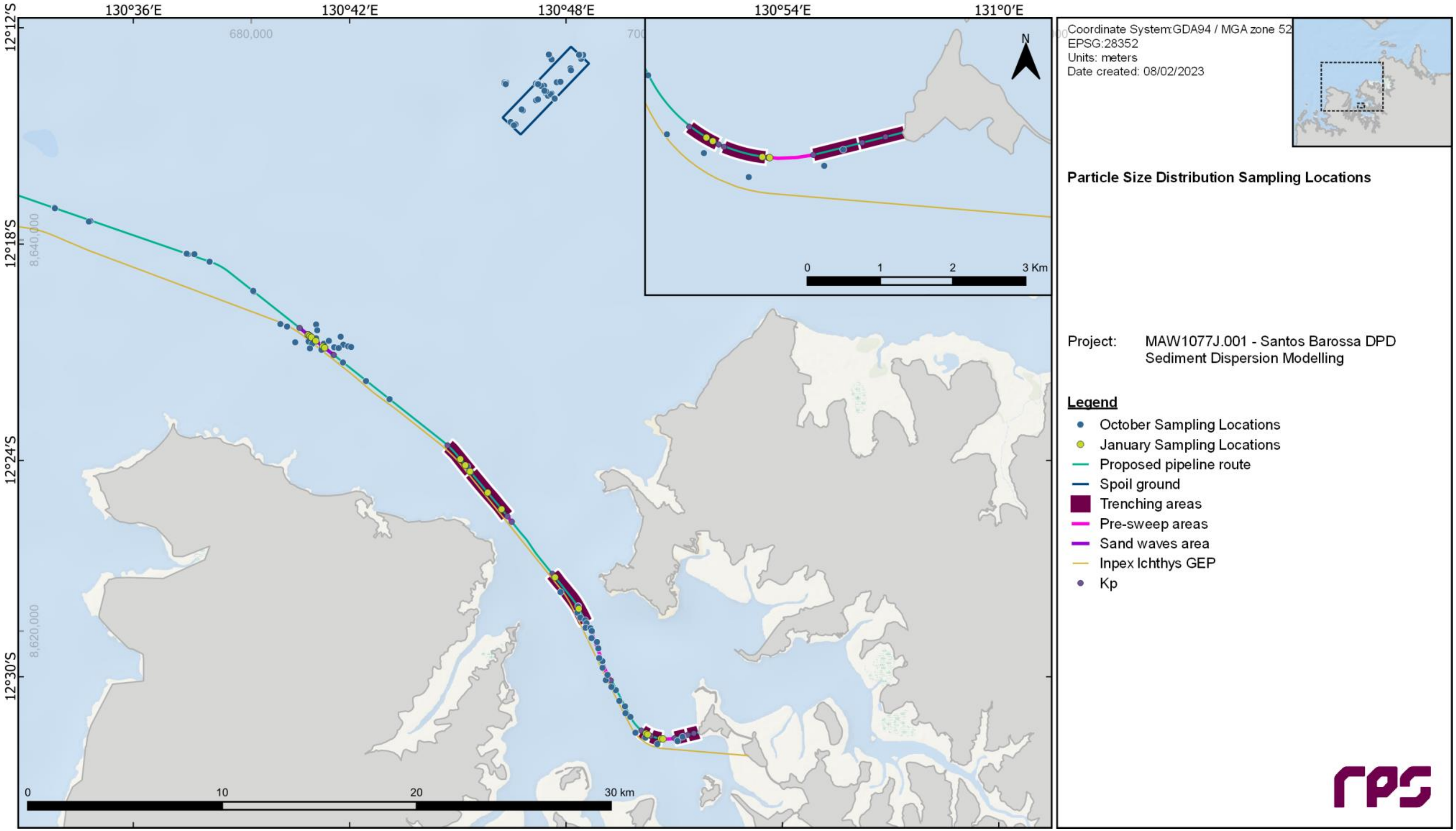

Figure 5.2 **PSD sediment sample locations, with blue dots representing the 2021 survey and green dots representing the January 2022 survey. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

Table 5.11 ***In situ*** **PSDs broken down into DREDGEMAP material classes for each pipeline section to be dredged, derived from available geotechnical information.**

Sediment Grain Size Class	Size Range (µm)	Trench Zone 1 (%)	Trench Zone 2 (%)	Pre-Sweep Area 1 (%)	Trench Zone 3 (%)	Trench Zone 4 (%)	Pre-Sweep Area 2 (%)	Trench Zone 5 (%)	Pre-Sweep Area 3 (%)	Trench Zone 6 (%)	Trench Zone 7 (%)	Sand Waves Area (%)
Clay	<7	5.43	5.43	7.33	7.02	8.86	4.44	2.94	6.23	7.75	8.72	1.24
Fine Silt	7-34	8.61	8.61	8.89	8.32	11.66	6.45	4.36	9.23	9.52	9.00	1.90
Coarse Silt	35-74	7.75	7.75	5.52	4.62	7.76	5.09	3.82	9.49	8.89	6.08	2.78
Fine Sand	75-130	8.64	8.64	4.69	3.29	4.69	3.93	3.06	6.36	5.96	3.74	2.49
Coarse Sand	>130	69.58	69.58	73.57	76.76	67.04	80.09	85.82	68.69	67.88	72.47	91.60

Table 5.12 ***In situ*** **wet bulk densities and estimated dry bulk densities, based on the available wet bulk density and voids ratio data.**

Pipeline Zone	Wet Bulk Density (Sediment)	Wet Bulk Density (Rock)	Estimated Dry Bulk Density (Sediment)	Estimated Dry Bulk Density (Rock)
Trench Zone 1	1.83	2.35	1.21	2.16
Trench Zone 2	1.83	2.35	1.21	2.16
Pre-Sweep Area 1	1.83	-	1.21	-
Trench Zone 3	1.83	2.35	1.21	2.16
Trench Zone 4	1.83	2.35	1.21	2.16
Pre-Sweep Area 2	1.83	-	1.21	-
Trench Zone 5	1.83	2.35	1.21	2.16
Pre-Sweep Area 3	1.83	-	1.21	-
Trench Zone 6	1.83	2.35	1.21	2.16
Trench Zone 7	1.83	2.35	1.21	2.16
Sand Waves Area	1.89	-	1.32	-

5.6 Model Sediment Sources

5.6.1 Overview

To accurately represent the pipeline trenching and disposal operations in DREDGEMAP, a range of information was defined for the proposed operations, including trenching and disposal methodology, production rates, and sediment/rock types and quantities (see Section 5.4). It is evident that there will be six different sources of suspended sediment plumes during trenching and disposal operations, which can be broadly defined as:

1. Direct suspension of material from the BHD bucket, from grabbing and lifting sediments and rock through the water column, accounting for periods of no-dewatering and dewatering from the SHBs.
2. Disposal of sediment and rock excavated by the BHD from the SHBs to the spoil ground.
3. Direct suspension of material by the TSHD during trenching of sediments, and CSD-crushed material, accounting for no-overflow and overflow periods.
4. Disposal of sediment and CSD-crushed material removed by the TSHD to the spoil ground.
5. Direct suspension of material by the CSD during trenching of rock and casting material behind the dredge at low velocity, just above the seabed.
6. Indirect suspension of material due to the propeller-wash of the SHB and TSHD while trenching.

Each of these sources of suspended sediment plumes will vary in strength and persistence depending on the nature of the operations. In the DREDGEMAP model, each source is defined by specifying the time-varying flux rate, PSD and vertical profile in the water column. The following sections outline how the information provided has been used to represent the trenching operations in the model and explain any assumptions that have been made to supplement the available information.

5.6.2 Representation of BHD Trenching

A BHD will be used to excavate all sediment and rock from Trench Zone 1 and Trench Zone 2. The BHD will use a large excavator arm fitted with an open bucket of (nominally) 16 m^3 capacity. The excavator will lift material in the bucket and deliver it to one of two waiting SHBs – assumed for the purposes of modelling to be 2,700 m^3 in capacity – for transport to the proposed offshore spoil ground for disposal.

Sources of sediment suspension from this type of operation include:

- Disturbance of the seabed sediments by the excavator bucket.
- Dewatering of the SHB, resulting in the discharge of water and entrained sediments.

Past observations have shown that material is suspended due to the initial grab at the seabed. Further suspension is generated as sediment spills from the bucket as it is lifted through the water column. Spillage of water and sediment also occurs as the bucket breaks free of the water surface and drains freely. Only sediments <130 µm in diameter are considered “lost” (i.e. suspended into the water column), because the coarser material spilled from the bucket while being lifted to the surface will fall immediately to the bottom where it will be re-excavated during subsequent grabs. As such, the distribution of material suspended by the bucket spillage is assumed to be distributed across the four smaller sediment size classes in the model.

For the trenching of sediments during periods with no dewatering from the SHB, the PSD used in the model is based on PSDs from nearby boreholes (see Section 5.5), with the proportion >130 µm removed and the remaining distribution normalised to 100% by scaling up the proportions in the four remaining size classes (Table 5.13). The same PSD is used for the rock component, assuming that due to the excavation action of the BHD the rock will break down into similar proportions of fines. Because the trenching action of the excavator involves no cutting or hydraulic pumping, this is a conservative assumption.

During dewatering periods, an increase in the rate of release of fine sediments, and hence initial turbidity, is observed (Anchor Environmental, 2003). The water released during dewatering of the SHB contains a high proportion of fines because the coarse material settles rapidly in the hopper while the fine material remains in suspension. After the barge begins dewatering, a PSD heavily weighted towards finer particles has been assumed based on previous field measurements of SHB dewatering at Geraldton Port (OPR, 2010), with the proportion >75 µm removed and the remaining distribution normalised to 100% by scaling up the proportions in the three remaining size classes (Table 5.14).

Table 5.15 shows the assumed vertical distribution of the suspended material during the BHD operations while the barge is not dewatering. The distribution is higher at the seabed and water surface, to represent the larger loss rate of material during the initial grab and as the bucket breaks free of the water column. After the barge begins dewatering, a uniform distribution of sediments throughout the water column, between the hull depth and the seabed, has been assumed to represent a continuous stream of material being discharged from the barge (Table 5.16).

Loss rates from similar operations are known to vary based on such factors as the size and type of bucket (i.e. open or closed), nature of the seabed material, presence of debris, current speed and depth of water, as well as the care of the operator (Hayes & Wu, 2001; Anchor Environmental, 2003). Reported rates compared by Anchor Environmental (2003) varied from 0.1% to 10%, with a mean of 2.1%. In the absence of measurements for the specific situation and equipment, the mean of 2.1% of production rate is assumed for BHD operations during periods with no dewatering, and a rate of 2.4% of production rate is assumed for all BHD operations during dewatering periods. The latter value is in line with the average overflow rate calculated for the TSHD hopper overflow (see Section 5.6.4).

Table 5.13 Assumed PSDs of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is not dewatering.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment and Rock Removal – Trench Zone 1	PSD (%) for Sediment and Rock Removal – Trench Zone 2
Clay	<7	17.84	17.84
Fine Silt	7-34	28.29	28.29
Coarse Silt	35-74	25.47	25.47
Fine Sand	75-130	28.39	28.39
Coarse Sand	>130	0.00	0.00

Table 5.14 Assumed PSDs of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is dewatering.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment and Rock Removal – Trench Zone 1	PSD (%) for Sediment and Rock Removal – Trench Zone 2
Clay	<7	48.45	48.45
Fine Silt	7-34	29.73	29.73
Coarse Silt	35-74	21.83	21.83
Fine Sand	75-130	0.00	0.00
Coarse Sand	>130	0.00	0.00

Table 5.15 Assumed vertical distribution of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is not dewatering.

Elevation	Example Elevation (m ASB) – 10 m Water Depth	Vertical Distribution (%) of Sediments
Surface/water depth	10	23
0.8 x water depth	8	16
0.5 x water depth	5	14
0.3 x water depth	3	19
0.1 x water depth	1	28

Table 5.16 Assumed vertical distribution of sediments initially suspended into the water column during BHD trenching operations along the pipeline route while the SHB is dewatering.

Elevation	Example Elevation (m ASB) – 10 m Water Depth and 5 m Hull Depth	Vertical Distribution (%) of Sediments
Surface/water depth	10	8
Hopper hull elevation	5	23
0.66 x hull elevation	3.3	23
0.33 x hull elevation	1.7	23
0.50 m (ASB)	0.5	23

5.6.3 Representation of Disposal of BHD-Trenched Material

All material trenched by the BHD will be placed into one of two waiting 2,700 m^3 SHBs and transported to the proposed offshore spoil ground for disposal (Figure 1.1). This material will include all sediment and rock material from Trench Zone 1 and Trench Zone 2.

For the disposal of sediment trenched by BHD, the PSD used in the model is based on PSDs from nearby boreholes (see Section 5.5). The same PSD is used for the rock component, assuming that due to the excavation action of the BHD the rock will break down into similar proportions of fines. Because the trenching action of the excavator involves no cutting or hydraulic pumping, this is a conservative assumption. This PSD is adjusted by removal of the component treated as suspended during trenching (see Section 5.6.2), but as this represents only 2.1-2.4% of the mass for the minor components, the modified PSD is not significantly different to the *in situ* PSD (Table 5.17).

Once at the offshore spoil ground, the SHB will open to release the sediments from the bottom of the hull at a depth of approximately 5 m below sea level. Previous observations of sediment dumping from hopper vessels (e.g., CSMW, 2005) have shown that there is an initial rapid descent of solids, with the heavy particles tending to entrain lighter particles, followed by a billowing of lighter components back into the water column after contact with the seabed (Figure 5.3). A proportion of the lighter components will also remain suspended and may be trapped by density layers, if present.

Because simulations in this study focused on the far-field fate of sediment particles due to transport and sinking after the initial dump phase, simulations were run with the initial vertical distribution specified to represent the post-collision phase for a case where a high proportion of the sediments are resuspended after collision with the seabed. To represent this, an assumed vertical distribution for the sediments (Table 5.18) has been specified following published information from previous hopper disposal operations (CSMW, 2005; NEPA, 2001). This vertical distribution, with the majority of the material input near the seabed and only 7% of the material released in the upper half of the water column, is in line with values quoted in the recent literature review by Mills & Kemps (2016), which found that sediment resuspension from individual dredged material disposal events was generally less than 10% of the disposed material load.

It is estimated that 95-99% of the bulk load deposits directly onto the seabed in a typical case, with the remainder released into the water column (CSMW, 2005, NEPA, 2001). It is difficult to find other definitive source values in the literature, but a value of 5% of each load agrees well with past experience and appears to be a conservative estimate based on the values quoted above. Accordingly, 5% of each hopper load was placed in suspension in the water column in the sediment fate model.

In addition to the proportion of material immediately suspended in the water column, disposal from the barge will result in the stockpiling of sediment as a mound on the seabed that will be subject to resuspension by tidal and wave forces. Because fine sediments in the deposited mass may be subject to ongoing resuspension and dispersion over time, it was necessary to specify the deposits as a further source of sediment potentially subject to resuspension.

The proportion of the newly deposited trenched material available for resuspension is characterised by a finite limit regulated by PSDs and the occurrence of natural sediment capping. As a result of the selective resuspension of the smaller-sized particles (silts and clays), the deposited mound surface layer gradually contains a greater proportion of larger particle sizes. These larger particles act as armouring against bottom shear stress, protecting and retaining the remaining fine particles in the mound. Therefore, in the model it was assumed that 5% of the deposited mass – representing the volume of the upper surface layer – would be subject to resuspension. It should be noted that the model maintains a mass balance estimate of the remaining sediment of each size class within each grid cell to derive an estimate of the median particle size in the surface-layer sediments. In turn, the potential for ongoing resuspension of fines is calculated. In this way, the model represents the increased armouring of sediments as the average particle size increases.

The disposal time for the SHB within each trenching cycle was assumed to be 15 minutes (Table 5.4). The disposal location within the spoil ground was varied for each trenching cycle in a randomised manner, with the aim of ensuring an even distribution of trenched material within the spoil ground by the conclusion of activities.

Table 5.17 Assumed PSDs of sediments initially suspended into the water column during SHB disposal operations at the offshore spoil ground.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment and Rock Disposal – Trench Zone 1	PSD (%) for Sediment and Rock Disposal – Trench Zone 2
Clay	<7	4.53	4.53
Fine Silt	7-34	7.94	7.94
Coarse Silt	35-74	7.22	7.22
Fine Sand	75-130	8.44	8.44
Coarse Sand	>130	71.88	71.88

Table 5.18 Assumed vertical distribution of sediments initially suspended into the water column during SHB disposal operations at the offshore spoil ground.

Elevation	Example Elevation (m ASB) – 30 m Water Depth	Vertical Distribution (%) of Sediments
Surface/water depth	30	2
0.6 x water depth	18	5
0.4 x water depth	12	15
0.15 x water depth	4.5	35
0.1 x water depth	3	43

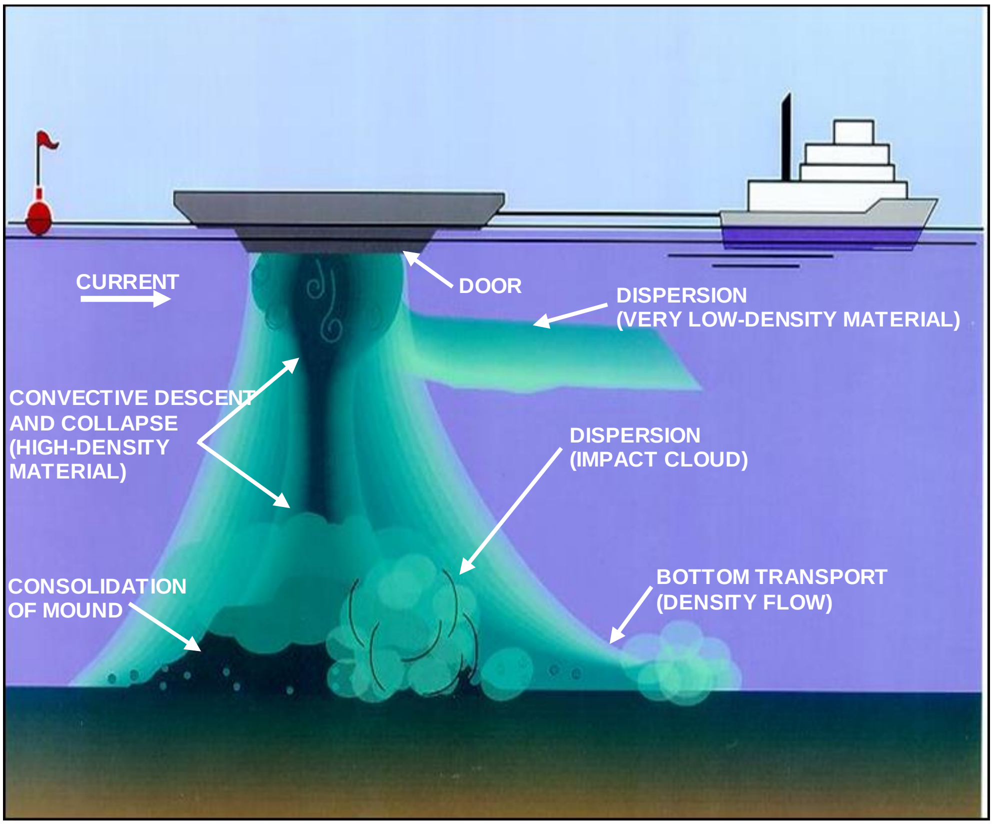

Figure 5.3 Conceptual diagram showing the general behaviour of sediments dumped from a barge/SHB in open water and the vertical distribution of material set up by entrainment and billowing (Source: Moritz & Randall, 1992).

5.6.4 Representation of TSHD Trenching

A TSHD will be used to excavate all sediments from Pre-Sweep Areas 1, 2 and 3, Trench Zones 3, 4, 5, 6 and 7, the Sand Waves Area, and all rock material crushed by CSD in Trench Zones 3, 4, 5, 6 and 7, with disposal at the proposed offshore spoil ground (Figure 1.1). For the purposes of modelling, the capacity of the TSHD to be used for trenching of the pipeline route and borrow grounds was assumed to be 15,000 m^3.

TSHD vessels remove sediments by dragging a large draghead over the seabed and drawing up the disturbed sediment by hydraulic suction. Sources of sediment suspension from this type of operation include:

- Hydraulic disturbance of the seabed sediments by the trailing arm.
- Propeller-wash generated as the vessel manoeuvres.
- Overflow of the on-board hoppers, resulting in the discharge of water and entrained sediments.

The characteristics of each of these sources vary greatly due to a wide range of factors (USACE, 2008) making the generalisation of source terms difficult. It appears however, that the overflow source term is dominant, being typically an order of magnitude greater than the draghead and propeller-wash terms.

For the pre-sweep trenching of the sediment during periods with no overflow, the PSDs used in the model are based on PSDs from nearby boreholes (see Section 5.5). The PSDs applied during periods with no overflow to pre-sweep trenching along the pipeline route are shown in Table 5.19. For the post-sweep trenching of the material that has been crushed by the CSD during periods with no overflow, the PSDs are based on the assumed PSD for the crushed material as outlined in Section 5.6.6, with an adjustment made to account for the loss of fine material during CSD operations (Table 5.21).

During overflow periods, an increase in the rate of release of fine sediments, and hence initial turbidity, is observed (Anchor Environmental, 2003). The overflow water contains a high proportion of fines because the coarse material settles rapidly in the hopper while the fine material remains in suspension. After the hopper begins overflowing, PSDs heavily weighted towards finer particles have been assumed based on previous field measurements of hopper barge dewatering at Geraldton Port (OPR, 2010), with the proportion >75 µm removed and the remaining distribution normalised to 100% by scaling up the proportions in the three remaining size classes. The PSDs applied during overflow periods to pre-sweep trenching along the pipeline route are shown in Table 5.20 and post-sweep trenching of CSD-crushed material are shown in Table 5.22.

Table 5.23 shows the assumed vertical distribution of the suspended material during the TSHD operations while the hopper is not overflowing. The distribution is concentrated near the seabed and decreases in intensity towards the surface, to represent the disturbance of seabed material by the draghead and propeller-wash effects (HR Wallingford, 2003). After the hopper begins overflowing, a uniform distribution of sediments throughout the water column, between the hull depth and the seabed, has been assumed to represent a continuous stream of material being discharged from the hopper through an overflow system incorporating a ‘green valve’ (Table 5.24). This is consistent with measured ADCP profiles presented by Hitchcock & Bell (2004), which show a reasonably even distribution of sediment through the water column during hopper overflow.

It should be noted that the installation of a green valve within an overflow system is designed to reduce the proportion of air entrained into the overflow mixture, which in turn will result in a reduced proportion of discharged material mixing and billowing upwards to the water surface. To account for this process in the modelling, the vertical distribution applied during hopper overflow (Table 5.24) is not uniform throughout the entire water column, but only from the hull depth to the seabed.

Table 5.19 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for pre-sweep of sediment while the hopper is not overflowing.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Pre-Sweep Area 1	PSD (%) for Sediment Removal – Trench Zone 3	PSD (%) for Sediment Removal – Trench Zone 4	PSD (%) for Sediment Removal – Pre-Sweep Area 2	PSD (%) for Sediment Removal – Trench Zone 5	PSD (%) for Sediment Removal – Pre-Sweep Area 3	PSD (%) for Sediment Removal – Trench Zone 6	PSD (%) for Sediment Removal – Trench Zone 7	PSD (%) for Sediment Removal – Sand Waves Area
Clay	<7	7.33	7.02	8.86	4.44	2.94	6.23	7.75	8.72	1.24
Fine Silt	7-34	8.89	8.32	11.66	6.45	4.36	9.23	9.52	9.00	1.90
Coarse Silt	35-74	5.52	4.62	7.76	5.09	3.82	9.49	8.89	6.08	2.78
Fine Sand	75-130	4.69	3.29	4.69	3.93	3.06	6.36	5.96	3.74	2.49
Coarse Sand	>130	73.57	76.76	67.04	80.09	85.82	68.69	67.88	72.47	91.60

Table 5.20 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for pre-sweep of sediment while the hopper is overflowing.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Pre-Sweep Area 1	PSD (%) for Sediment Removal – Trench Zone 3	PSD (%) for Sediment Removal – Trench Zone 4	PSD (%) for Sediment Removal – Pre-Sweep Area 2	PSD (%) for Sediment Removal – Trench Zone 5	PSD (%) for Sediment Removal – Pre-Sweep Area 3	PSD (%) for Sediment Removal – Trench Zone 6	PSD (%) for Sediment Removal – Trench Zone 7	PSD (%) for Sediment Removal – Sand Waves Area
Clay	<7	50.37	51.05	48.31	50.65	51.82	47.51	48.36	50.64	52.99
Fine Silt	7-34	30.02	29.93	31.03	29.14	28.36	29.49	29.46	29.58	27.30
Coarse Silt	35-74	19.61	19.03	20.67	20.21	19.82	23.00	22.18	19.80	19.72
Fine Sand	75-130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coarse Sand	>130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.21 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for post-sweep of material that has been crushed by CSD while the hopper is not overflowing.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Trench Zone 3	PSD (%) for Sediment Removal – Trench Zone 4	PSD (%) for Sediment Removal – Trench Zone 5	PSD (%) for Sediment Removal – Trench Zone 6	PSD (%) for Sediment Removal – Trench Zone 7
Clay	<7	4.37	3.89	1.80	3.50	4.59
Fine Silt	7-34	5.19	5.13	2.67	4.30	4.74
Coarse Silt	35-74	2.88	3.41	2.34	4.01	3.20
Fine Sand	75-130	2.05	2.06	1.87	2.69	1.97
Coarse Sand	>130	85.50	85.50	91.32	85.50	85.50

Table 5.22 Assumed PSDs of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route for post-sweep of material that has been crushed by CSD while the hopper is overflowing.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Trench Zone 3	PSD (%) for Sediment Removal – Trench Zone 4	PSD (%) for Sediment Removal – Trench Zone 5	PSD (%) for Sediment Removal – Trench Zone 6	PSD (%) for Sediment Removal – Trench Zone 7
Clay	<7	52.53	52.05	53.06	52.00	52.69
Fine Silt	7-34	28.83	28.77	27.83	28.11	28.36
Coarse Silt	35-74	18.64	19.18	19.11	19.89	18.95
Fine Sand	75-130	0.00	0.00	0.00	0.00	0.00
Coarse Sand	>130	0.00	0.00	0.00	0.00	0.00

Table 5.23 Assumed vertical distribution of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route while the hopper is not overflowing.

Elevation	Example Elevation (m ASB) – 30 m Water Depth	Vertical Distribution (%) of Sediments
10.0 m (ASB)	10	5
7.0 m (ASB)	7	15
3.0 m (ASB)	3	20
2.0 m (ASB)	2	40
1.0 m (ASB)	1	20

Table 5.24 Assumed vertical distribution of sediments initially suspended into the water column during TSHD trenching operations along the pipeline route while the hopper is overflowing

Elevation	Example Elevation (m ASB) – 30 m Water Depth and 10m Hull Depth	Vertical Distribution (%) of Sediments
Hopper hull elevation	20	20
0.75 x hull elevation	15	20
0.50 x hull elevation	10	20
0.25 x hull elevation	5	20
0.50 m (ASB)	0.5	20

The resuspension of sediment when the TSHD hopper is not overflowing was estimated by combining the draghead and propeller-wash terms. The propeller-wash component typically dominates the draghead component, but both sources were assessed. Propeller-wash generation was estimated by applying a model of the bed-induced shear stress from the TSHD vessel over the range of under-keel clearances expected during the dredging operations.

Field measurements of draghead-induced sediment suspension were reported by Coastline Surveys Ltd (CSL, 1999). The inferred production rate was less than 1 kg/s and it was concluded that, generally, draghead production is small in comparison to the quantity of sediment released via overflow. Given the above, a loss rate of 0.6% of the gross production rate, representing a combined sediment flux due to losses from the draghead and propeller-wash, was assumed when the TSHD is not overflowing. This rate is within the range of values (less than 1%) summarised in a review of contemporary practice conducted as part of the WAMSI Dredging Science Node by Kemps & Masini (2017).

The resuspension of sediment from hopper overflow is the most complex source term associated with a TSHD. The discharged water-sediment mixture forms a negatively-buoyant jet (dynamic plume) that descends towards the seabed. Due to mixing and entrainment as the plume descends, not all of the sediment in the dynamic plume directly descends to the seabed, forming a passive plume in the water column below the TSHD. Based on evidence from numerous field measurements, Spearman *et al.* (2011) state that the dynamic plume retains the bulk of the overflow sediment, with a small proportion (in the range of 5-15%) contained in the passive plume. The proportion of sediment contained in the passive plume is a function of the air content in the overflow mixture, with the use of a green valve shown to significantly reduce the proportion of the overflow sediment that forms the passive plume (Spearman *et al.*, 2011).

The overflow source term was calculated for each discrete trench zone and material type based on a method outlined in Becker *et al.* (2015) and recommended in Kemps & Masini (2017). This method was applied as it allows the proportion of fines in the material being trenched in each zone to be considered in determination of the source terms. This is important given the significant variations in the fines proportion between trench zones and material types. Additionally, this method allows for the use of a green valve in the overflow system to be accounted for in the source term estimates.

The Becker *et al.* (2015) method considers the following parameters:

- The total flux of fines entering the hopper during trenching.
- The proportion of the trenched fines flux that settles (and is trapped) in the hopper.
- The proportion of the trenched fines flux that exits the hopper in the overflow water.
- The relative proportions of the overflow fines flux that contribute to the dynamic and passive plumes.

In calculating these parameters, the method takes into account:

- The PSDs and dry bulk densities of the material to be trenched.
- The production/pumping rates of the TSHD.
- The rate at which material settles/traps in the hopper.
- The overflow-to-loading ratio based on the trench cycle times.

Becker *et al.* (2015) state that a reasonable estimate of the proportion of overflow fines that becomes the passive plume will fall in the range of 0-20%. This broadly agrees with the range of 5-15% found in Spearman *et al.* (2011). Values of this order of magnitude are confirmed by field measurements taken during operation of a sand dredger (8,225 m^3 capacity) in Hong Kong, which suggested 15% of the overflow fines flux contributed to the passive plume (Whiteside *et al.*, 1995).

It should be noted that in the Hong Kong study a green valve was not employed to moderate the overflow. There is limited experimental data available on the degree to which a green valve will reduce the proportion of the overflow fines flux that becomes a passive plume. DHI (2010) state that an appropriate estimate for the proportion of fines remaining in the passive plume when a green valve is in use is around 7% of the total overflow fines flux, with this assessment informed by monitoring activities undertaken in the vicinity of marine construction vessels in Singapore.

The proposed use of a green valve during the DPD project is accounted for in this modelling study by assuming that 10% of the overflow fines flux will become a passive plume. This represents a moderate value in the context of the ranges stated above. Calculation of the overflow source rates using a proportional value of 10%

are presented in Table 5.25, for each trench zone and material type, expressed as a proportion of the trenching production rate.

Table 5.25 Calculated source rates of sediments initially suspended into the water column during TSHD hopper overflow for pre-sweep sediment and post-sweep CSD-crushed material, using the methodology outlined in Becker *et al.* (2015).

Zone	Source Rate (% Production Rate)	
	Pre-Sweep Material	Post-Sweep Material
Pre-Sweep Area 1	2.20	-
Trench Zone 3	2.02	1.26
Trench Zone 4	2.87	1.26
Pre-Sweep Area 2	1.62	-
Trench Zone 5	1.13	0.69
Pre-Sweep Area 3	2.53	-
Trench Zone 6	2.65	1.20
Trench Zone 7	2.41	1.27
Sand Waves Area	0.60	-

The overflow source rate values calculated using the Becker *et al.* (2015) method range from 0.60% to 2.87% of the gross production rate, which compares well with the range of published measurements from TSHD operations (0.1-5.0%; Hayes & Wu, 2001) and is within the range of values used in modelling studies (0.3-9.8%) outlined in a review of contemporary practice by Kemps & Masini (2017). The lower overflow source rate values (<1.5% of total production) were calculated for the trench areas containing material that had lower fines content, such as the Sand Waves Area, Trench Zone 5 and material that has been crushed by CSD (see Sections 5.5 and 5.6.6). Overflow source rate values quoted in literature for areas with low fines content range from 0.3 to 2.1% of total production, giving confidence in the calculated values. For the trenching areas where the fines content is higher (Pre-Sweep Areas 1 and 3 and Trench Zones 3, 4, 6 and 7; Section 5.5), the calculated overflow source rate values are in the mid-range of the literature values.

To further contextualise the overflow source rate values calculated using the Becker *et al.* (2015) method, the corresponding suspended sediment concentrations (SSC) in the hopper overflow have been calculated and compared to values found in literature. Passive plume concentrations calculated without accounting for a green valve are in the range 2,600-6,300 mg/L for the areas with lower fines content (Sand Waves Area, Trench Zone 5, Pre-Sweep Area 2 and material that has been crushed by CSD), and in the range 5,600-8,000 mg/L for the remaining trenching areas. When a green valve is considered, the calculated concentrations are reduced to 2,100-5,100 mg/L for the areas with lower fines content and 4,600-6,500 mg/L for the remaining areas.

Field measurements taken of SSC within overflowing waters adjacent to the hopper are typically in the 5,000-6,000 mg/L range and are generally less than 10,000 mg/L (Hitchcock & Bell, 2004). These values correlate well with data drawn from other Western Australian projects that cannot be cited here for reasons of confidentiality. From comparisons, the calculated values above fall into a range that past experience suggests is realistic.

5.6.5 Representation of Disposal of TSHD-Trenched Material

All material trenched by the TSHD along the pipeline route will be transported to the proposed offshore spoil ground for disposal (Figure 1.1). This material will include all sediment and CSD-crushed rock from Pre-Sweep Areas 1, 2 and 3, Trench Zones 3, 4, 5, 6, and 7, and the Sand Waves Area.

For the disposal of the sediment trenched by TSHD in the pre-sweep of each area, the PSDs used in the model are based on PSDs from nearby boreholes (see Section 5.5). For the disposal of the CSD-crushed material removed by TSHD in the post-sweep trenching, the PSDs are based on the assumed PSD for the trenching of the CSD-crushed material as outlined in Section 5.6.4. Both sets of PSDs have been adjusted by removal of the component treated as suspended during trenching along the pipeline route (see Section 5.6.4), but as this represents only between 1.1% and 3.2% (averaged value depending on the relative contributions of overflow and non-overflow periods to the overall mass flux) of the mass for the minor components, the modified PSDs are not significantly different to the trenched PSDs (Table 5.26 and Table 5.27).

Once at the proposed spoil ground, the hopper will open to release the sediments from the bottom of the hull at a depth of approximately 10 m below sea level. Previous observations of sediment dumping from hopper vessels (e.g. CSMW, 2005) have shown that there is an initial rapid descent of solids, with the heavy particles tending to entrain lighter particles, followed by a billowing of lighter components back into the water column after contact with the seabed (Figure 5.3). A proportion of the lighter components will also remain suspended and may be trapped by density layers, if present.

Because simulations in this study focused on the far-field fate of sediment particles due to transport and sinking after the initial dump phase, simulations were run with the initial vertical distribution specified to represent the post-collision phase for a case where a high proportion of the sediments are resuspended after collision with the seabed. To represent this, an assumed vertical distribution for the sediments (Table 5.28) has been specified following published information from previous hopper disposal operations (CSMW, 2005; NEPA, 2001). This vertical distribution, with the majority of the material input near the seabed and only 15% of the material released at hull depth or above, is in line with values quoted in the recent literature review by Mills & Kemps (2016), which found that sediment resuspension from individual dredged material disposal events was generally less than 10% of the disposed material load.

It is estimated that 95-99% of the bulk load deposits directly onto the seabed in a typical case, with the remainder released into the water column (CSMW, 2005, NEPA, 2001). It is difficult to find other definitive source values in the literature, but a value of 5% of each load agrees well with past experience and appears to be a conservative estimate based on the values quoted above. Accordingly, 5% of each hopper load was placed in suspension in the water column in the sediment fate model.

In addition to the proportion of material immediately suspended in the water column, disposal from the hopper will result in the stockpiling of sediment as a mound on the seabed that will be subject to resuspension by tidal and wave forces. Because fine sediments in the deposited mass may be subject to ongoing resuspension and dispersion over time, it was necessary to specify the deposits as a further source of sediment potentially subject to resuspension.

The proportion of the newly deposited trenched material available for resuspension is characterised by a finite limit regulated by PSDs and the occurrence of natural sediment capping. As a result of the selective resuspension of the smaller-sized particles (silts and clays), the deposited mound surface layer gradually contains a greater proportion of larger particle sizes. These larger particles act as armouring against bottom shear stress, protecting and retaining the remaining fine particles in the mound. Therefore, in the model it was assumed that 5% of the deposited mass – representing the volume of the upper surface layer – would be subject to resuspension. It should be noted that the model maintains a mass balance estimate of the remaining sediment of each size class within each grid cell to derive an estimate of the median particle size in the surface-layer sediments. In turn, the potential for ongoing resuspension of fines is calculated. In this way, the model represents the increased armouring of sediments as the average particle size increases.

The disposal time for the hopper material within each trench cycle was assumed to be 15 minutes (Table 5.5). The disposal location within the spoil ground was varied for each trench cycle in a randomised manner, with the ultimate aim of ensuring an even distribution of trenched material within each spoil ground by the conclusion of all activities.

Table 5.26 Assumed PSDs of sediments initially suspended into the water column during TSHD hopper disposal operations at spoil ground for the pre-sweep material.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Pre-Sweep Area 1	PSD (%) for Sediment Disposal – Trench Zone 3	PSD (%) for Sediment Disposal – Trench Zone 4	PSD (%) for Sediment Disposal– Pre-Sweep Area 2	PSD (%) for Sediment Disposal – Trench Zone 5	PSD (%) for Sediment Disposal – Pre-Sweep Area 3	PSD (%) for Sediment Disposal – Trench Zone 6	PSD (%) for Sediment Disposal – Trench Zone 7	PSD (%) for Sediment Disposal – Sand Waves Area
Clay	<7	5.92	5.68	7.79	3.57	1.32	4.69	6.29	8.11	1.24
Fine Silt	7-34	8.05	7.53	10.97	5.95	3.47	8.27	8.63	8.65	1.90
Coarse Silt	35-74	4.97	4.12	7.30	4.74	3.20	8.74	8.22	5.84	2.78
Fine Sand	75-130	4.69	3.29	4.69	3.93	3.06	6.36	5.96	3.74	2.49
Coarse Sand	>130	76.37	79.38	69.26	81.82	88.95	71.94	70.89	73.67	91.60

Table 5.27 Assumed PSDs of sediments initially suspended into the water column during TSHD hopper disposal operations at spoil ground for the post-sweep of CSD-crushed material.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Disposal – Trench Zone 3	PSD (%) for Sediment Disposal – Trench Zone 4	PSD (%) for Sediment Disposal – Trench Zone 5	PSD (%) for Sediment Disposal – Trench Zone 6	PSD (%) for Sediment Disposal – Trench Zone 7
Clay	<7	3.40	2.92	1.12	2.56	3.60
Fine Silt	7-34	4.65	4.60	2.31	3.79	4.21
Coarse Silt	35-74	2.54	3.06	2.09	3.66	2.85
Fine Sand	75-130	2.05	2.06	1.87	2.69	1.97
Coarse Sand	>130	87.36	87.36	92.61	87.30	87.37

Table 5.28 Assumed vertical distribution of sediments initially suspended into the water column during TSHD hopper disposal operations at the offshore spoil ground.

Elevation	Example Elevation (m ASB) – 20 m Water Depth and 10 m Hull Depth	Vertical Distribution (%) of Sediments
Surface/water depth	20	5
Hopper hull elevation	10	10
0.75 x hull elevation	7.5	20
0.50 x hull elevation	5	30
0.25 x hull elevation	2.5	35

5.6.6 Representation of CSD Trenching

For this project it is proposed that a large CSD will be used to cut/crush all rock from Trench Zones 3, 4, 5, 6 and 7. The CSD proposed for the project will be trenching rock with a strength of up to approximately 40 MPa, therefore a large CSD is required. For the purposes of modelling a CSD with a total installed power of 28,200 kW was specified. The proposed methodology that has been modelled is for all material cut/crushed by CSD to be cast behind the dredge at low velocity, just above the seabed. The crushed material will be subsequently removed by TSHD and taken to the proposed offshore spoil ground. There are several proposed methodologies for the CSD trenching component of the program; however, this methodology was anticipated to represent a "worst case" in terms of the generation of suspended sediment due to the additional pass with the TSHD that is required (see Section 5.6.4). A similar methodology was used in the Ichthys project for CSD operations (INPEX, 2010, 2011). Sources of sediment suspension from this type of operation include:

- Centrifugal dispersion of seabed sediments by the rotating cutterhead.
- Suspension of sediments due to casting/pumping behind the dredge and billowing of lighter components back into the water column after contact with the seabed.

Past studies have found that CSDs cutting rock produce material of mixed size-fractions, ranging from fine silts to small rock fragments (Fitzpatrick *et al.*, 2009). Based on past dredging operations in Darwin Harbour, approximately 80% of the material generated by the CSD was assumed to be in the form of rocks and gravel (RPS, 2009). PSDs were estimated for each zone by adjusting the measured PSDs to have 80% in the coarse sand size class and calculating a weighted reduction of the proportion of each of the smaller size classes. The PSDs applied to CSD crushing and casting back material while trenching along the pipeline route are shown in Table 5.29.

The plume that results from the action of the CSD cutterhead is typically concentrated near the seabed, with only small concentrations reaching the surface (CSMW, 2005). The majority of the source is located near the seabed, mostly within 3 m of the bottom. The casting of material behind the CSD via a pipeline just above the seabed will result in a similar plume vertical profile. Sediment release from the pipe will occur as a stream of slurry that will have an initial rapid descent of solids followed by a billowing of lighter components back into the water column after contact with the seabed (Swanson *et al.*, 2004). The plume that results from disposal of a stream of slurry from a pipe is typically concentrated near the seabed, with most of the material within 3 m of the bottom, and lower concentrations extending up towards the surface (Swanson *et al.*, 2004). Table 5.30 shows the assumed vertical distribution of the suspended material for the CSD cutterhead and casting source.

There is a reasonable amount of literature pertaining to the generation rate of suspended sediments at the cutterhead during CSD operations. Results from field measurement and empirical models have been presented by Hayes & Wu (2001) and Anchor Environmental (2003). A broad range of source rates have been found, generally being less than 0.5% of the gross production rate (USACE, 2008). Hayes & Wu (2001) quote a maximum source rate of 0.51% from approximately 400 observations, with most rates less than 0.3%. Anchor Environmental (2003) quote additional data, citing a median source rate of 0.3% of gross production based on the collected data set. A validation model study undertaken for a project in Cockburn Sound, Western Australia, dredging sedimentary rock, found that 0.3% was a suitable input for a large CSD (Fitzpatrick *et al.*, 2009). Investigation of the data sets from the studies presented showed that the largest observed rates resulted from the dredging of very fine sediment with high water content, typical of riverine or sedimentary estuarine conditions, rather than open coastal environments. Given the location of the trenching within the vicinity of

Darwin Harbour, for this study a source rate of 0.5% of the gross production rate (more typical of estuarine trenching) has been adopted for the CSD cutterhead source.

For the casting back of material via a pipeline it is estimated that 95-99% of the bulk load will deposit directly onto the seabed in a typical case, with the remainder released into the water column (CSMW, 2005, NEPA, 2001). It is difficult to find other definitive source values in the literature, and no site-specific sampling has been conducted for pipe placement operations, but a value of 5% of production rate agrees well with past experience and appears to be a conservative estimate based on the values quoted above. Accordingly, a source of 5% of the gross production rate was placed in suspension in the water column in the sediment fate model.

Table 5.29 Assumed PSDs of sediments initially suspended into the water column during CSD trenching operations along the pipeline route for crushing and casting of material.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Removal – Trench Zone 3	PSD (%) for Sediment Removal – Trench Zone 4	PSD (%) for Sediment Removal – Trench Zone 5	PSD (%) for Sediment Removal – Trench Zone 6	PSD (%) for Sediment Removal – Trench Zone 7
Clay	<7	6.03	5.37	2.94	4.83	6.33
Fine Silt	7-34	7.16	7.08	4.36	5.93	6.54
Coarse Silt	35-74	3.98	4.71	3.82	5.54	4.42
Fine Sand	75-130	2.83	2.85	3.06	3.71	2.72
Coarse Sand	>130	80.00	80.00	85.82*	80.00	80.00

* The coarse sand fraction of the Trench Zone 5 PSD was initially more than 80%, so no further adjustment was applied.

Table 5.30 Assumed vertical distribution of sediments initially suspended into the water column during CSD trenching operations along the pipeline route for crushing and casting of material.

Elevation	Example Elevation (m ASB) – 30 m Water Depth	Vertical Distribution (%) of Sediments
3.0 m (ASB)	3	16
2.5 m (ASB)	2.5	16
2.0 m (ASB)	2	16
1.0 m (ASB)	1	22
0.5 m (ASB)	0.5	30

5.6.7 Representation of SHB/TSHD Propeller-Wash

Modelling of sediments suspended by propeller-induced motion at the seabed was conducted to estimate likely sediment concentrations generated by the TSHD and SHB propellers while manoeuvring during trenching operations. A specialised numerical model developed by RPS, named PROPMAP, was used to estimate a time- and space-varying rate of sediment flux from the seabed due to the thrust imposed by each vessel's propellers at the seabed level behind the moving vessel. The model uses characteristics of the vessel of interest to estimate the three-dimensional thrust-field generated by the propellers. This thrust-field is then combined with the grain size and degree of cohesion of the seabed sediments, and the varying under-keel clearance along the typical vessel paths, to calculate variations in the suspended sediment flux from the seabed in time and space.

The following details were used as input to PROPMAP to calculate variable rates of sediment flux from the seabed due to propeller-wash effects:

- Vessel tracks and speeds.
- Vessel draft, engine power and propeller size.
- Bathymetry along the vessel tracks.

- Grain size distributions of the sediment, defining the proportions of clay and silt along the vessel tracks.

The calculation steps applied by PROPMAP at discrete intervals along each vessel path were as follows:

- Based on the vessel's engine power and propeller size, determine the propeller-induced velocity profile.
- Based on the vessel's draft and the local bathymetry, determine the intersection of the thrust-field with the seabed and find the thrust imposed on it.
- Based on the velocity of water flow at the seabed, calculate the shear stress acting on it.
- Based on the calculated shear stress, and the sediment grain size and cohesiveness, calculate a theoretical erosion flux (mass per unit time) for seabed sediment.

Propeller-induced velocity profiles were calculated using empirical expressions from Blaauw & van de Kaa (1978). Thrust at the seabed will depend upon the level of the bed, which will intersect as a plane (Figure 5.4). For an under-keel clearance of 1 m, a velocity field exceeding 5 m/s would intersect the bed in this example, while at a clearance of 4 m the bed velocity would be reduced to <2 m/s. The influence of this thrust will vary with the sediment grain size. Consequently, outcomes will be sensitive to the magnitude of the thrust, the under-keel clearance and the PSD of the bed.

Sediment erosion flux was estimated from the derived velocity field using the empirical formulations of van Rijn (1989). The sediment flux component attributable to propeller-wash was found to be depth-limited for areas where the under-keel clearance was less than 3 m, assuming a fully-loaded vessel (maximum draft). Simulations over deeper areas, including the areas where vessels would transit to the spoil grounds, indicated that flux would be minimal (compared to other sources) and representative of short-lived suspension of the surface-layer sediments followed by rapid settlement. This settlement time was estimated to be shorter than the simulation output time step. Propeller-wash was found to be more significant in the shallow areas and would be greater over sediments previously suspended by dredging.

These findings were used to inform the definition of the sediment flux rates during TSHD dredging operations (see Section 5.6.4).

In summary, propeller-wash effects were considered: (i) along each pipeline section during trenching; (ii) between each pipeline section and the spoil grounds during disposal.

In the absence of definitive information relating to the seabed composition of the areas traversed by the SHB or TSHD between the pipeline, and spoil ground for simplicity the seabed composition was assumed to be described by the PSD of the area from which the vessel began its journey.

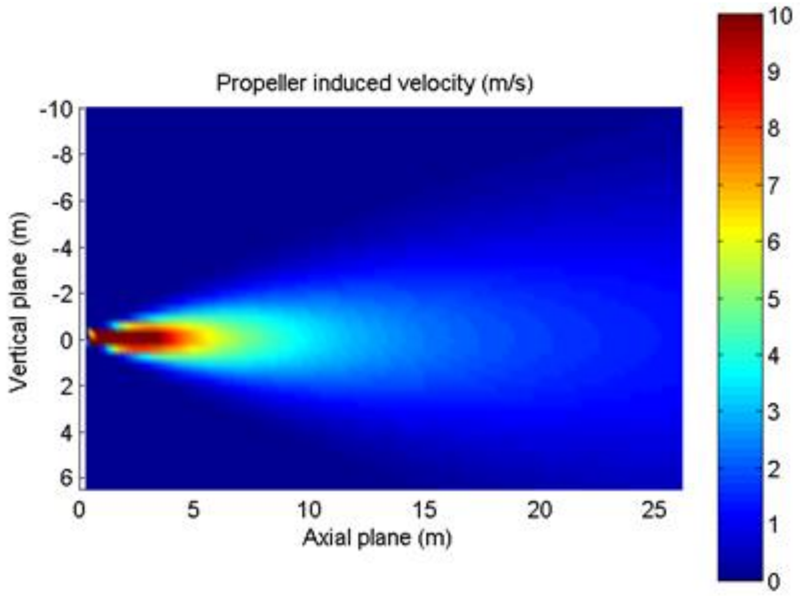

Figure 5.4 Two-dimensional view of a propeller-induced velocity profile.

5.6.8 Summary of Source Rates

For each source of suspended sediment plumes during trenching and disposal operations, as described in the preceding sections, Table 5.31 and Table 5.32 summarise the associated loss rates and approximate volumes of suspended sediment expected. The volumes assigned to the respective non-overflow and overflow periods for TSHD trenching, and non-dewatering period for BHD trenching, are based on the modelled cycle times detailed in Table 5.4 and Table 5.5.

A total of approximately 23,489 m^3 of sediment is expected to be initially suspended in the water column over the course of the modelled program. This volume represents approximately 7.7% of the *in situ* trenched volume (306,212 m^3, see Table 5.7). If all deposited material assumed to be available for potential resuspension following spoil ground disposal operations is actually resuspended, a total of 41,245 m^3 of sediment will be suspended in the water column over the program duration; this will represent approximately 13.5% of the *in situ* trenched volume.

Table 5.31 Summary of sediment sources applied in the model.

Operation	Source Rate (% Production Rate)	Trenched Volume (m^3)	Suspended Volume (m^3)
BHD excavator bucket	2.10	22,220	511
BHD excavator bucket + dewatering from SHB	2.40		
Disposal from SHB	5 (water column) 5 (seabed; potential)		1,085 *1,085*
TSHD draghead + propeller-wash	0.60	281,725*	6,004
TSHD draghead + propeller-wash + overflow	Specified per zone (see table below)		
Disposal from TSHD	5 (water column) 5 (seabed; potential)		13,786 *13,786*
CSD draghead + casting behind	0.5 (cutterhead)	90,672	*453*
	5 (casting behind)		*4,534*
	Totals	**394,617***	**23,489** ***41,245***

* Note these volumes include the proportion of material that has been crushed by CSD and subsequently picked up by TSHD, therefore this material is included twice. The total *in situ* trenched volume is 306,212 m^3 (Table 5.7).

Table 5.32 Sediment source rates applied in the model for the TSHD while overflowing.

Pipeline Zone	Source Rate (% Production Rate)	
	Pre-Sweep Material	Post-Sweep Material
Pre-Sweep Area 1	2.80	-
Trench Zone 3	2.62	1.86
Trench Zone 4	3.47	1.86
Pre-Sweep Area 2	2.22	-
Trench Zone 5	1.73	1.29
Pre-Sweep Area 3	3.13	-
Trench Zone 6	3.25	1.80
Trench Zone 7	3.01	1.87
Sand Waves Area	1.20	-

6 ENVIRONMENTAL THRESHOLD ANALYSIS

Predictions of SSC and sedimentation for each scenario were assessed against a series of water quality and sedimentation thresholds to categorise the modelled outcomes into management zones of influence and impact, defined with regard to environmental sensitivities in the study region. The thresholds and the approach to be applied to the DPD project are based on the extensive environmental monitoring and threshold work that INPEX completed for the Ichthys project environmental impact statements, and its capital and maintenance dredge management plans in Darwin Harbour (INPEX, 2010, 2011, 2013, 2018).

6.1 Thresholds

To calculate areas of potential impact from trenching-induced excess SSC and sedimentation, INPEX established seasonal tolerance limits/thresholds for sensitive receptors including mangrove, seagrass and hard coral habitats (Table 6.1). The INPEX tolerance limits for SSC were derived from its comprehensive site-specific water quality monitoring data (covering multiple years and locations), and the tolerance limits for sedimentation were derived from habitat-specific dose-response experiments and field observations reported in the scientific literature (INPEX, 2018). The defined tolerance limits also varied across four trenching impact reporting zones, which were defined based on available water quality monitoring data (INPEX, 2018). The trenching impact reporting zones are named as follows, with the spatial extents agreed for this study shown in Figure 6.1:

- East Arm.
- Middle Arm.
- Middle Harbour.
- Offshore.

Table 6.1 Tolerance limits for excess SSC and sedimentation (INPEX, 2018).

Habitat	Trenching Impact Reporting Zone	Season	SSC (mg/L)	Sedimentation (mm)
Mangrove	Anywhere	All	N/A	50
Coral	East Arm	Dry	11.9	15
		Wet	23.8	
	Middle Arm	Dry	12.4	15
		Wet	27.0	
	Mid Harbour	Dry	10.7	15
		Wet	28.4	
	Offshore	Dry	17.9	15
		Wet	64.2	
Seagrass	Anywhere	Dry	13.3	40
		Wet	60.6	

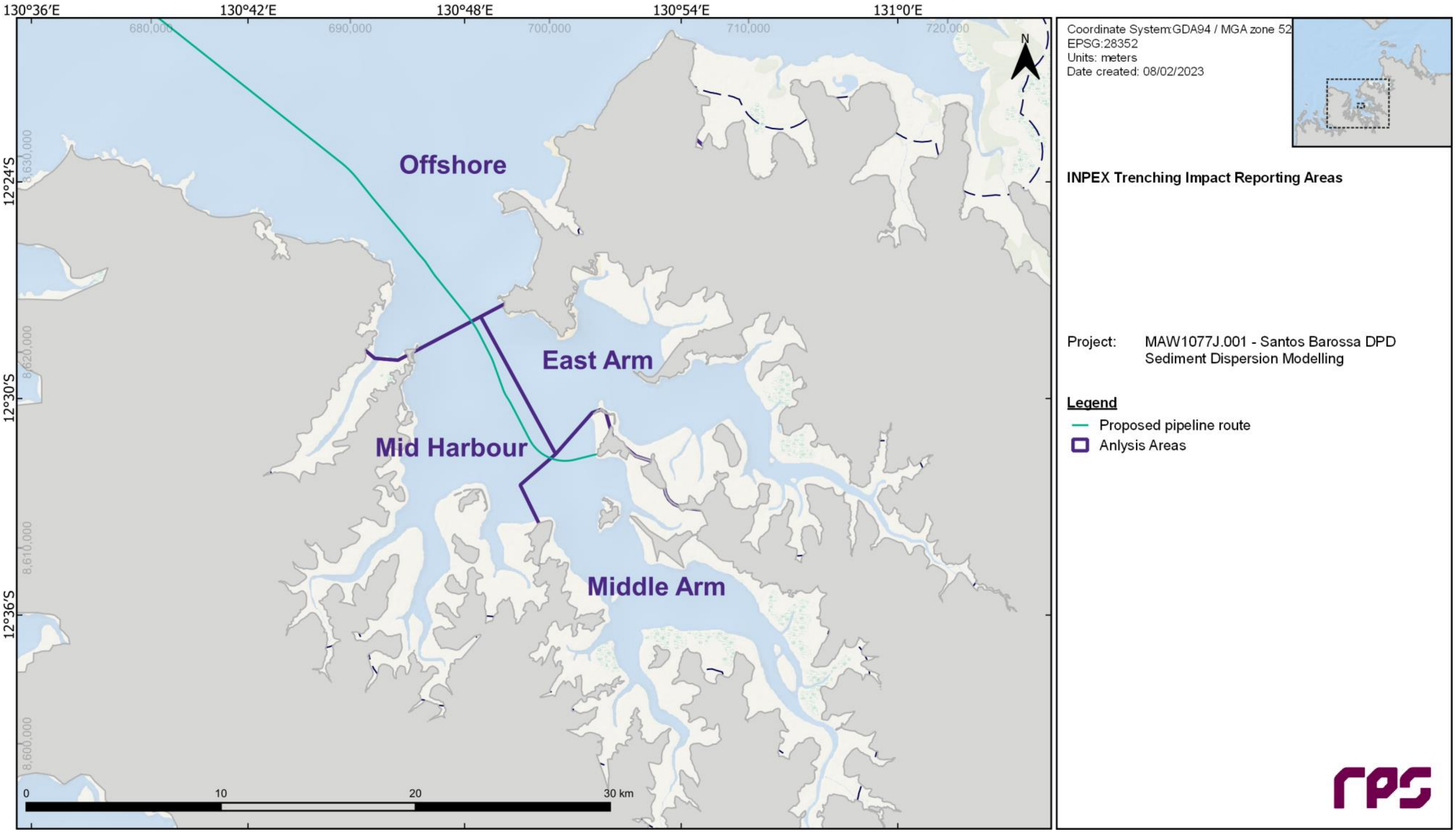

Figure 6.1 **Delineation of the proposed trenching impact reporting zones (East Arm, Middle Arm, Mid Harbour and Offshore) based on INPEX, 2010. Thresholds used to define the management zones will vary in magnitude between the trenching impact reporting zones.**

6.2 Management Zones

Three management zones were defined in the approach applied by INPEX (2010, 2011, 2013, 2018), based on varying levels of impact on sensitive receptor communities: a Zone of High Impact (ZoHI), a Zone of Moderate Impact (ZoMI), and a Zone of Influence (ZoI). The definition of each of these management zones, and how the thresholds have been applied to the sediment dispersion modelling results to determine the predicted management zones for the proposed trenching and disposal program, is presented in the following sections.

6.2.1 Zone of High Impact

The Zone of High Impact (ZoHI) is defined as the area where direct impact from trenching and disposal will occur, such as removal of substrate or smothering of substrate (INPEX, 2018). Predicted impacts within this zone are expected to be severe and often irreversible. This zone includes the top width of the trench footprint and disposal area with a 20 m buffer extending outwards from these areas. The results from the sediment dispersion modelling will have no effect on the outline of the ZoHI as it is defined here, and as such this zone is not presented in this report.

6.2.2 Zone of Moderate Impact

The Zone of Moderate Impact (ZoMI) is defined as the area where sensitive receptor communities are predicted to be indirectly impacted by elevated SSC and sedimentation due to trenching and disposal activities (INPEX, 2018). Damage/mortality of sensitive receptor communities may occur, but the disturbed areas are considered to have good potential for recovery.

Sensitive receptors are within the ZoMI if their respective ecological tolerance limits for SSC are exceeded for 10% of the time or where the simulated sedimentation thickness exceeds their respective sedimentation tolerance limits at the end of the simulation (INPEX, 2018). For this project the maximum sedimentation thickness predicted at any time throughout the trenching operations was used for comparison against the sedimentation tolerance limits. Due to the variable nature of the sedimentation with tidal cycles and the strong currents in Darwin Harbour, larger amounts of sedimentation may occur earlier in the trenching program.

The predicted ZoMI based on exceedances of the thresholds for SSC was evaluated over the duration of each trenching scenario by:

- Creating a three-dimensional time series (hourly) of trenching-excess SSC values in each model grid cell for the entire trenching program.
- Calculating the 90th percentile SSC value of each cell (i.e. the value that is exceeded 10% of the time).
- Assessing the 90th percentile data against the seasonal threshold SSC values for each sensitive receptor habitat type and trenching impact reporting zone.

The predicted ZoMI based on exceedances of the thresholds for sedimentation was evaluated over the duration of each trenching scenario by:

- Calculating the maximum trenching-excess sedimentation thickness values in each model grid cell for the entire trenching program. A density of 700 kg/m^3 was assumed for newly deposited sediments in the modelling based on field observations of the *in situ* density of surface material present over the mangrove areas of Darwin Harbour (INPEX, 2009).
- Assessing the maximum trenching-excess sedimentation thickness data against the seasonal threshold sedimentation thickness values for each sensitive receptor habitat type and trenching impact reporting zone.

The overall predicted ZoMI for each scenario was then calculated by combining both of the predicted ZoMIs from exceedance of thresholds for SSC and sedimentation thickness.

6.2.3 Zone of Influence

The Zone of Influence (ZoI) is defined as the area where sensitive receptor communities are predicted to be indirectly influenced by elevated SSC and sedimentation (INPEX, 2018). Sensitive receptor communities may, at some time experience detectable elevations in SSC and sedimentation (beyond expected background levels). However, no sublethal stress or mortality of benthic communities is expected to occur (INPEX, 2018).

Sensitive receptor communities are predicted to be indirectly influenced where their respective ecological tolerance limits for SSC are exceeded for 5% of the time or where the simulated sedimentation thickness exceeds 3 mm at the end of the simulation (INPEX, 2018). For this project the maximum sedimentation thickness predicted at any time throughout the trenching operations was used for comparison against the 3 mm sedimentation tolerance limit. Due to the variable nature of the sedimentation with tidal cycles and the strong currents in Darwin Harbour, larger amounts of sedimentation may occur earlier in the trenching program.

The predicted ZoI based on exceedances of the thresholds for SSC was evaluated over the duration of each trenching scenario by:

- Creating a three-dimensional time series (hourly) of trenching-excess SSC values in each model grid cell for the entire trenching program.
- Calculating the 95th percentile SSC value of each cell (i.e. the value that is exceeded 5% of the time).
- Assessing the 95th percentile data against the seasonal threshold SSC values for each sensitive receptor habitat type and trenching impact reporting zone.

The predicted ZoI based on exceedances of the thresholds for sedimentation was evaluated over the duration of each trenching scenario by:

- Calculating the maximum trenching-excess sedimentation thickness values in each model grid cell for the entire trenching program. A density of 700 kg/m^3 was assumed for newly deposited sediments in the modelling based on field observations of the *in situ* density of surface material present over the mangrove areas of Darwin Harbour (INPEX, 2009).
- Assessing the maximum dredge excess sedimentation thickness data against the 3 mm tolerance limit.

The overall predicted ZoI for each scenario was then calculated by combining both of the predicted ZoIs from exceedance of thresholds for SSC and sedimentation thickness.

7 RESULTS OF SEDIMENT FATE MODELLING

7.1 General Plume Movement

7.1.1 Summary

Simulations indicated that there may be significant spatial patchiness in the distribution of SSC and sedimentation at any point in time during the trenching and disposal operations because of variability in the number of sediment suspension sources, variability in the flux from each of these sources, and the varying dynamics of the transport, settlement and resuspension processes affecting the sediments.

The SSC results presented in the following section are depth-averaged. It should be noted, however, that there is significant variability in the vertical distributions of SSC in the water column, with a distinct increase in concentration towards the seabed. Most material will initially be suspended low in the water column, and material suspended higher in the water column will sink as it moves away from the source. Frequent resuspension of material will also mostly affect the lower reaches. Thus, the spatial area affected above a given concentration is typically greater in the near-seabed layer than in the near-surface layer. Nonetheless, there are instances throughout the simulations where elevated concentrations will occur in the near-surface layers – during SHB/TSHD disposal operations, or during strong resuspension events affecting sediments that have migrated to shallow areas – but these will typically not be sustained for extended periods of time.

The localised movement and dispersion of the trenching-generated suspended sediment is governed over short time scales by the tide, with very strong tidal flows in the areas where trenching is planned to occur and at the offshore disposal ground. Most of the activities related to trenching of the pipeline route will take place within Darwin Harbour, which is dominated by tidal currents year-round and is relatively sheltered from the variations in large-scale circulation observed offshore. Beyond the harbour entrance, superimposed on the tidal motion is the gradual migration of sediment due to the wind-driven residual component of the current, which drives some seasonal differences in the overall drift patterns of the suspended sediments. However, given the strength of the tidal currents even in the area offshore of the harbour the seasonal differences are small. The sediment plume extends slightly more southwards during the winter/dry season scenario and slightly more northwards during summer/wet season scenario.

7.1.2 Plume Movement over the Spring and Neap Tide

Given the dominance of the tidal flows in the Darwin area the typical sediment plume movements are predicted to reflect the oscillations of the ebbing and flooding tide. Figure 7.1 and Figure 7.2 show example two-hourly snapshot sequences of modelled sediment plume movement during a spring tide cycle and a neap tide cycle, respectively, in the winter/dry season scenario. On the ebbing tide sediment plumes from trenching at zones within the harbour are predicted to move towards the harbour entrance, or in a north-westerly direction parallel to the coast for the trenching zones outside the harbour entrance. On the flooding tide the sediment plumes from trenching zones outside and near the harbour entrance are predicted to move into the harbour, typically staying close to the western side (Woods Inlet and West Arm), and at trenching zones inside the harbour the sediment plumes move deeper into the harbour, extending south into Middle Arm. At the proposed offshore disposal site sediment plumes from disposal operations move south-west towards Darwin Harbour on the ebbing tide and north-east towards Clarence Strait on the flooding tide. As is expected, the predicted plume drift trajectories during the spring tide periods are much longer than during neap tide periods, with the suspended material being more widely dispersed and SSC becoming patchy.

Figure 7.3 and Figure 7.4 show example two-hourly snapshot sequences of modelled sediment plume movement during a spring tide cycle and a neap tide cycle, respectively, in the summer/wet season scenario. The figures reveal the patterns of plume movement are very similar to those of the winter/dry season scenario, which is expected given the dominance of the tide on the hydrodynamics of Darwin Harbour and Beagle Gulf.

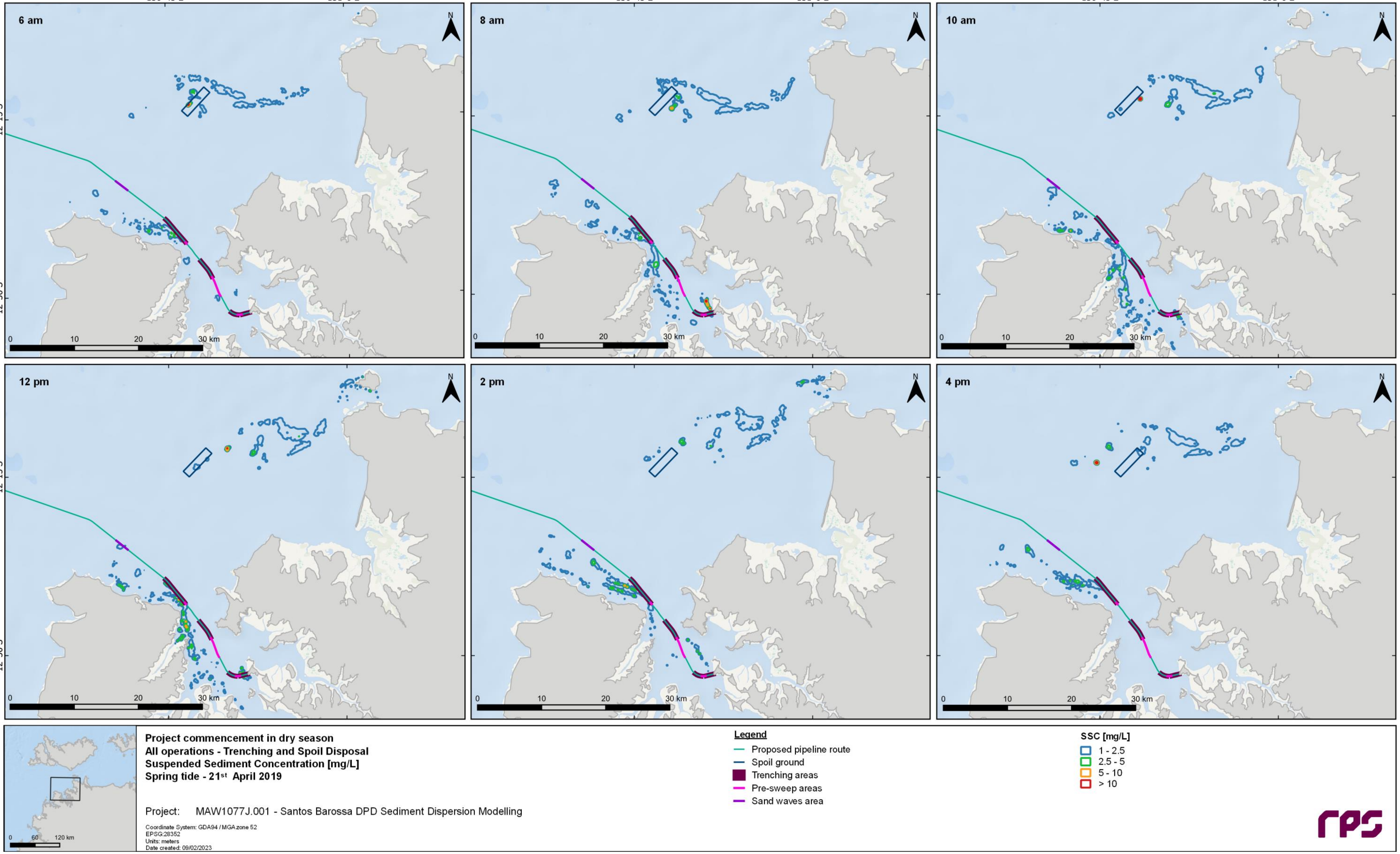

Figure 7.1 Example two-hourly snapshots of modelled sediment plume movement during a nominal spring tide cycle in the winter/dry season scenario (based on 21 April 2019 6am to 2pm, flooding to ebbing tide). At this point in the simulation the TSHD is working near the northern end of Trench Zone 6, the CSD is working near the southern end of Trench Zone 6, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

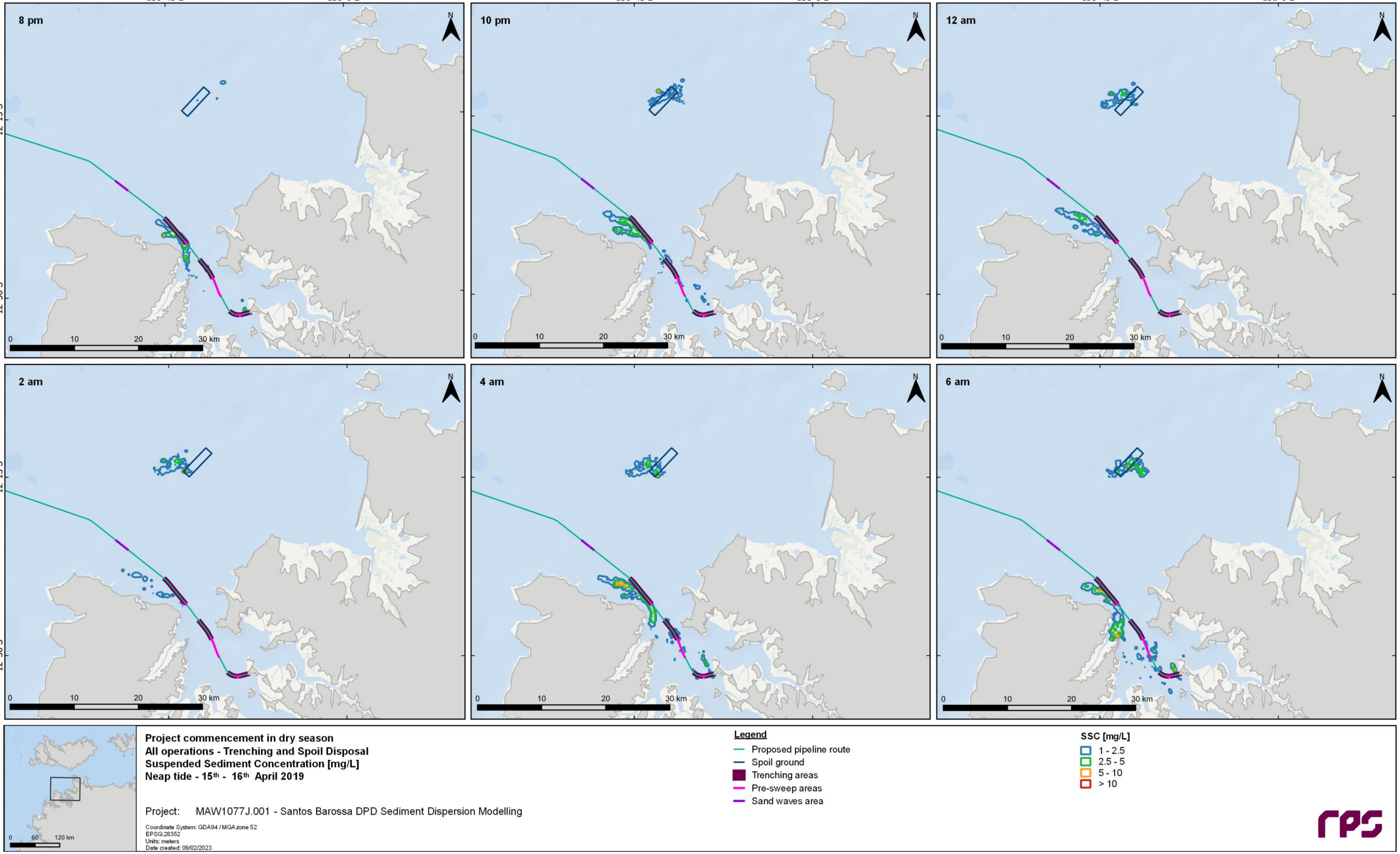

Figure 7.2 Example two-hourly snapshots of modelled sediment plume movement during a nominal neap tide cycle in the winter/dry season scenario (based on 15-16 April 2019 8pm to 6am, ebbing to flooding tide). At this point in the simulation the TSHD is working in Trench Zone 6, the CSD is working in Trench Zone 5, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

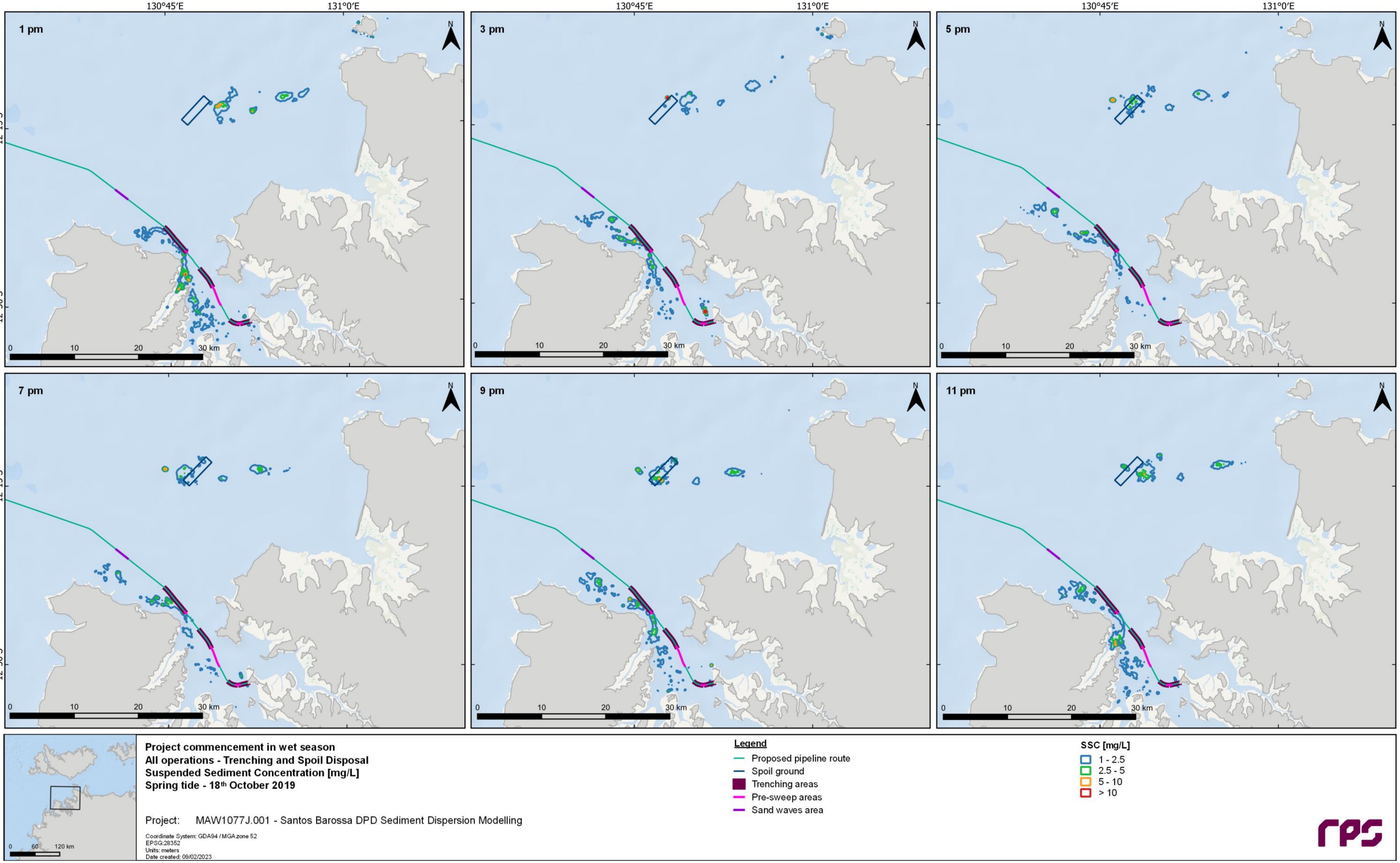

Figure 7.3 Example two-hourly snapshots of modelled sediment plume movement during a nominal spring tide cycle in the summer/wet season scenario (based on 18 October 2019 1pm to 11pm, from high tide ebb to slack tide to high tide flood). At this point in the simulation the TSHD is working in Trench Zone 6, the CSD is working in Trench Zone 5, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

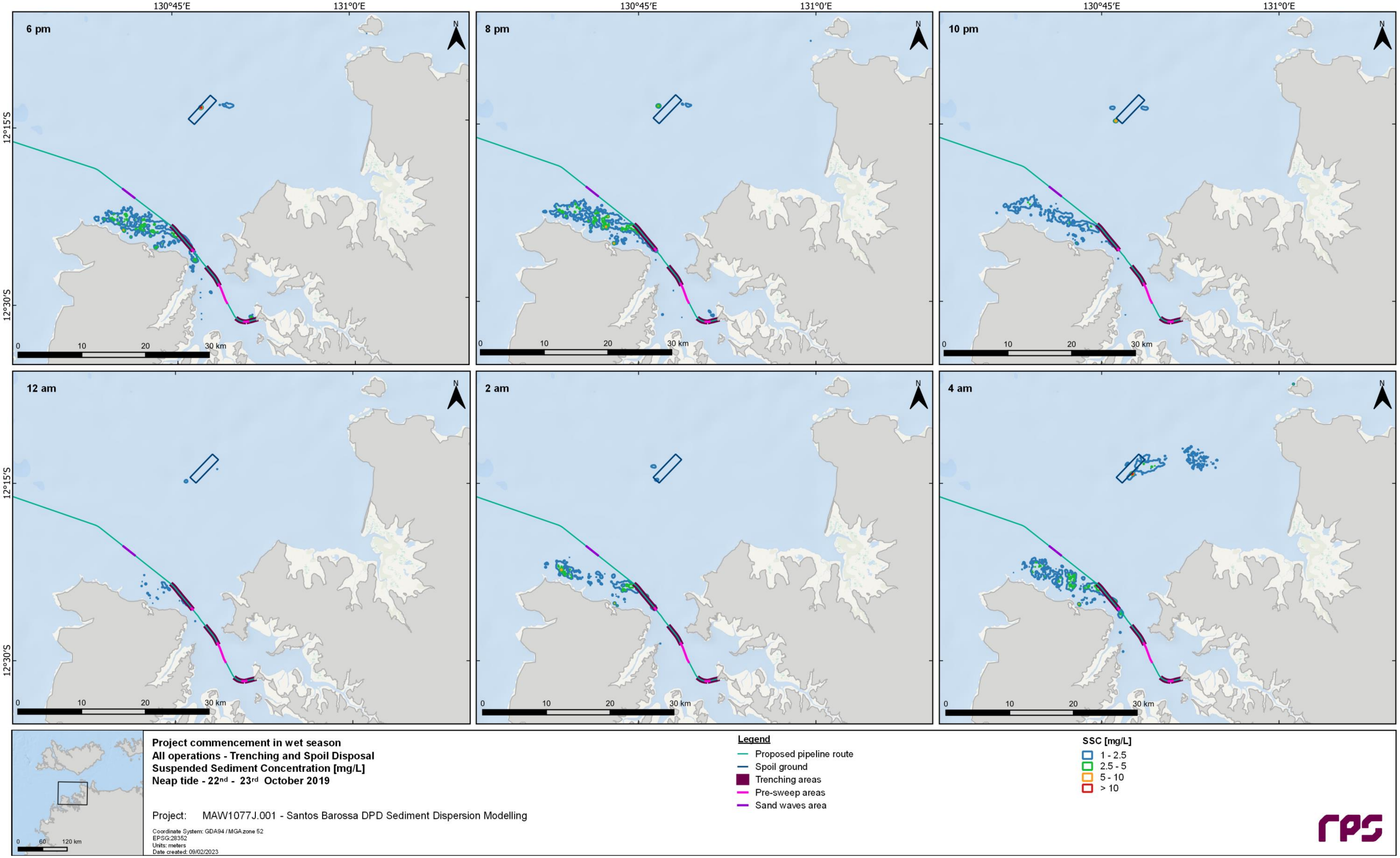

Figure 7.4 Example two-hourly snapshots of modelled sediment plume movement during a nominal neap tide cycle in the summer/wet season scenario (based on 22-23 October 2019 6pm to 4am, ebbing to slack tide to flooding). At this point in the simulation the TSHD is working in Trench Zone 7, the CSD is working in Trench Zone 6, and the BHD is working in Trench Zone 1. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

7.1.3 Plume Movement at the Disposal Ground

The localised movement and dispersion of the suspended sediment generated by disposal/dumping at the offshore disposal area is also dominated over short time scales by the tide, with very strong tidal flows at the offshore disposal ground. As such, the movement of the predicted suspended sediment plumes reflect the ebbing and flooding tidal oscillations with longer trajectories during spring tides and shorter trajectories during neap tides. Additional variability occurs at the disposal area due to the sporadic nature of the disposal sources, which are variable in time and space.

To show more clearly the predicted variability and persistence of suspended sediment plumes generated by dumping at the offshore disposal area, and the potential for interaction of plumes from consecutive disposals, a more detailed snapshot sequence (hourly and zoomed to the disposal area) of depth-averaged SSC for a typical spring and neap tide sequence in the winter/dry season scenario has been presented. Figure 7.5 and Figure 7.6 present hourly depth-averaged SSC snapshots for a 12-hour period during a typical spring tide, while Figure 7.7 and Figure 7.8 present hourly snapshots for a 12-hour period during a typical neap tide. Disposal times from the TSHD and BHD are outlined in each caption and individual disposal plumes are identified with dashed circles overlaid on the panels.

The snapshot sequences show that during spring tide periods the interaction between suspended sediment plumes from consecutive disposals is minimal, due to the rapid movement and dispersion of the plumes. The exception to this is when the timings and locations of disposals from the TSHD and BHD are close together (see dashed circles 1 and 2 in Figure 7.5 and Figure 7.6). It should be noted that the SSC generated from BHD disposals is predicted to be significantly lower than for TSHD disposals, due to the lower volume of material in each load. During neap tide periods, when plume movement is slower and trajectories are shorter, there is more potential for interaction between consecutive disposals; however, the predicted depth-averaged SSC of the interacting plumes remains relatively low.

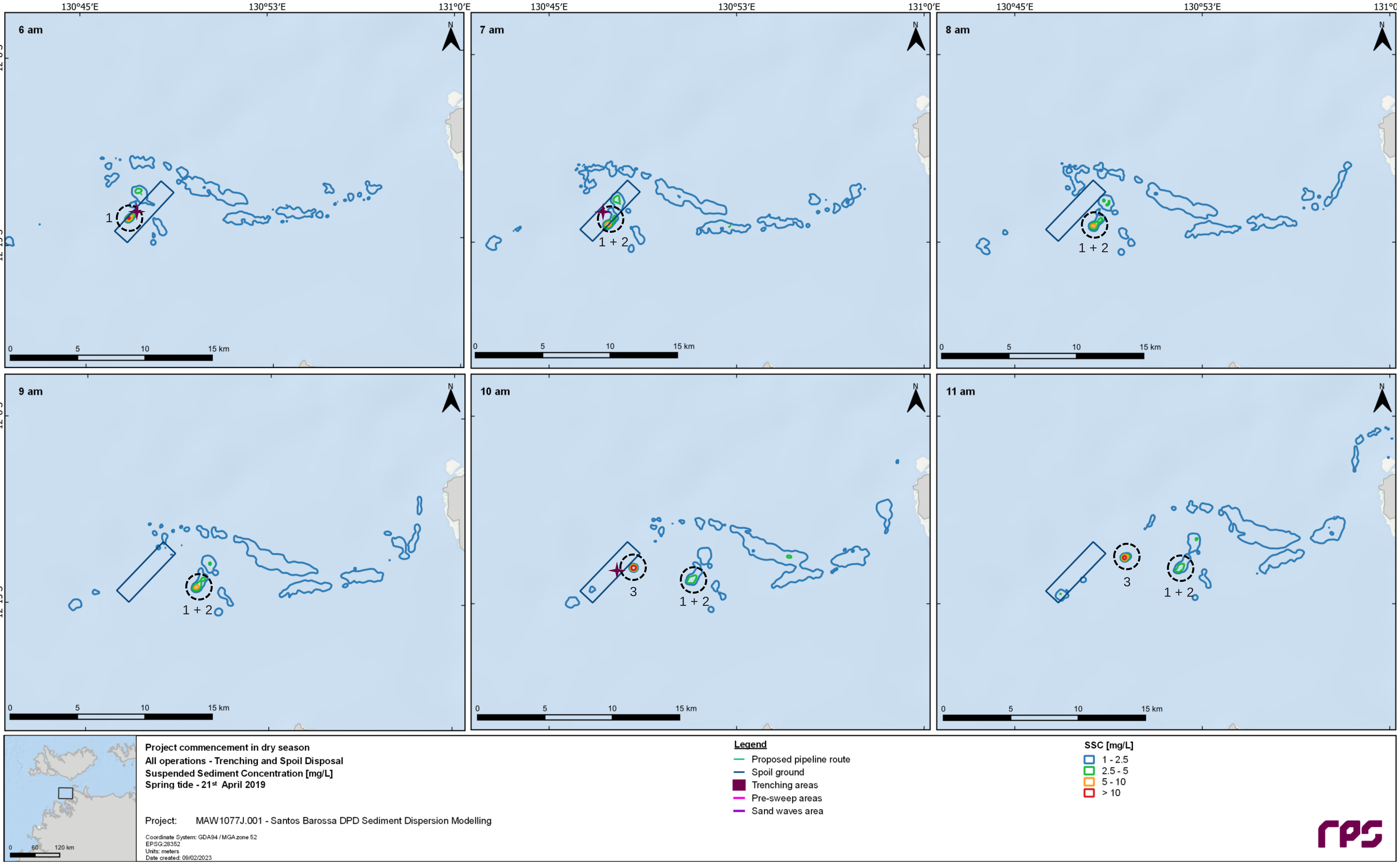

Figure 7.5 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal spring tide cycle in the winter/dry season scenario (based on 21 April 2019 6am to 11am, flooding to start of ebbing tide). At this point in the simulation, disposals from the TSHD occur at 5:10am, first seen in the 6am snapshot (dashed circle 1) and at 9:40am, first seen in the 10am snapshot (dashed circle 3), and a disposal from the BHD occurs at 6:10am, first seen in the 7am snapshot (dashed circle 2). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear.

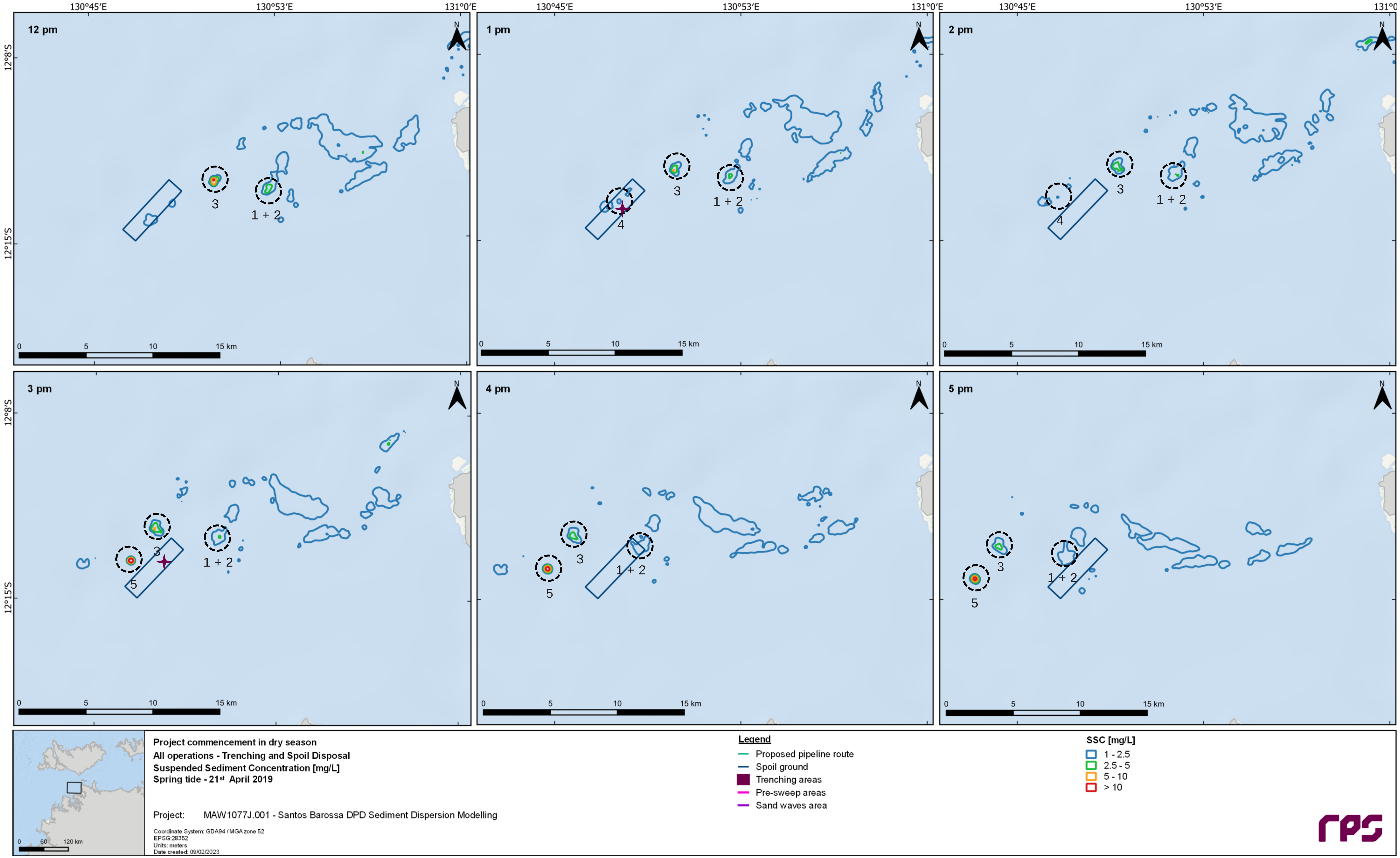

Figure 7.6 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal spring tide cycle in the winter/dry season scenario (based on 21 April 2019 12pm to 5pm, ebbing tide). At this point in the simulation, a disposal from the TSHD occurs at 2:05pm, first seen in the 3pm snapshot (dashed circle 5), and a disposal from the BHD occurs at 12:30pm, first seen in the 1pm snapshot (dashed circle 4). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear.

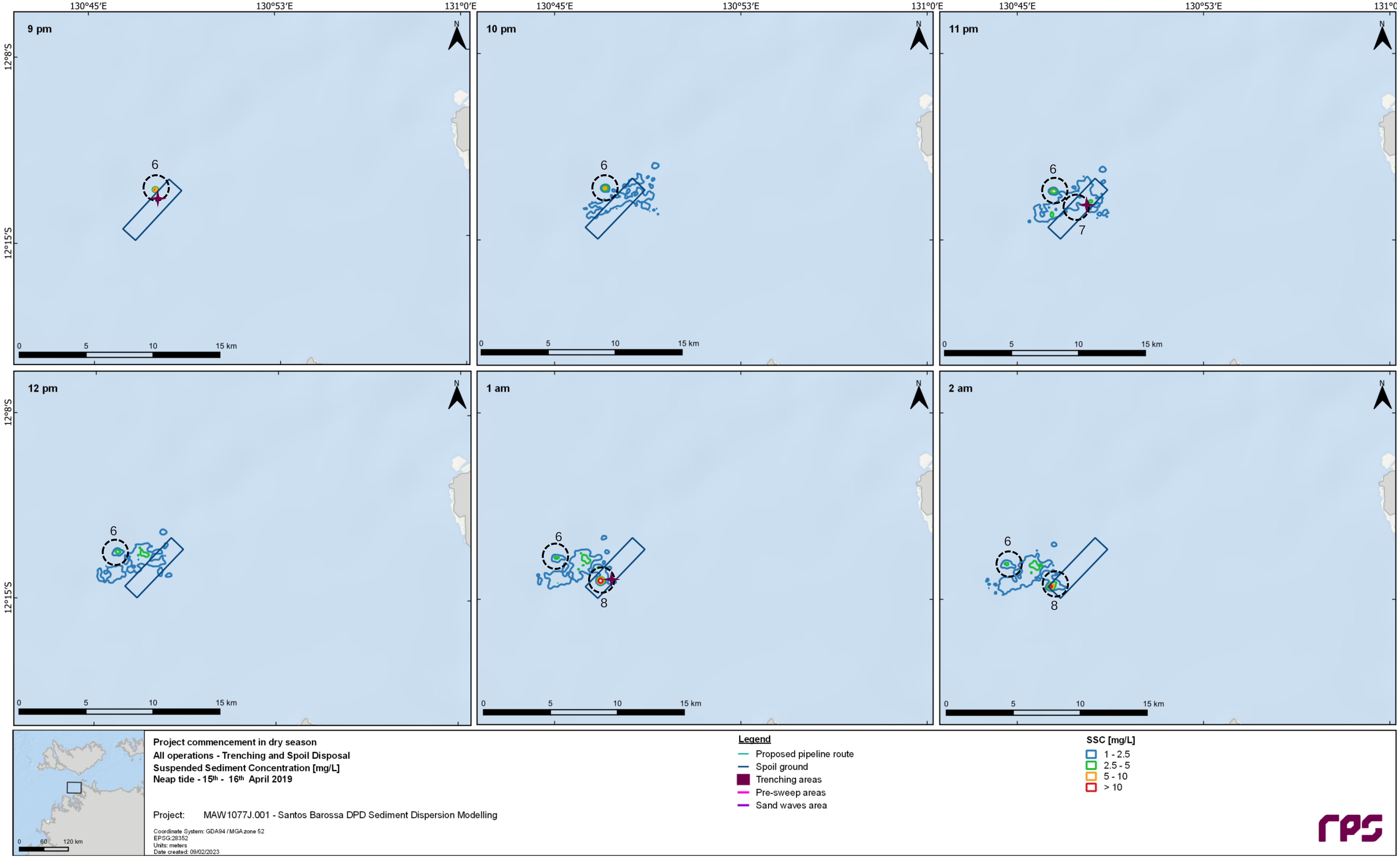

Figure 7.7 **Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal neap tide cycle in the winter/dry season scenario (based on 15-16 April 2019 9pm to 2am, ebbing tide). At this point in the simulation, disposals from the TSHD occur at 8:10pm, first seen on the 9pm snapshot (dashed circle 6) and at 12:36am, first seen on the 1am snapshot (dashed circle 8), and a disposal from the BHD occurs at 10:10pm, first seen on 11pm snapshot (dashed circle 7). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear.**

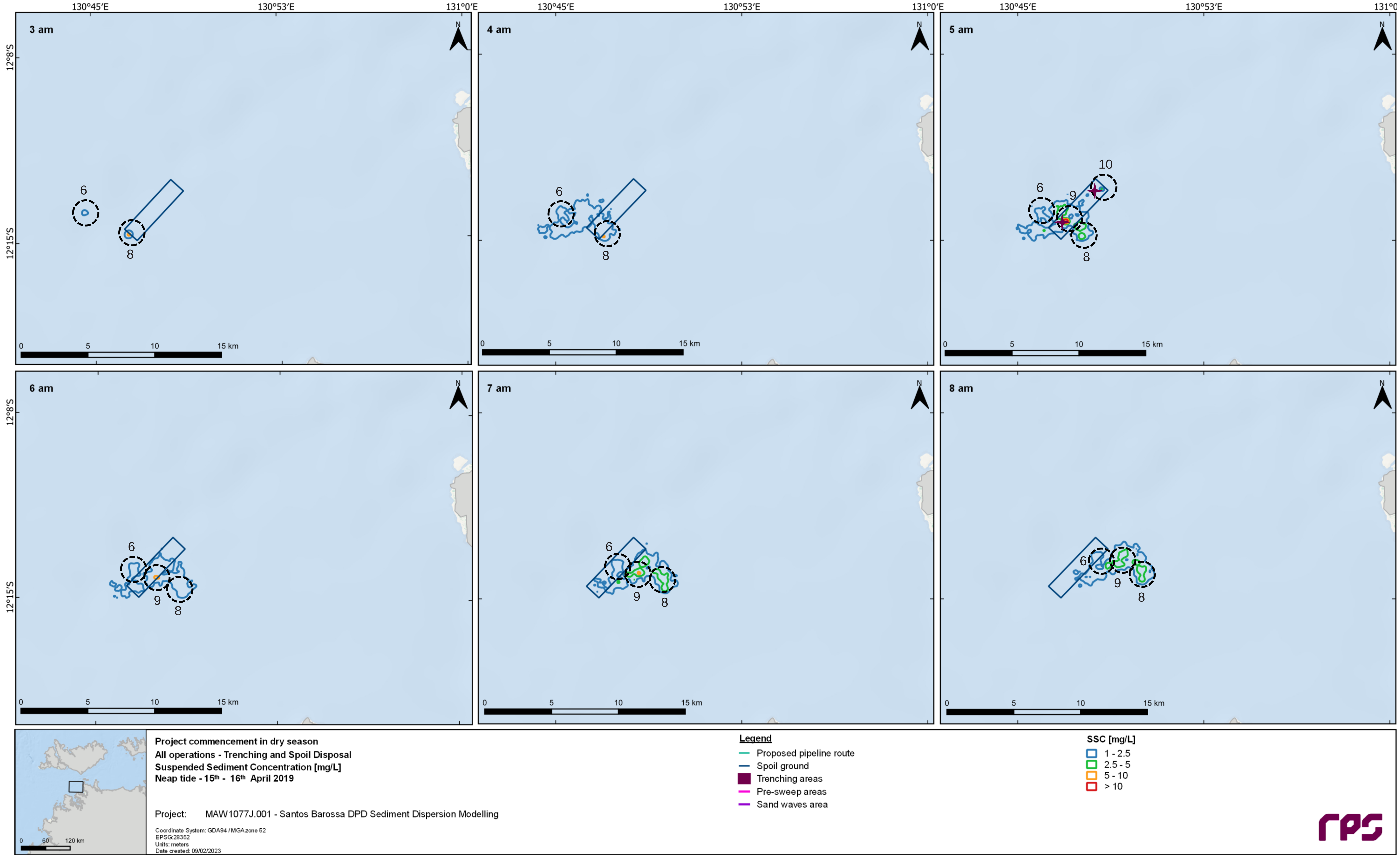

Figure 7.8 Example hourly snapshots of modelled sediment plume movement at the spoil ground during a nominal neap tide cycle in the winter/dry season scenario (based on 16 April 2019 3am to 8am, flooding tide). At this point in the simulation, disposals from the TSHD occur at 4:55am, first seen on the 5am snapshot (dashed circle 9) and BHD occur at 4:35 am, first seen on the 5am snapshot (dashed circle 10). The purple crosses show the location of disposals that have occurred prior to the snapshot in which the associated plumes first appear.

7.2 Spatial and Temporal Characteristics of SSC

7.2.1 Spatial Distribution of SSC

The results observed on any given day will not always be representative of the typical transport patterns, and plume concentrations and distributions are forecast to vary markedly. To explore this variability, statistical distributions for each scenario are examined. Percentile distributions will summarise the outcomes over the duration of the trenching and disposal operations (not including the run-on period) and do not represent an instantaneous plume footprint at any point in time.

Forecasts of median depth-averaged SSC values (values exceeded 50% of the time) do not exceed 1 mg/L in both seasonal scenarios, while at the 80th percentile values 1 mg/L or greater are forecast to be found in small, isolated patches just offshore of West Point (in line with Trench Zone 6) and at Wickham Point near the shore crossing area.

At the 90th percentile, the winter/dry season scenario forecasts show depth-averaged SSC values 1 mg/L or greater are found in a continuous band stretching north-westwards parallel with the coast to just offshore Charles Point, and southwards into Darwin Harbour extending a short way into Woods Inlet and to the eastern side of Talc Head. Smaller patches above 1 mg/L are predicted at other locations: around Wickham Point, in the middle Harbour area, in the vicinity of the proposed offshore disposal site, and in the shallows at South West Vernon Island (Figure 7.9). The corresponding summer/wet season scenario forecast shows a similar spatial area affected by SSC levels above 1 mg/L with some slight seasonal differences evident (Figure 7.11). In the summer/wet season scenario, the predicted 90th percentile SSC forecast shows the largest band above 1 mg/L has a shorter extent to the south and does not extend into Woods Inlet, a slightly larger area in the middle Harbour, and an extension of 1 mg/L concentrations to the north-east at the offshore disposal site.

At the 95th percentile, the winter/dry season scenario forecasts show depth-averaged SSC values 1 mg/L or greater are found in a continuous band stretching north-westwards parallel with the coast past Charles Point, and southwards into Darwin Harbour extending a short way into Woods Inlet and West Arm, with smaller patches above 1 mg/L extending from Wickham Point into the middle Harbour and a short way into Middle Arm. Depth-averaged SSC values 1 mg/L or greater are also found in the vicinity of the proposed offshore disposal site extending outwards to the east and west, with a larger extent to the east (Figure 7.10). Some very small patches above 1 mg/L are predicted in the shallows at South West Vernon Island. As found in the 90th percentile SSC distributions, the corresponding summer/wet season forecast shows a similar spatial area above 1 mg/L with some slight seasonal differences (Figure 7.12). Again, during the summer/wet season the largest band above 1 mg/L has a shorter extent to the south and there is an extension of 1 mg/L concentrations to the north-east at the offshore disposal site.

In both scenarios the 95th percentile depth-averaged SSC values are predicted to exceed 2.5 mg/L (but remain below 5 mg/L) in isolated patches in the vicinity of Trench Zone 6, extending ~8 km north-west and also south into Woods Inlet in the winter/dry season scenario, and extending ~13 km north-west with only minimal extent to the south in the summer/wet season scenario. Additionally, in both seasons the 95th percentile depth-averaged SSC values are predicted to exceed 2.5 mg/L in a relatively small patch extending north from Wickham Point and a very small patch in the shallows at South West Vernon Island.

To put the depth-averaged results into context of the variability within the water column, maps of the predicted 90th and 95th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program have been included in Figure 7.13 and Figure 7.14 for the winter/dry season scenario and Figure 7.15 and Figure 7.16 for the summer/wet season scenario. The regions predicted to have elevated levels of SSC are similar to the depth-averaged results, however the spatial area above a given concentration is greater for the maximum-in-water-column SSC. The plots reveal that there is significant variability in the vertical distributions of SSC in the water column and the results show there is a distinct increase in concentration towards the seabed. Thus, the spatial area affected above a given concentration is greater in the near-seabed layer than in the near-surface layer. The 90th percentile results for both seasonal scenarios do not exceed 10 mg/L, with the 95th percentile values only exceeding 10 mg/L (but remaining below 16 mg/L) in the vicinity of the offshore disposal area for both seasonal scenarios, and in the vicinity of Trench Zone 6 extending ~15 km north-west in the summer/wet season scenario.

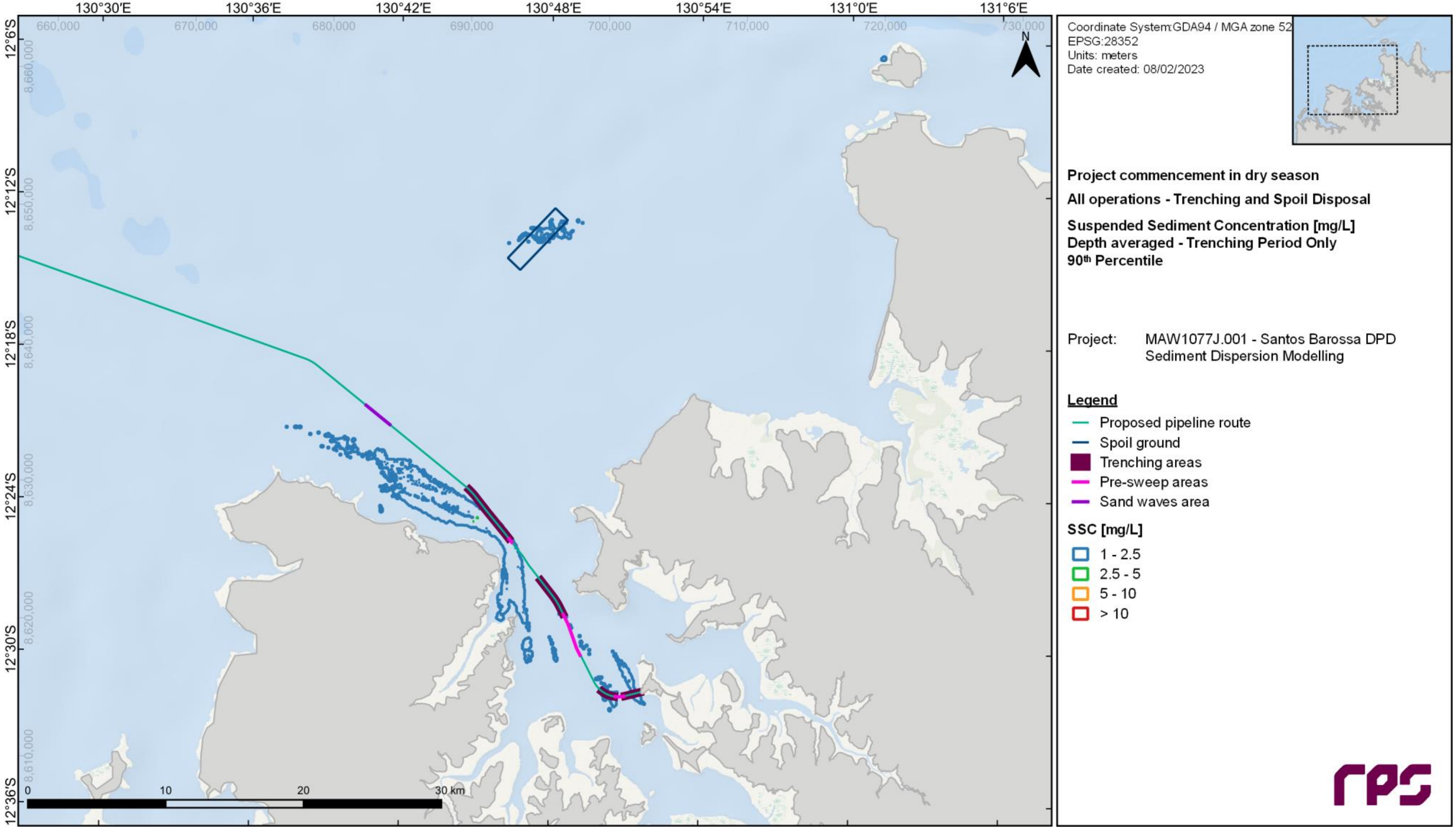

Figure 7.9 Predicted 90th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

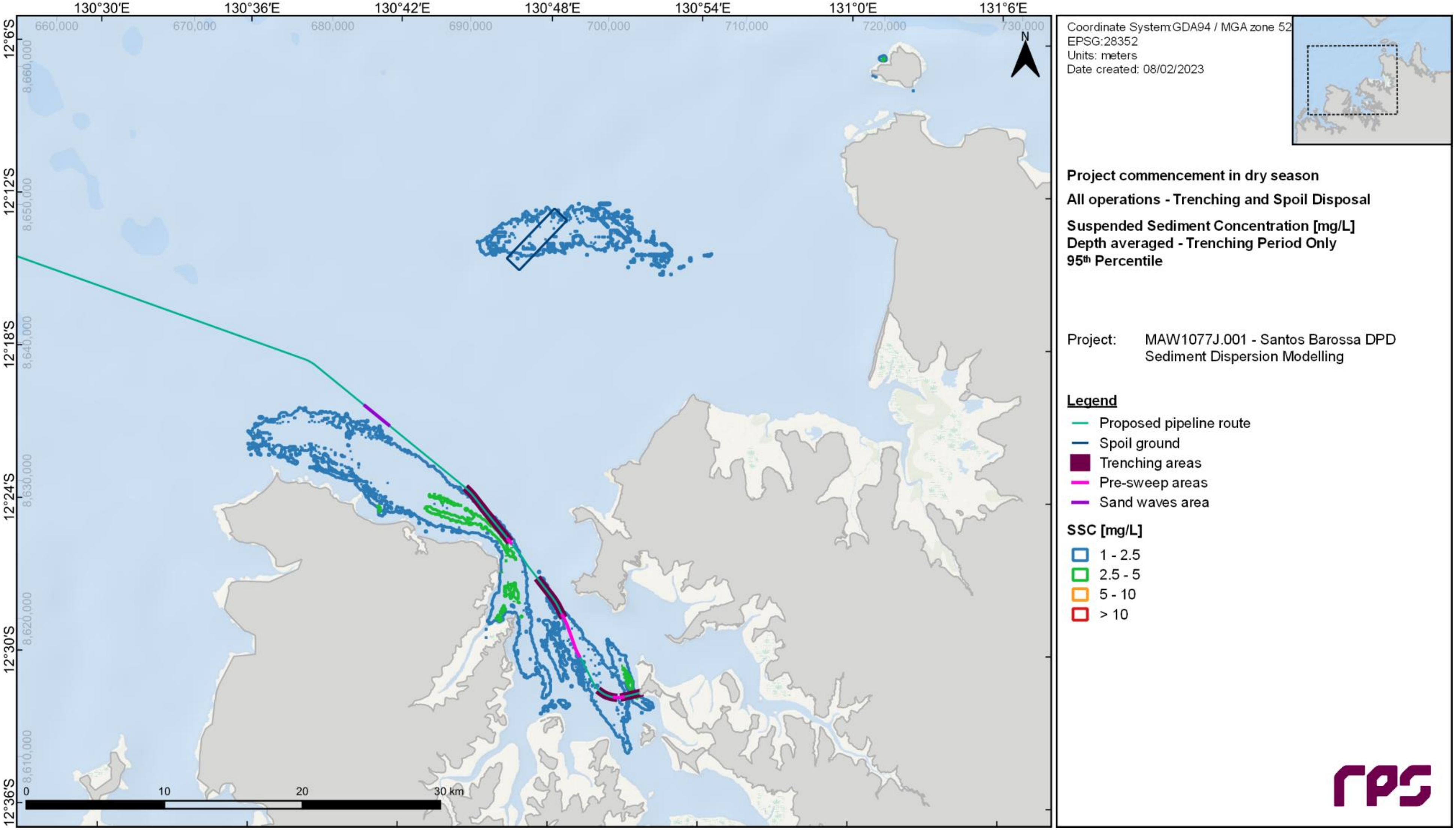

Figure 7.10 **Predicted 95th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

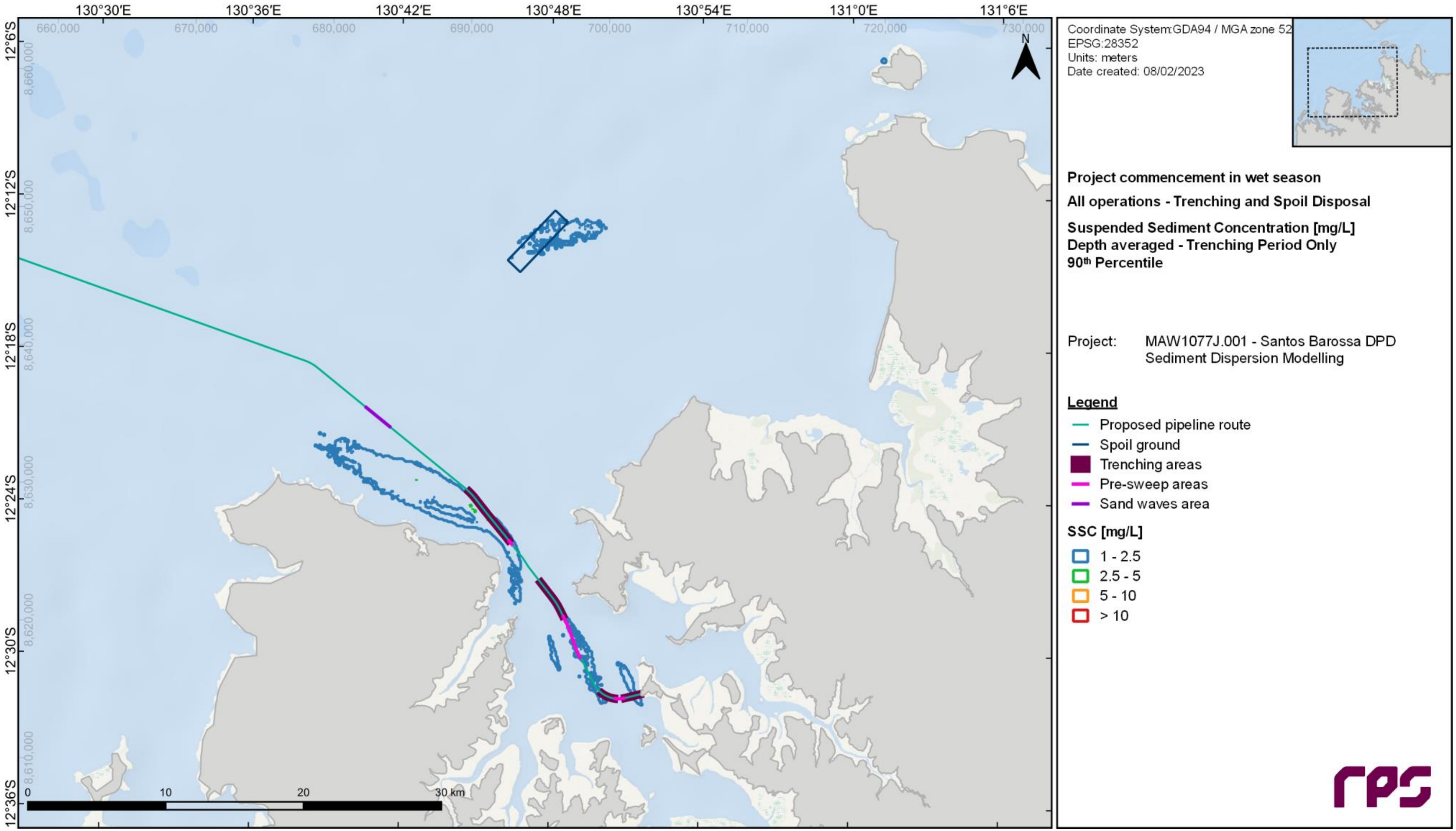

Figure 7.11 **Predicted 90th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

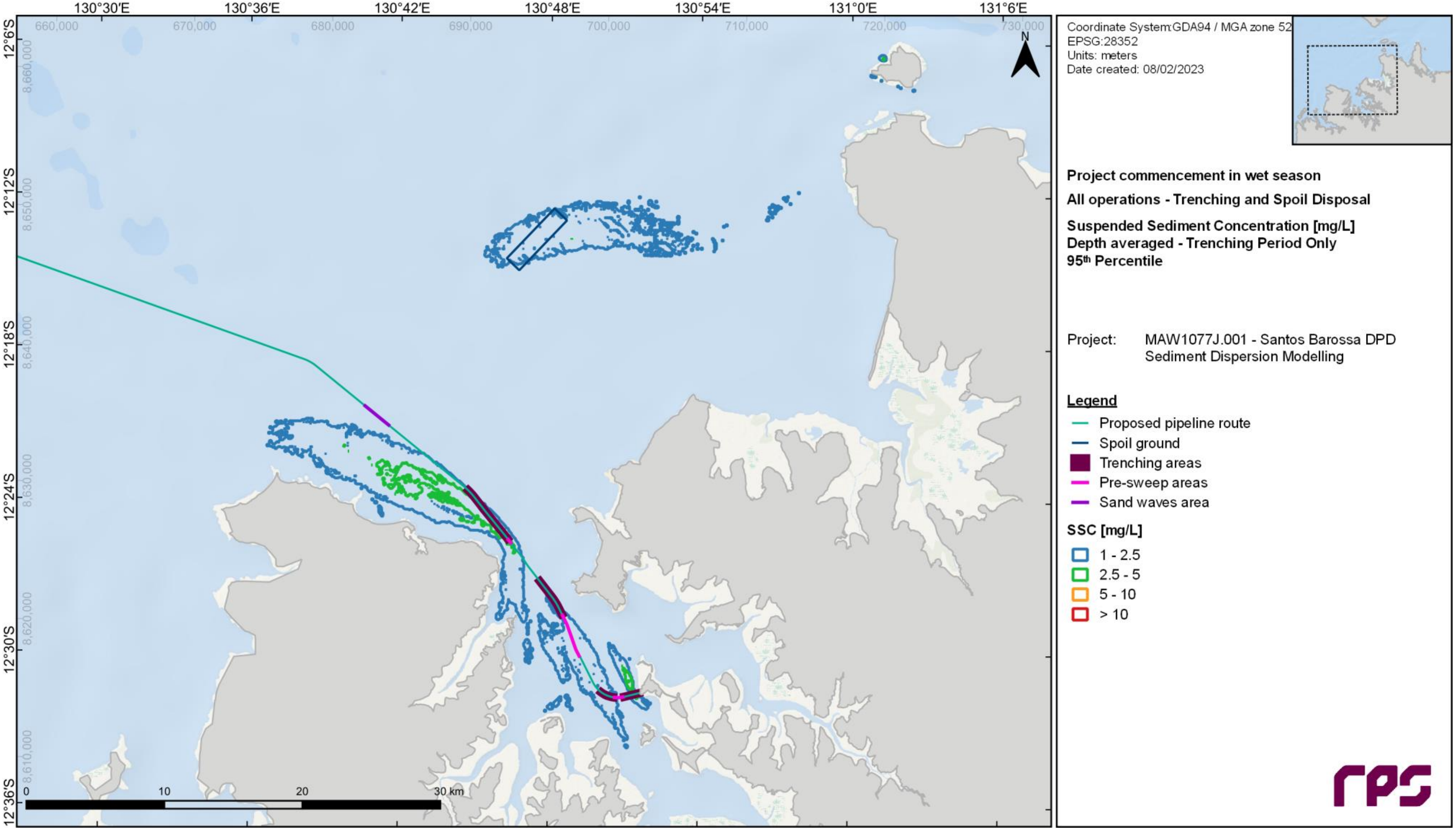

Figure 7.12 **Predicted 95th percentile depth-averaged trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

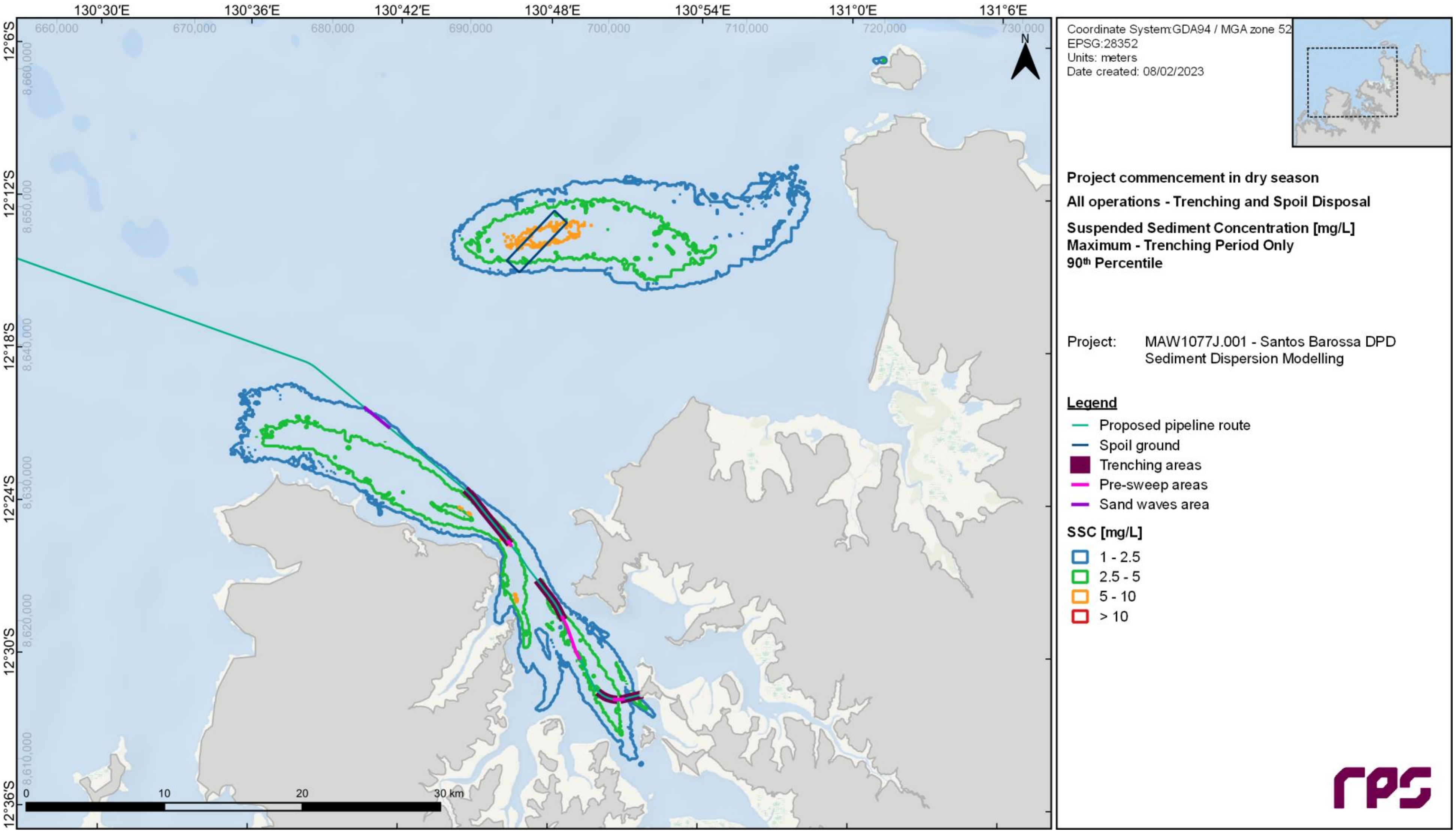

Figure 7.13 Predicted 90th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

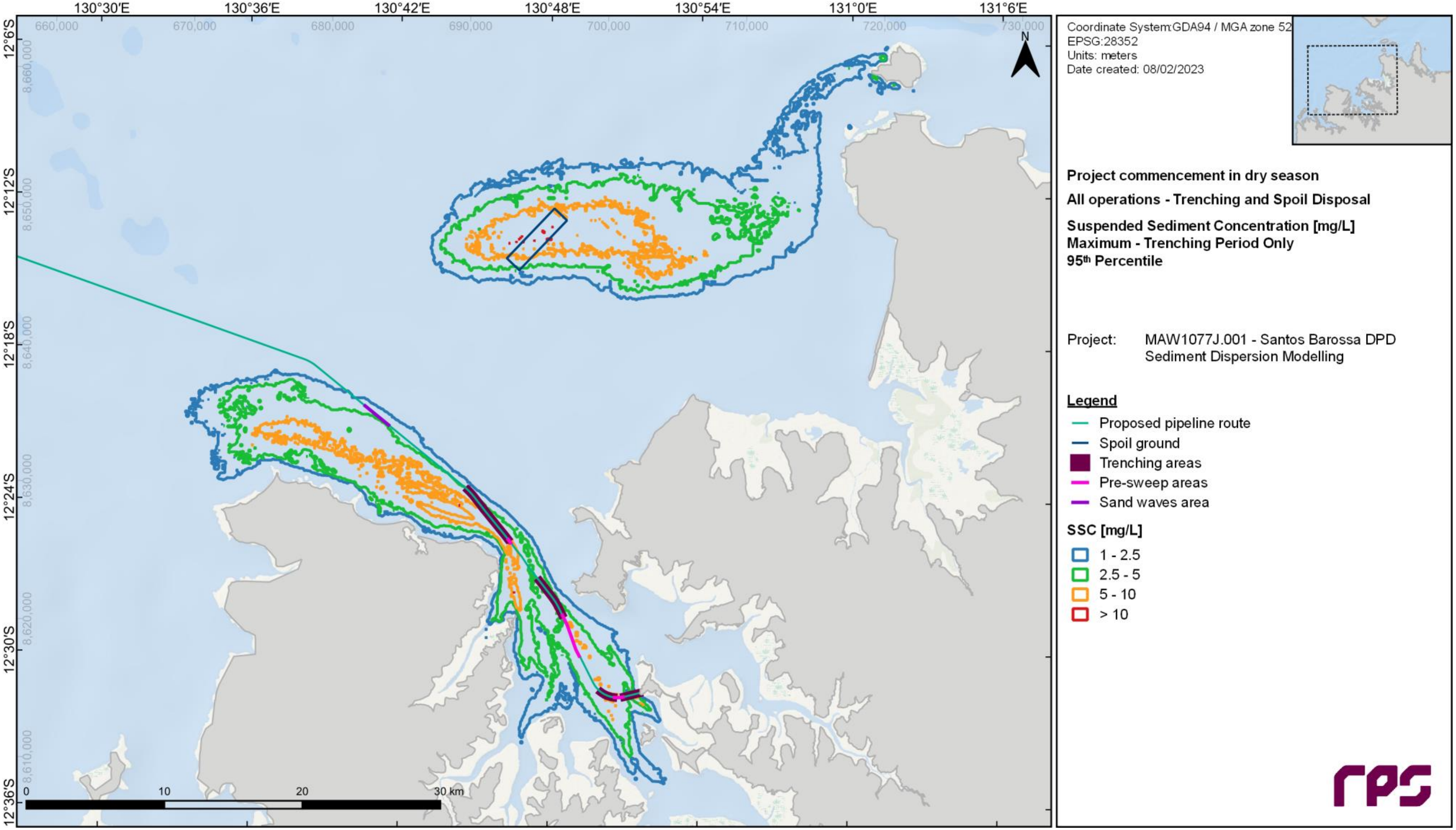

Figure 7.14 Predicted 95th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

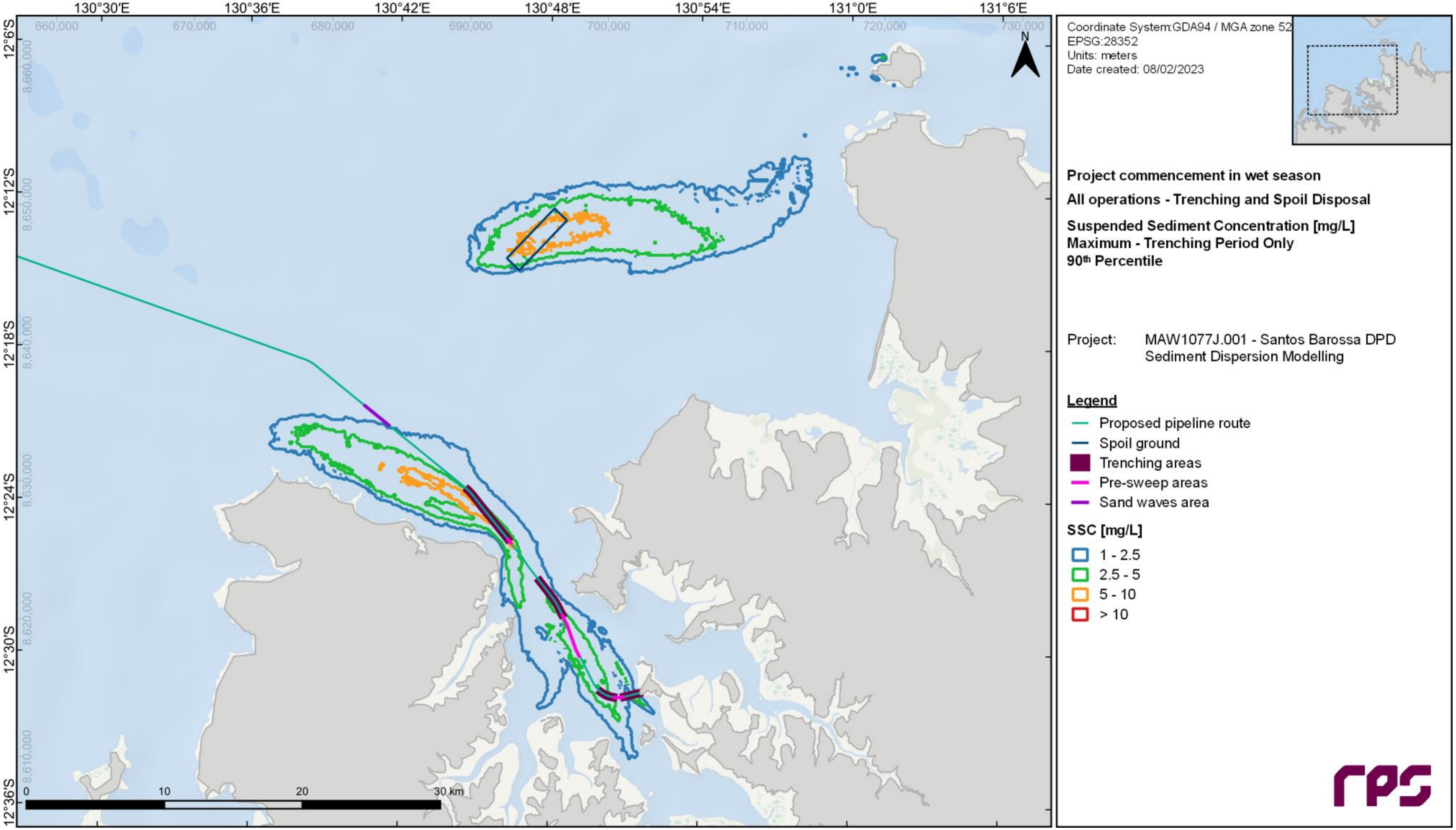

Figure 7.15 **Predicted 90th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

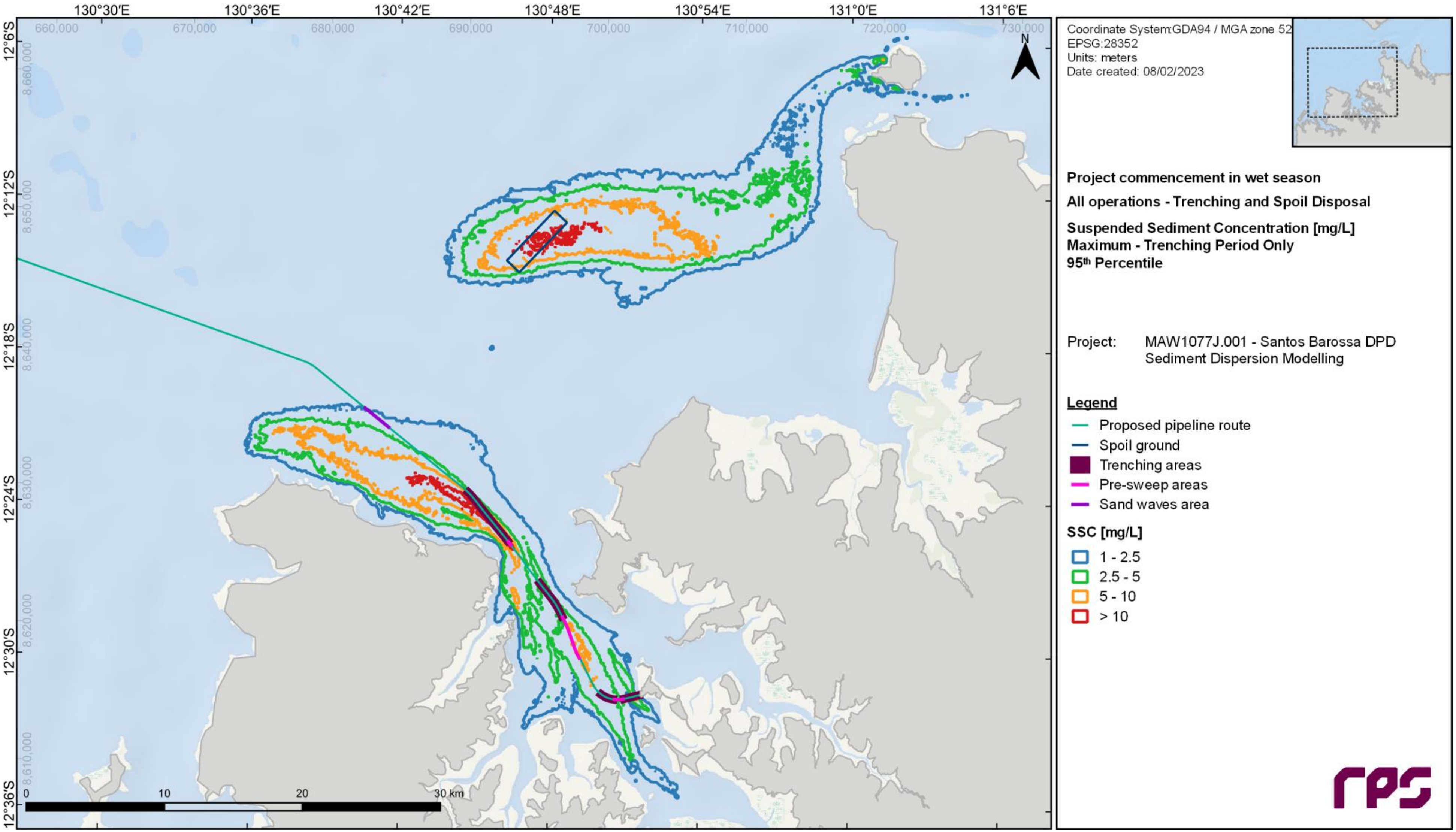

Figure 7.16 Predicted 95th percentile maximum-in-water-column trenching-excess SSC throughout the entire trenching program (not including run-on period) for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

7.2.2 Temporal Variability of SSC

The simulations indicated that there will be significant temporal variability in the distribution of SSC during the trenching and disposal operations. The vulnerability of sensitive receptors to elevated levels of SSC is a function of exposure intensity and duration (Sun *et al.*, 2020), and it will also depend on whether the exposure duration comprises multiple isolated (in time) events or a consecutive period of events.

To explore the temporal exposure of sensitive receptor sites, a time series analysis at a set of sensitive locations has been conducted to supplement the spatial maps. The set of analysis locations was selected from among the existing sensitive receptor monitoring sites that the model predicted would be reached by elevated SSC levels. In addition to the sensitive receptor monitoring sites, a set of locations was defined at the proposed offshore disposal area, and also at the Vernon Islands where elevated SSC levels were predicted by the model. Figure 7.17 and Table 7.1 present the locations of the points selected for the time series analysis. For presentation purposes the points have been split into groups as follows:

1. *WI_S*, *CHI* and *WED1* are the monitoring sites inside Darwin Harbour.
2. *CPW_1*, *MAN* and *CHP* are the monitoring sites outside Darwin Harbour.
3. *VI_S* and *VI_E* are the Vernon Island sites.
4. *OD1* to *OD5* are the offshore disposal ground long cross-section sites (aligned south-west to north-east).
5. *OD6* to *OD9* are the offshore disposal ground short cross-section sites (aligned north-west to south-east).

Table 7.1 Time series analysis point locations (reference datum: GDA94).

Point Name	Point Abbreviation	Longitude (°)	Latitude (°)
Woods Inlet South	WI_S	130.7683	-12.47390
Channel Island	CHI	130.8735	-12.55080
Weed Reef 1	WED1	130.7999	-12.48760
Charles Point West 1	CPW_1	130.6467	-12.38680
Mandorah	MAN	130.7700	-12.43530
Charles Point	CHP	130.6839	-12.40950
Vernon Islands – South West	VI_S	131.0184	-12.10627
Vernon Islands – East	VI_E	131.0700	-12.07746
Offshore Disposal Area Point 1	OD1	130.7553	-12.26529
Offshore Disposal Area Point 2	OD2	130.7814	-12.23756
Offshore Disposal Area Point 3	OD3	130.7904	-12.22830
Offshore Disposal Area Point 4	OD4	130.8001	-12.21846
Offshore Disposal Area Point 5	OD5	130.8253	-12.19286
Offshore Disposal Area Point 6	OD6	130.7773	-12.21576
Offshore Disposal Area Point 7	OD7	130.7869	-12.22465
Offshore Disposal Area Point 8	OD8	130.7952	-12.23249
Offshore Disposal Area Point 9	OD9	130.8036	-12.23999

Time series plots showing predicted depth-averaged and maximum-in-water-column trenching-excess SSC for each of the selected locations are presented for both the winter/dry and summer/wet season scenarios in Figure 7.18 through Figure 7.27 (note the scale on the y-axes changes between Figures). Supplementary to the plots, Table 7.2 presents the predicted 95th percentile, 98th percentile and maximum trenching-excess SSC for each of the selected locations in each seasonal scenario. The percentile values are presented because in some of the plots, to maintain a scale that clearly shows the general patterns of temporal variation at all sites, the y-axis limit has purposefully been selected to cut off the peaks. Lower percentiles have not been presented as at all sites analysed, for both the depth-averaged and maximum-in-water-column trenching-excess SSC, the median and 80th percentiles values are less than 1 mg/L.

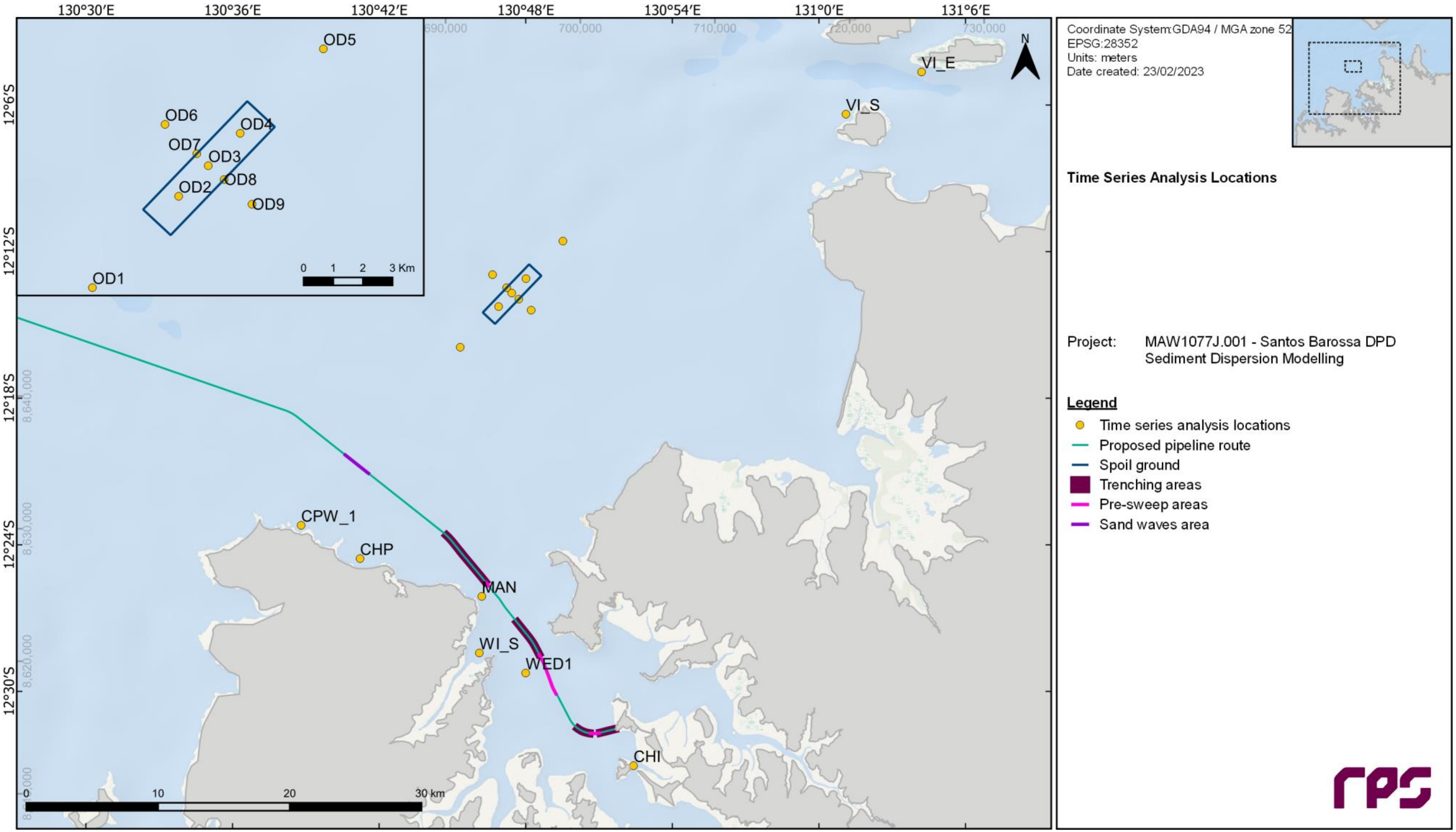

Figure 7.17 Time series analysis point locations. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation.

The temporal variation in trenching-excess SSC at all analysis sites reflects the spatial patchiness of the plumes and the oscillations of the dominant tidal flows in the area, with rapidly changing (over hourly scales) sharp peaks and troughs.

At the sites inside Darwin Harbour (Figure 7.18 and Figure 7.19) the intensity of SSC depends on the proximity to the trenching areas, with the plume rarely reaching *CHI* and only at low concentrations typically less than 4 mg/L. At *WI_S* the exposures show a clear tidal signal, with plumes predicted to reach the site during spring tidal periods and with minimal SSC exposure during neap tides. This site also shows seasonal differences, with higher peaks during the winter/dry season, reflecting the more southerly drift pattern during the dry season as found in the spatial plots. *WED1* sees similar levels of SSC to *WI_S*, however because it is in the mid-harbour close to the dredging areas there are minimal seasonal differences.

The sites outside Darwin Harbour along the coast from West Point to Charles Point (Figure 7.20 and Figure 7.21) show a similar pattern of exposure to the sites inside the harbour, with higher predicted SSC levels during spring tide periods, particularly towards the end of the trenching period when the dredging takes place closer to these sites. At *CPW1* and *MAN* the predicted trenching-excess SSC is relatively low, being less than 1 mg/L 98% of the time (Table 7.2). *CHP* is predicted to have higher SSC intensities than the other two sites, particularly during the summer/wet season when drift patterns tend towards the north-west along this section of the coast. However, as was found for all sites, the duration of the peaks in predicted SSC at *CHP* are short, and this is reflected in the 98th percentile SSC values which are less than 7 mg/L in both seasonal scenarios.

The time series of trenching-excess SSC at the Vernon Islands sites (Figure 7.22 and Figure 7.23) show that SSC intensities are predicted to be relatively low, particularly at *VI_E*. Peak SSC concentration are predicted to be typically higher in the summer/wet season scenario, showing the effect of increased drift trajectories towards the Clarence Strait during this season.

At the offshore disposal area sites, the temporal variability in predicted SSC also reflects the tidal oscillations with periods of spring and neap tides evident. However, superimposed on this signal is additional variability due to the sporadic nature of the disposal sources, which are variable in time and space (Figure 7.24 to Figure 7.27). The locations within the disposal ground (*OD2*, *OD3*, *OD4*, *OD7* and *OD8*) show similar overall patterns with periods of higher and lower SSC; however, the timings and intensities of the individual peaks vary due to the relative proximity of each site to individual disposal events. Although the peaks in SSC vary significantly between the sites, at the 95th and 98th percentile levels the values at the sites within the disposal area are very similar (less than 10 mg/L). These sites reveal that elevated SSC levels (in the order of 100-200 mg/L) occur immediately after disposal events but are rapidly dispersed and do not persist for long periods of time (scales of hours). The sites along the two cross-sectional alignments lying outside the disposal ground (*OD1*, *OD5*, *OD6* and *OD9*) show that the intensity of the modelled SSC values is predicted to reduce significantly within 1-3 km of the disposal ground boundaries.

Table 7.2 Percentiles (95th and 98th) and maximum predicted trenching-excess SSC (depth-averaged and maximum-in-water-column) for each of the time series analysis points, throughout the entire trenching program and run-on period for the winter/dry and summer/wet season scenarios.

Points	95th Percentile				98th Percentile				Maximum			
	Depth-Averaged		Maximum in Water Column		Depth-Averaged		Maximum in Water Column		Depth-Averaged		Maximum in Water Column	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
WI_S	1	1	1	1	2	1	3	1	15	6	16	6
CHI	0*	0*	0*	0*	0*	0*	0*	0*	4	2	6	5
WED1	1	1	2	2	1	1	4	4	4	4	17	15
CPW_1	0*	0*	0*	0*	0*	1	0*	1	3	10	5	17
MAN	1	0*	1	1	1	1	1	1	6	3	7	4
CHP	1	1	1	2	3	6	3	7	51	55	65	71
VI_S	0*	0*	1	1	0*	1	1	2	2	3	5	8
VI_E	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	2	3
OD1	0*	0*	1	1	0*	0*	1	1	1	3	6	19
OD2	1	1	4	4	1	1	8	9	33	9	163	42
OD3	1	1	5	5	1	2	9	10	10	14	52	88
OD4	1	1	4	5	1	1	7	7	6	11	27	50
OD5	0*	0*	1	1	0*	0*	2	2	2	2	17	16
OD6	0*	0*	2	2	1	1	5	5	9	3	47	21
OD7	1	1	5	6	1	2	9	10	18	5	102	36
OD8	1	1	4	5	1	2	8	10	13	12	68	86
OD9	0*	0*	2	2	1	1	5	5	6	3	36	19

* These values are greater than 0.0 but less than 0.5 mg/L.

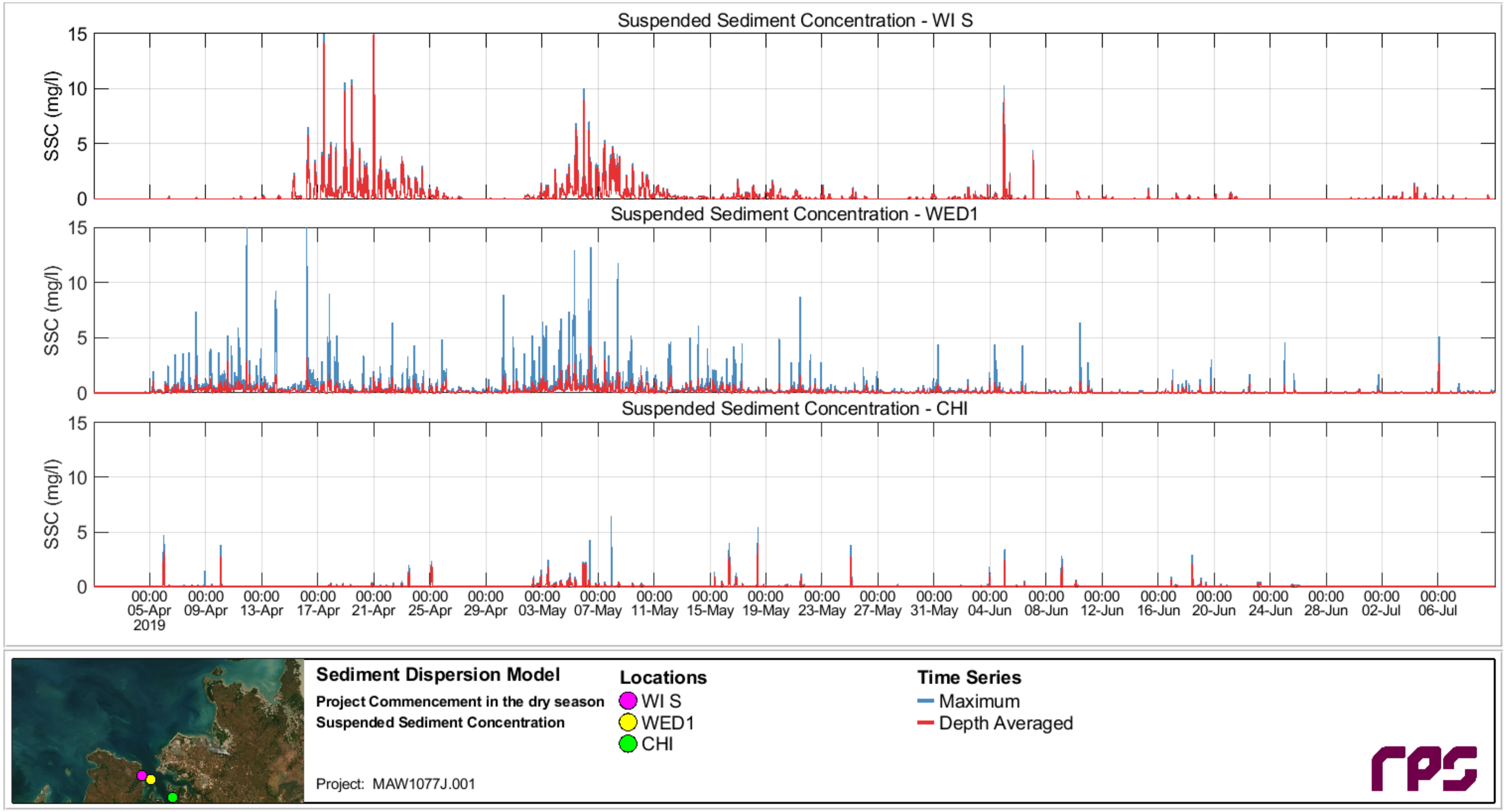

Figure 7.18 Time series of predicted trenching-excess SSC at the ***WI_S***, ***WED1*** and ***CHI*** sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

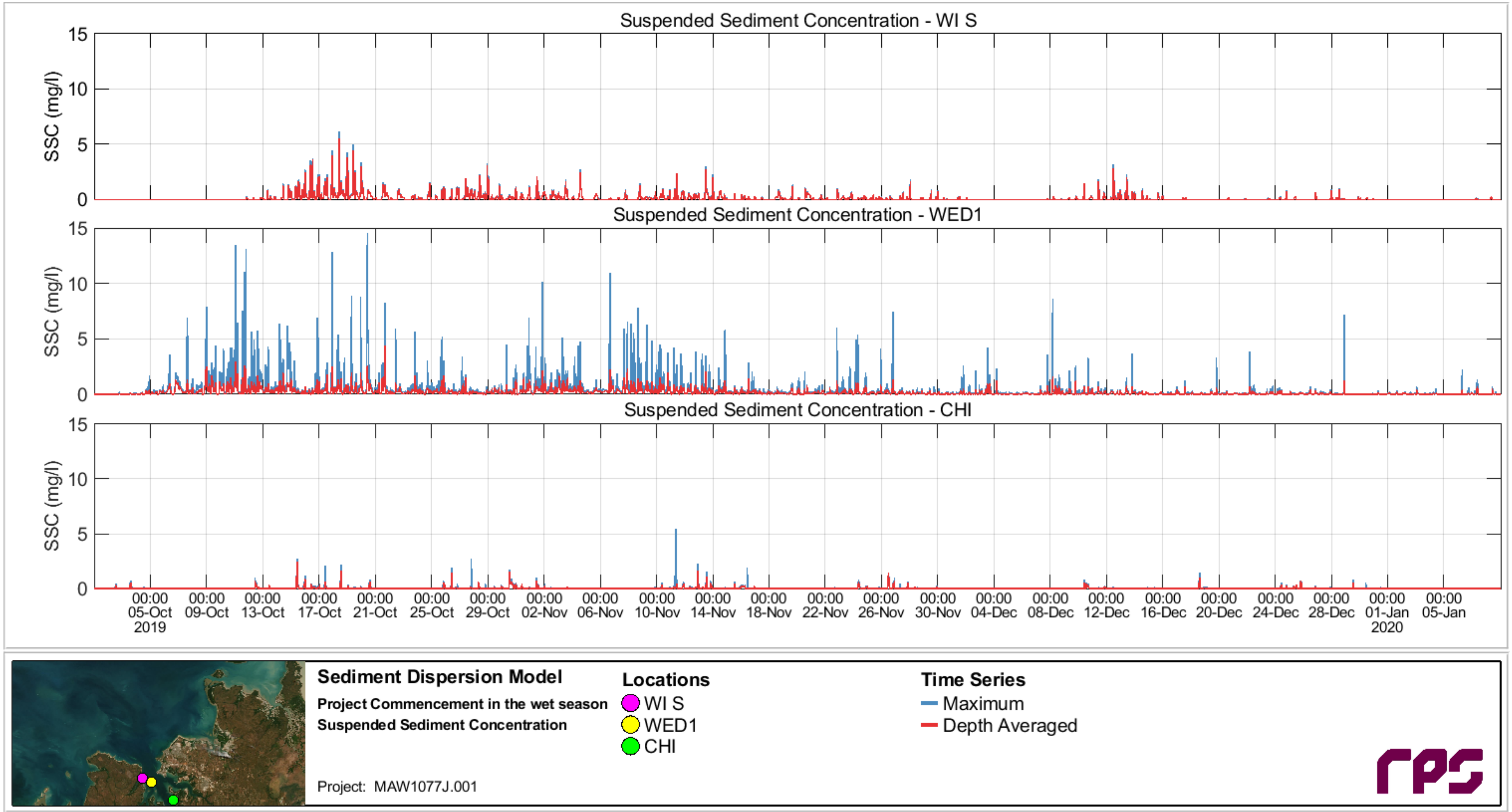

Figure 7.19 Time series of predicted trenching-excess SSC at the *WI_S*, *WED1* and *CHI* sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

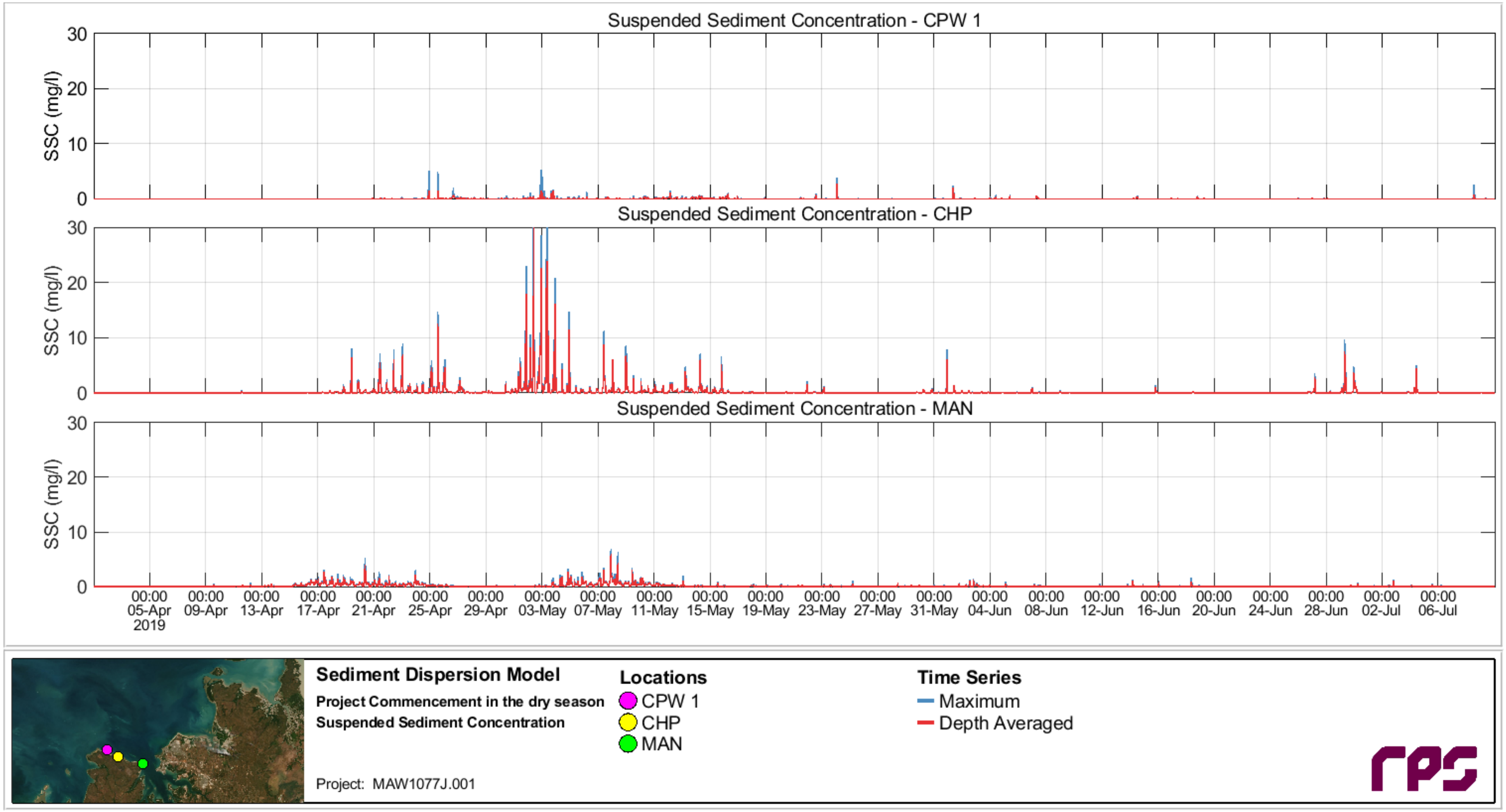

Figure 7.20 **Time series of predicted trenching-excess SSC at the *CPW1*, *MAN* and *CHP* sites throughout the entire trenching program and run-on period in the winter/dry season scenario.**

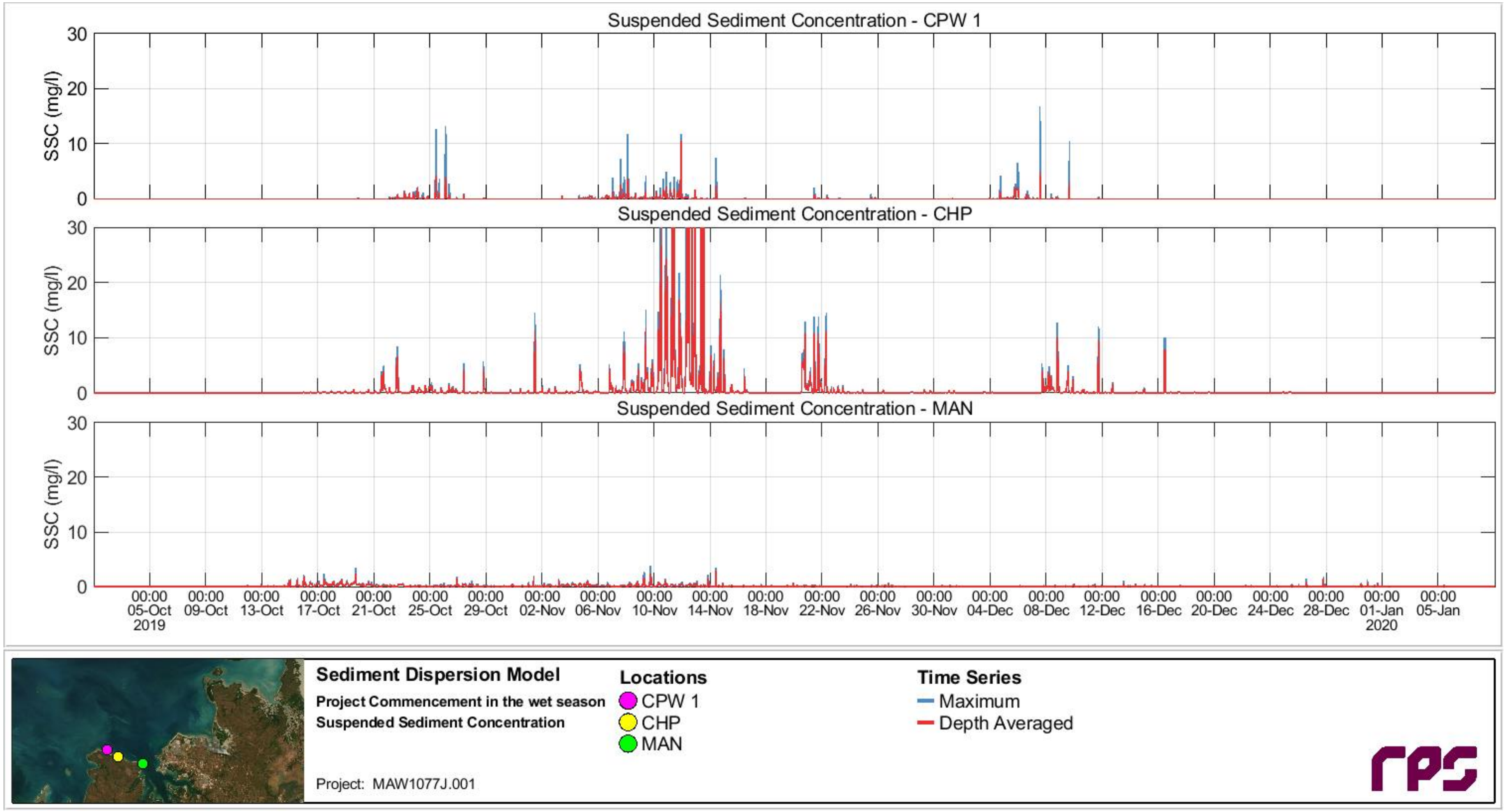

Figure 7.21 Time series of predicted trenching-excess SSC at the *CPW1*, *MAN* and *CHP* sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

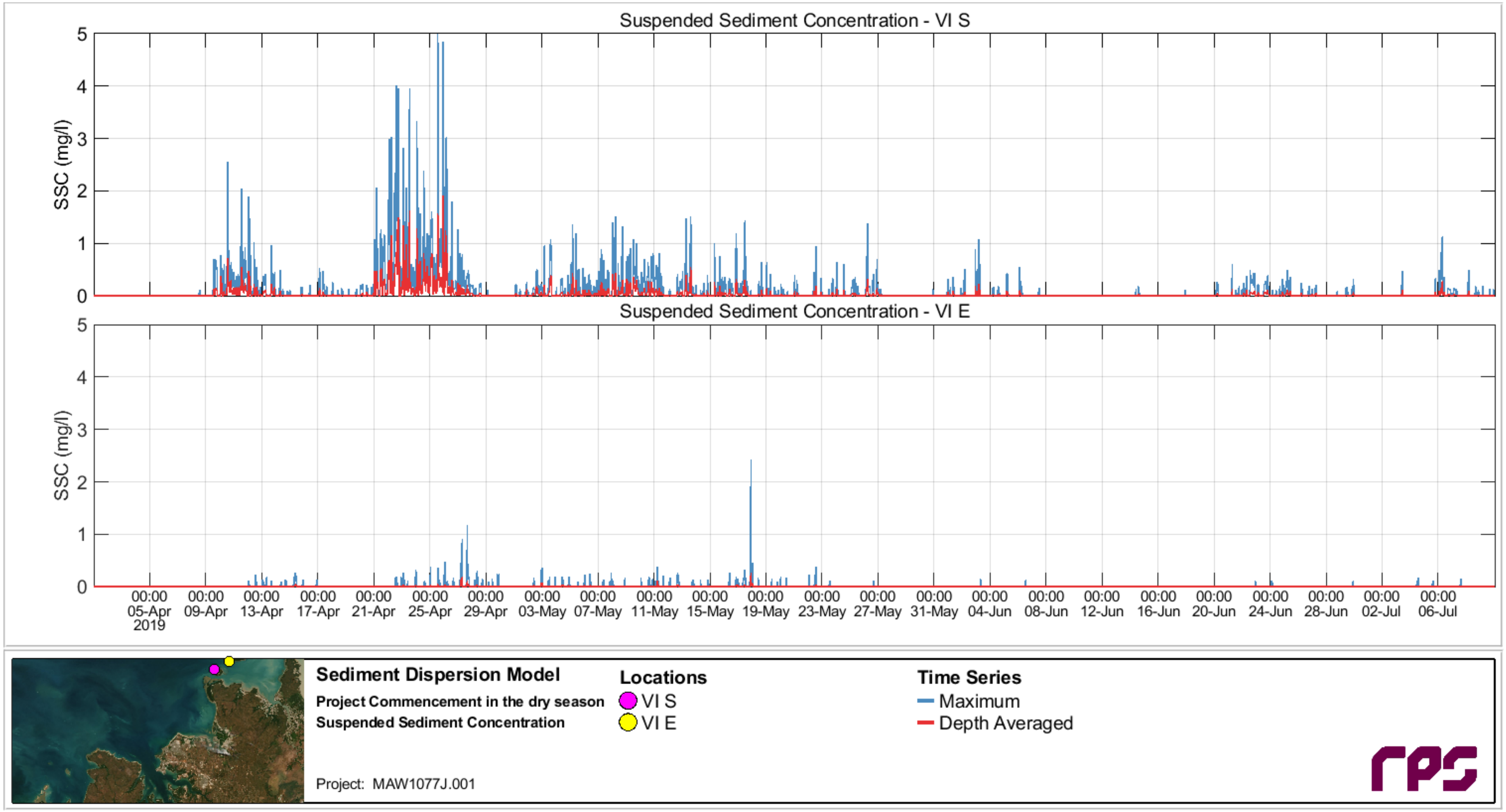

Figure 7.22 Time series of predicted trenching-excess SSC at the *VI_S* and *VI_E* sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

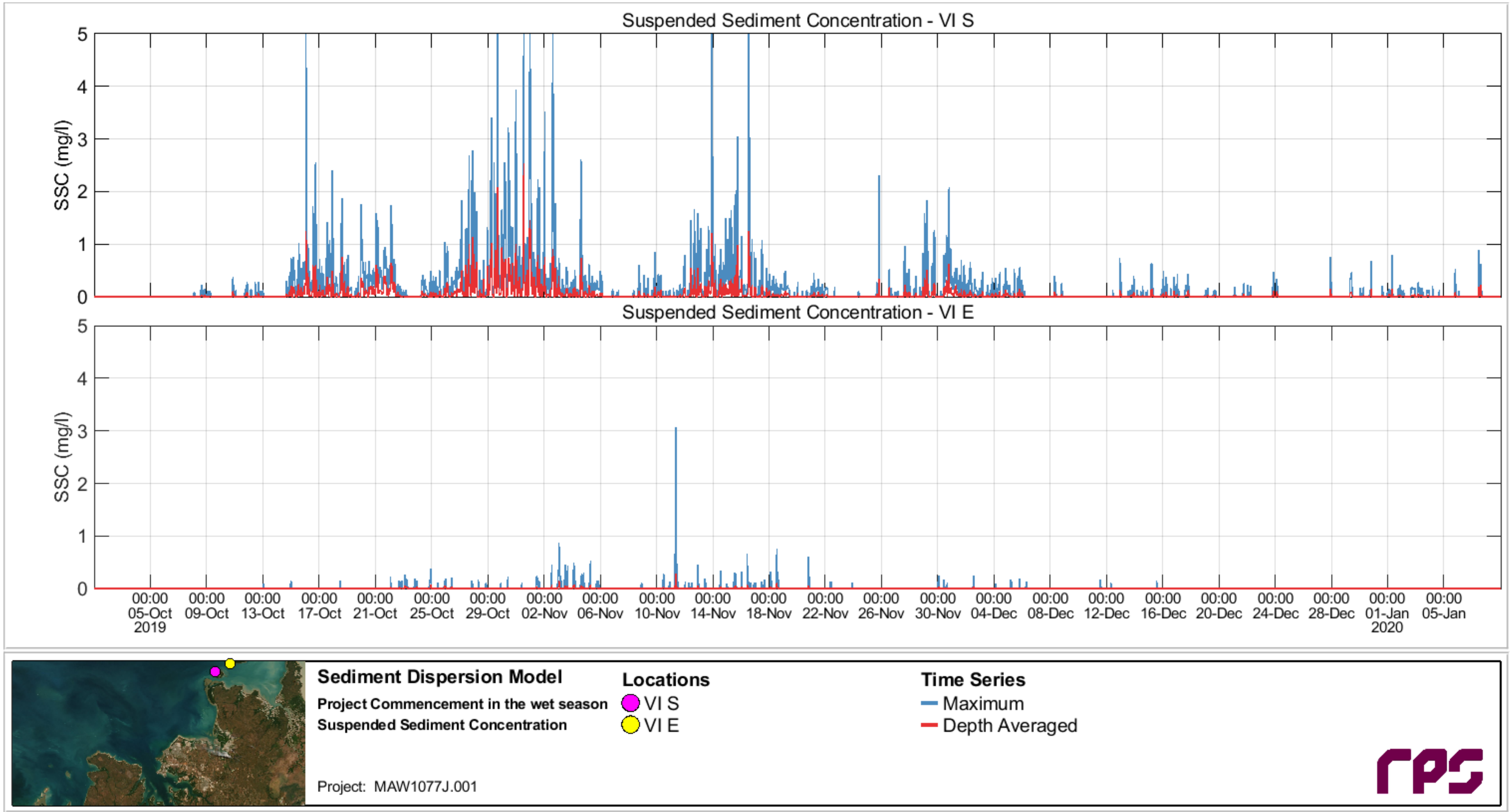

Figure 7.23 **Time series of predicted trenching-excess SSC at the *VI_S* and *VI_E* sites throughout the entire trenching program and run-on period in the summer/wet season scenario.**

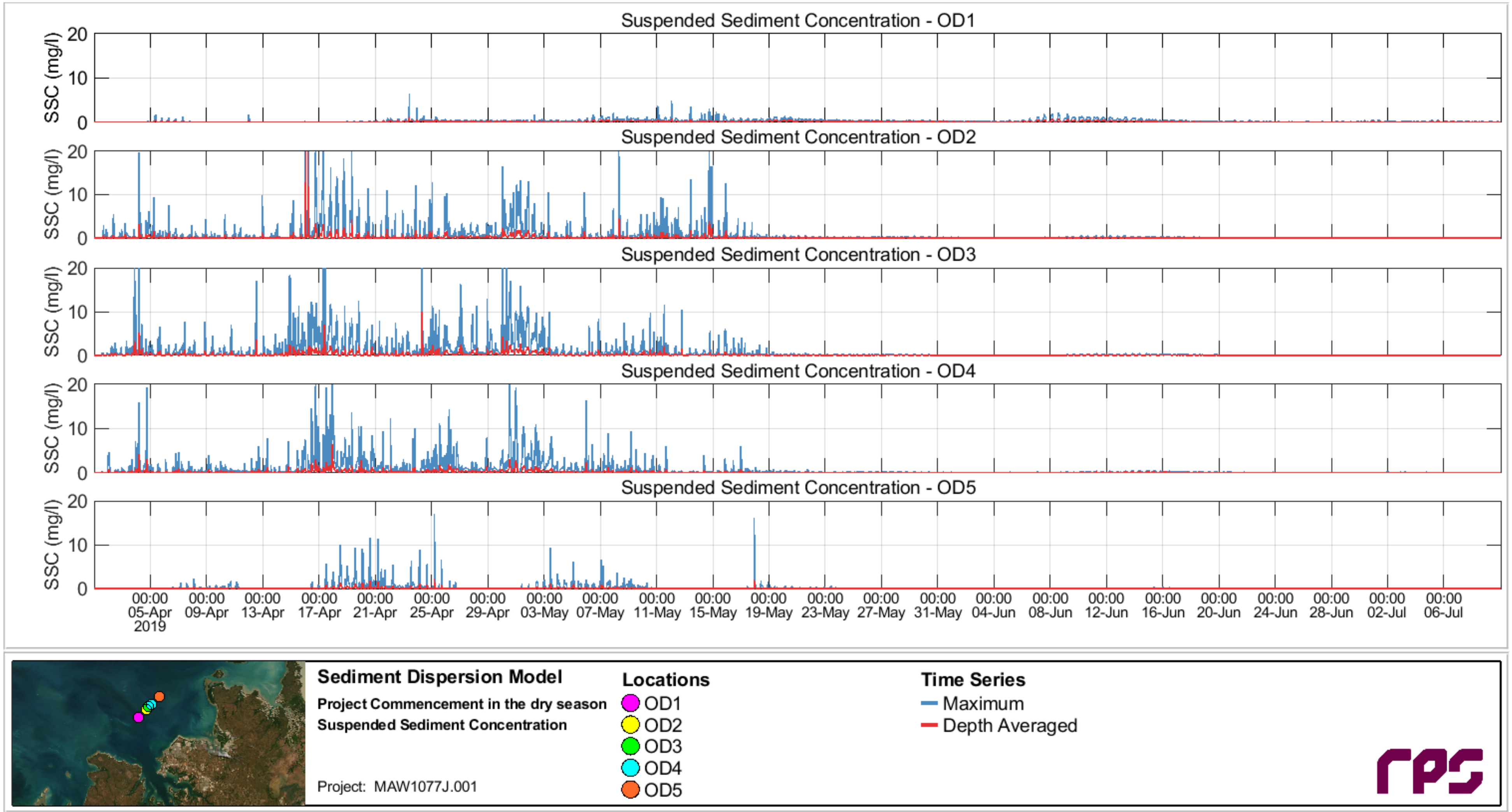

Figure 7.24 **Time series of predicted trenching-excess SSC at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the winter/dry season scenario.**

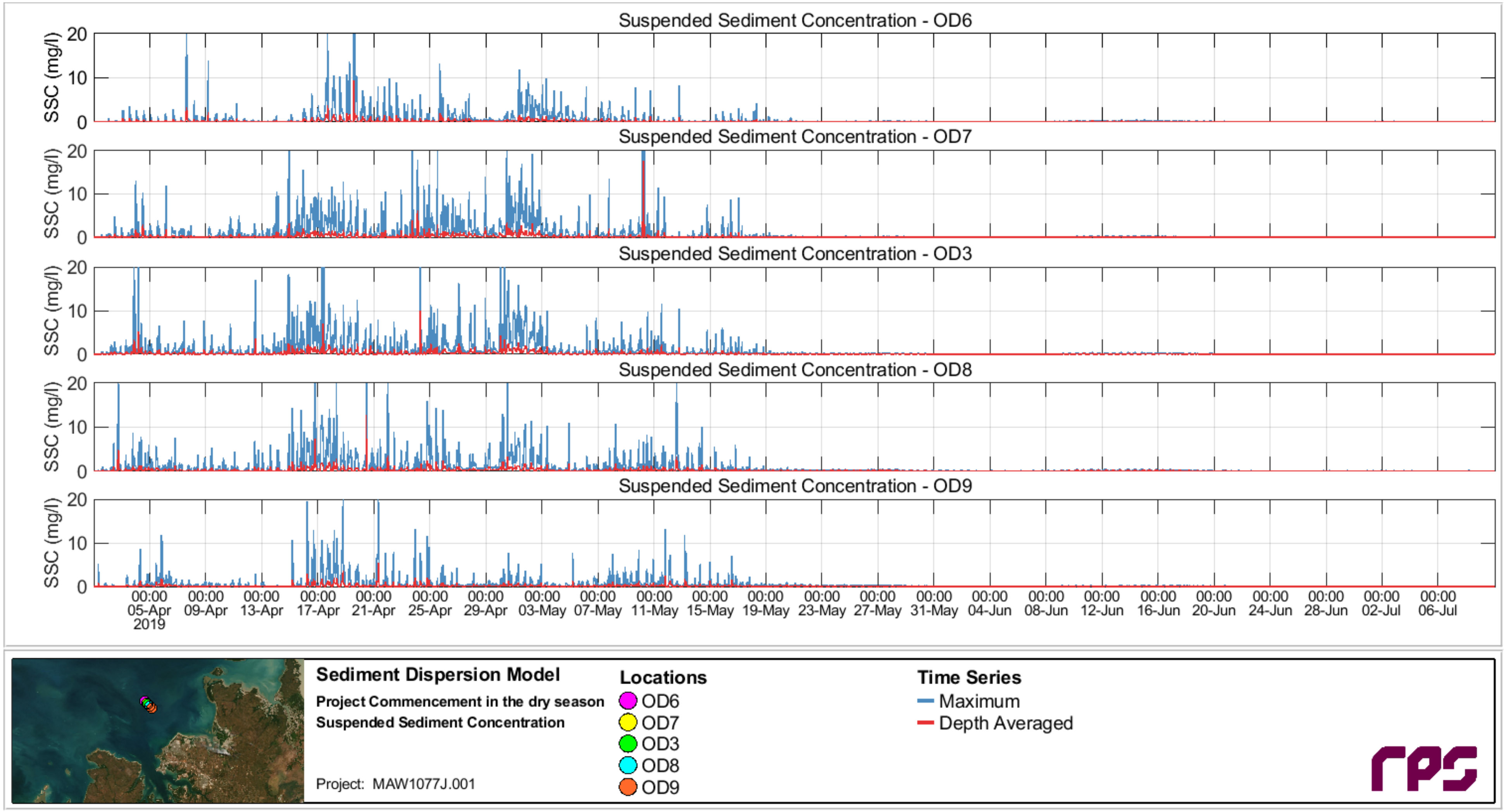

Figure 7.25 **Time series of predicted trenching-excess SSC at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the winter/dry season scenario.**

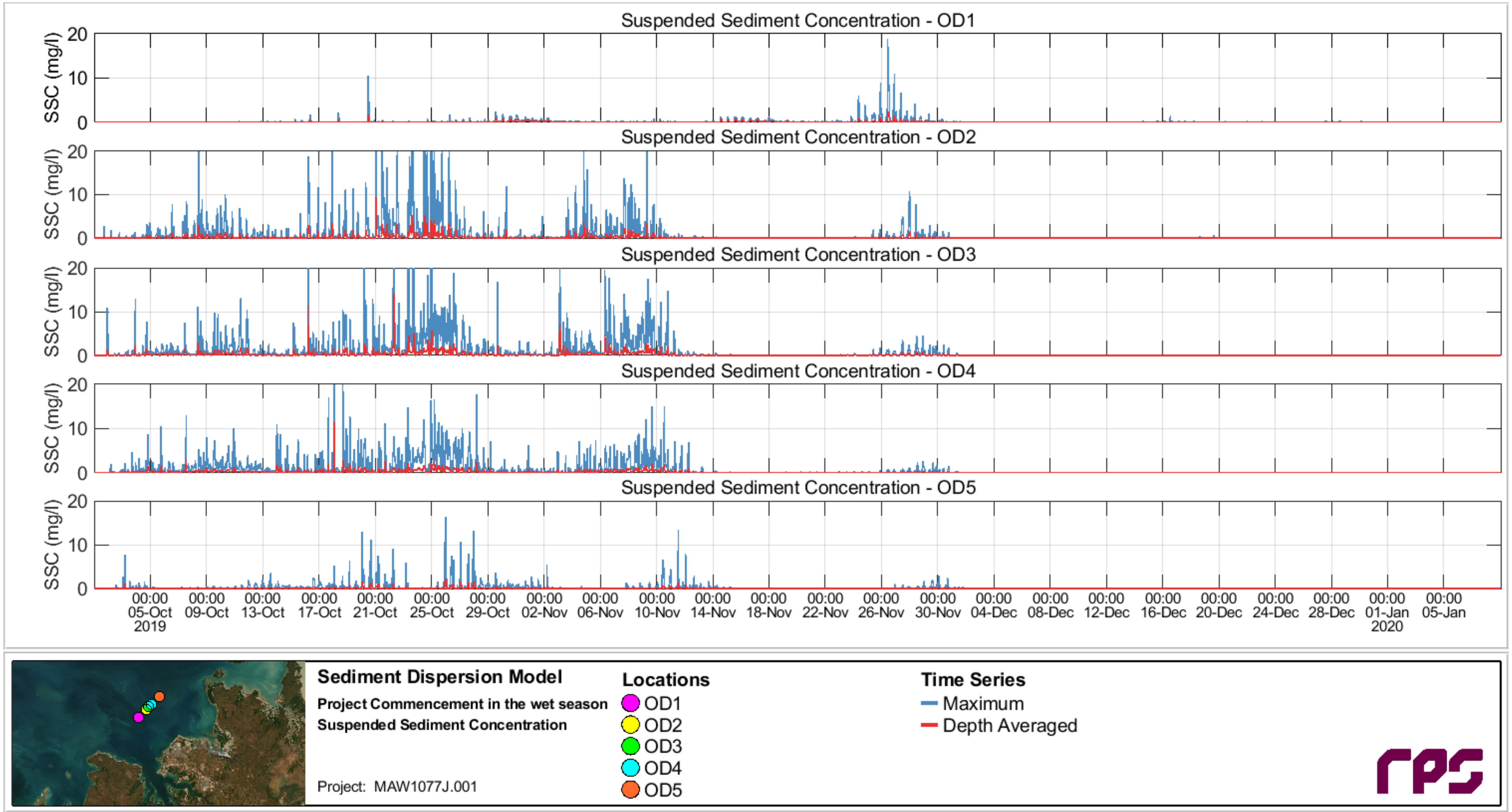

Figure 7.26 Time series of predicted trenching-excess SSC at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

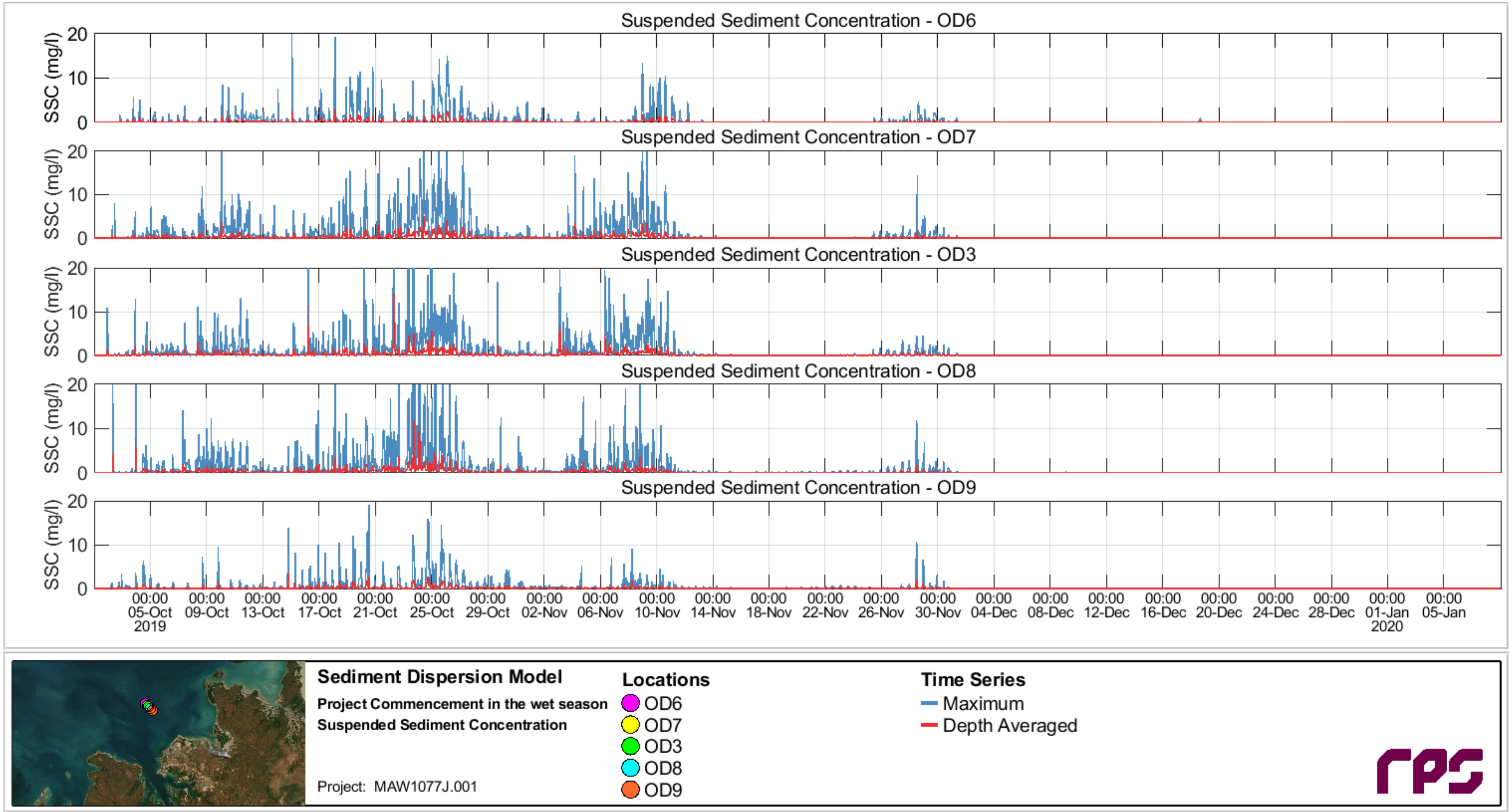

Figure 7.27 Time series of predicted trenching-excess SSC at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

7.3 Spatial and Temporal Characteristics of Sedimentation

7.3.1 Spatial Distribution of Sedimentation

Given the strong tidal flows in the Darwin area, settlement of the finer trenching-generated sediment is minimal with fine material (clay and silts) being continuously resuspended on each tide, particularly during spring tide periods where even fine sand size material is predicted to be resuspended. Coarse material (sand size) is predicted to settle rapidly near the trenching zones and at the proposed offshore disposal area, but the fine material will remain suspended, or will deposit at slack tide only to be resuspended on the following tide. This results in suspended sediment plumes having long drift trajectories, with sediments dispersed widely but at low concentrations, and with sediments deposited in thin layers.

Figure 7.28 presents the predicted maximum trenching-excess sediment thickness over the entire trenching and spoil disposal program, and Figure 7.29 and Figure 7.30 present the trenching-excess sediment thickness at the end of the trenching program (not including run-on period) and at the end of the run-on period respectively, for the winter/dry season scenario. A comparison of the spatial distributions in these three figures shows that sedimentation of greater than 1 mm thickness is typically limited to the vicinity of the trenching and disposal operations, with deposited sediments at greater distances being of very low concentration/thickness and most likely consisting of finer material that is resuspended and further dispersed by the end of the trenching program and run-on period.

The spatial distributions of sedimentation for the summer/wet season scenario (Figure 7.31, Figure 7.32 and Figure 7.33) show a similar pattern of deposition, with sedimentation of greater than 1 mm thickness typically limited to the vicinity of the trenching and disposal operations, and sediments deposited at greater distances being of very low concentration/thickness and further dispersed by the end of the trenching program and end of the run-on period. A small additional patch of sedimentation with a thickness greater than 1 mm is predicted in the shallows at South West Vernon Island for the summer/wet season scenario.

It should be noted that the disposal area sediment thickness values do not represent all material that will be placed at the disposal ground, but only the proportions of the material assumed to be initially suspended during placement or deposited in the surface layer available for potential resuspension (see Sections 5.6.3 and 5.6.5 for source rates). As such, actual sediment thicknesses within the disposal area may be greater than the values presented in the figures here.

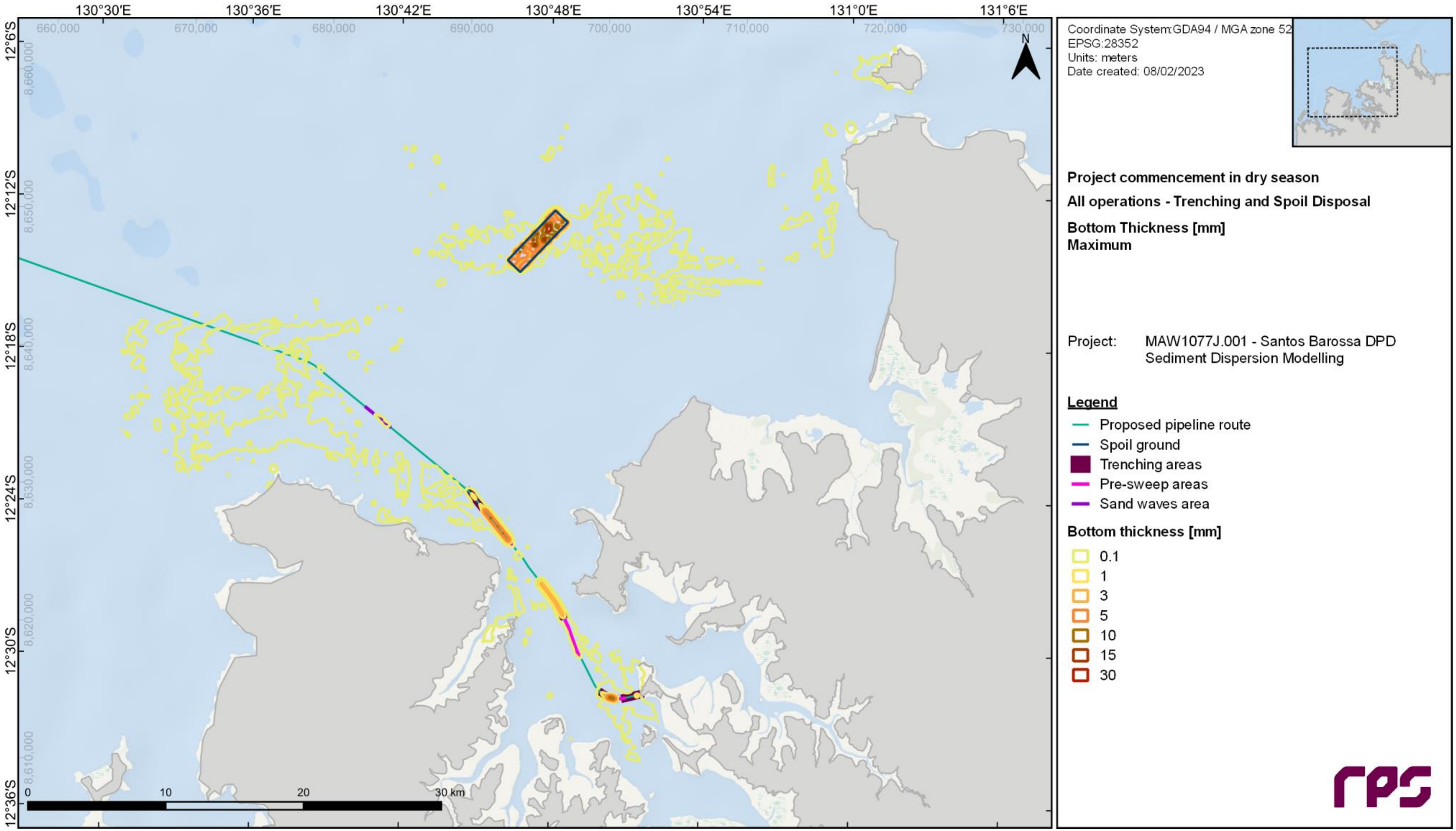

Figure 7.28 **Predicted maximum trenching-excess bottom thickness (mm) throughout the entire trenching program for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

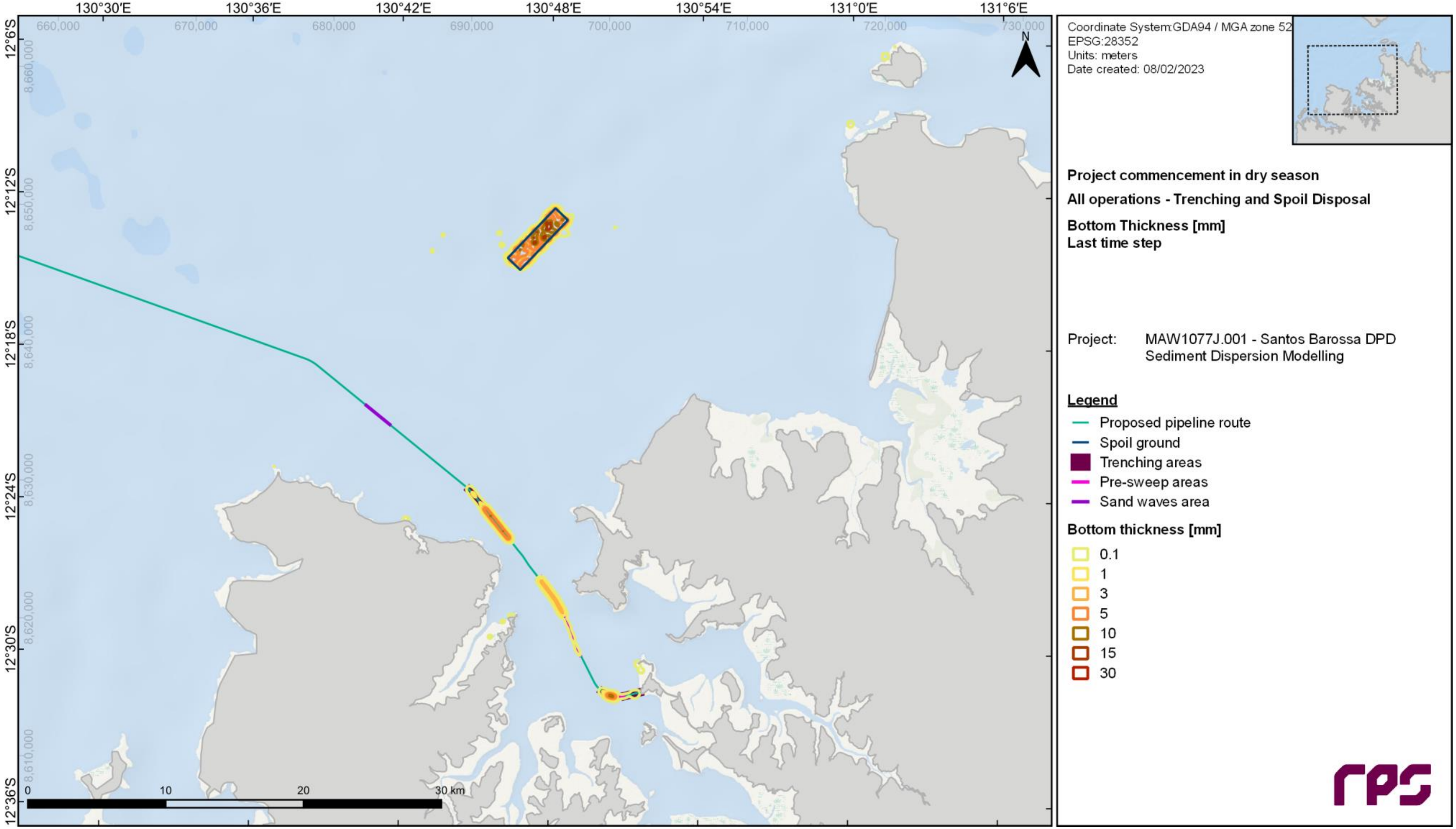

Figure 7.29 Predicted trenching-excess bottom thickness (mm) at the last time step of the trenching program (not including run-on period) for the winter/dry season scenario (based on 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

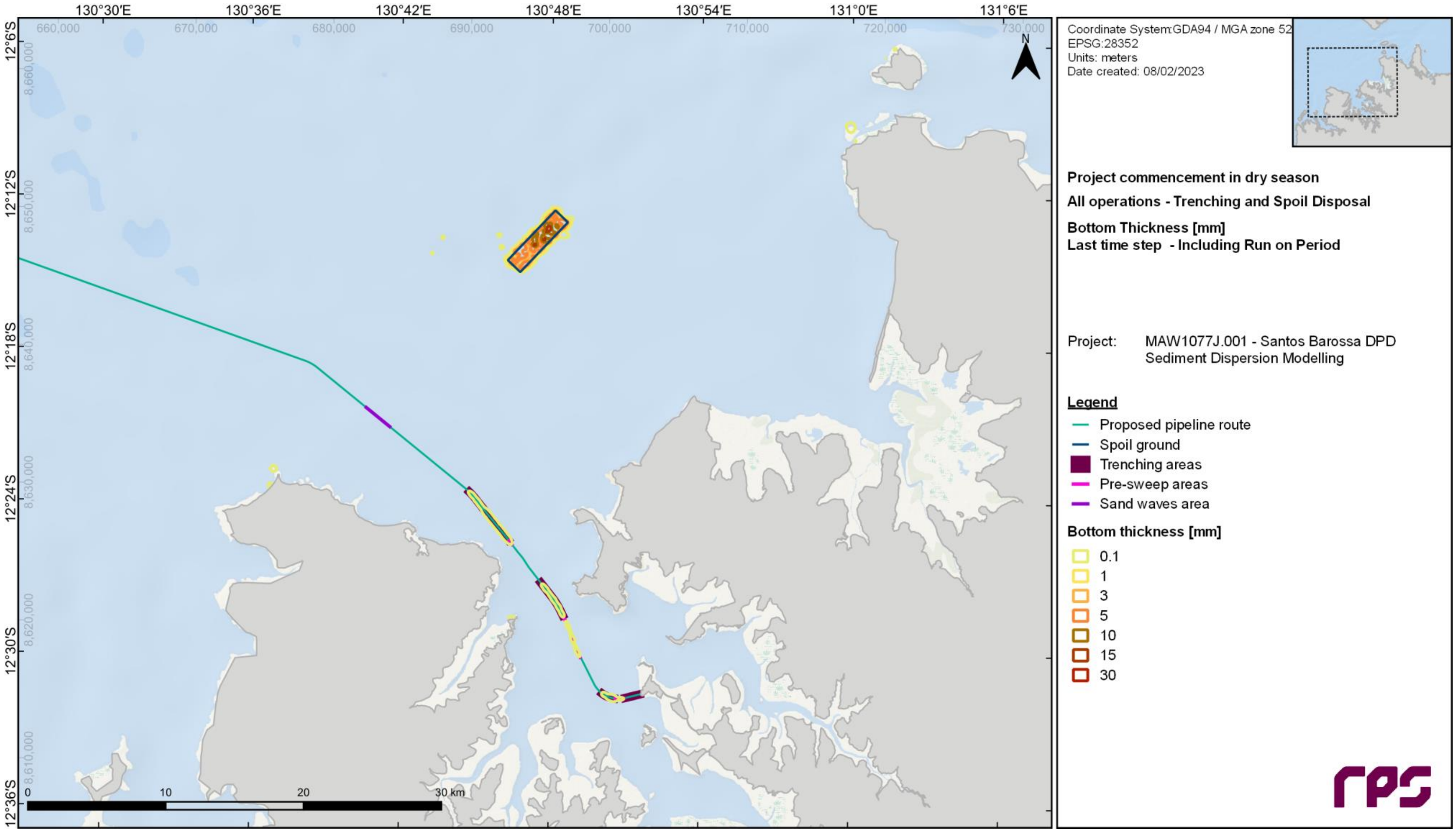

Figure 7.30 Predicted trenching-excess bottom thickness (mm) at the last time step of the simulation (end of run-on period) for the winter/dry season scenario (based on 10 July 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

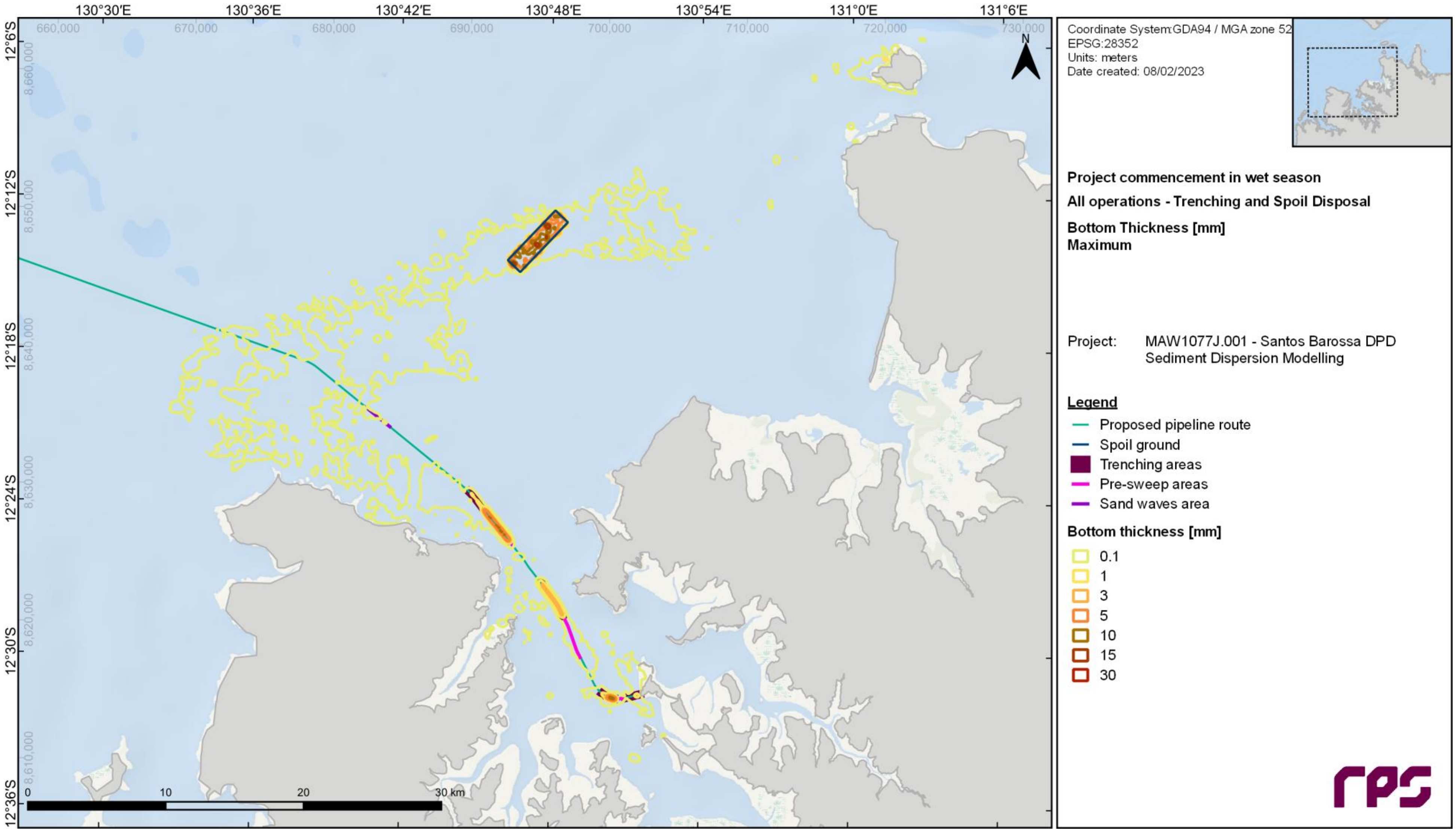

Figure 7.31 Predicted maximum trenching-excess bottom thickness (mm) throughout the entire trenching program for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

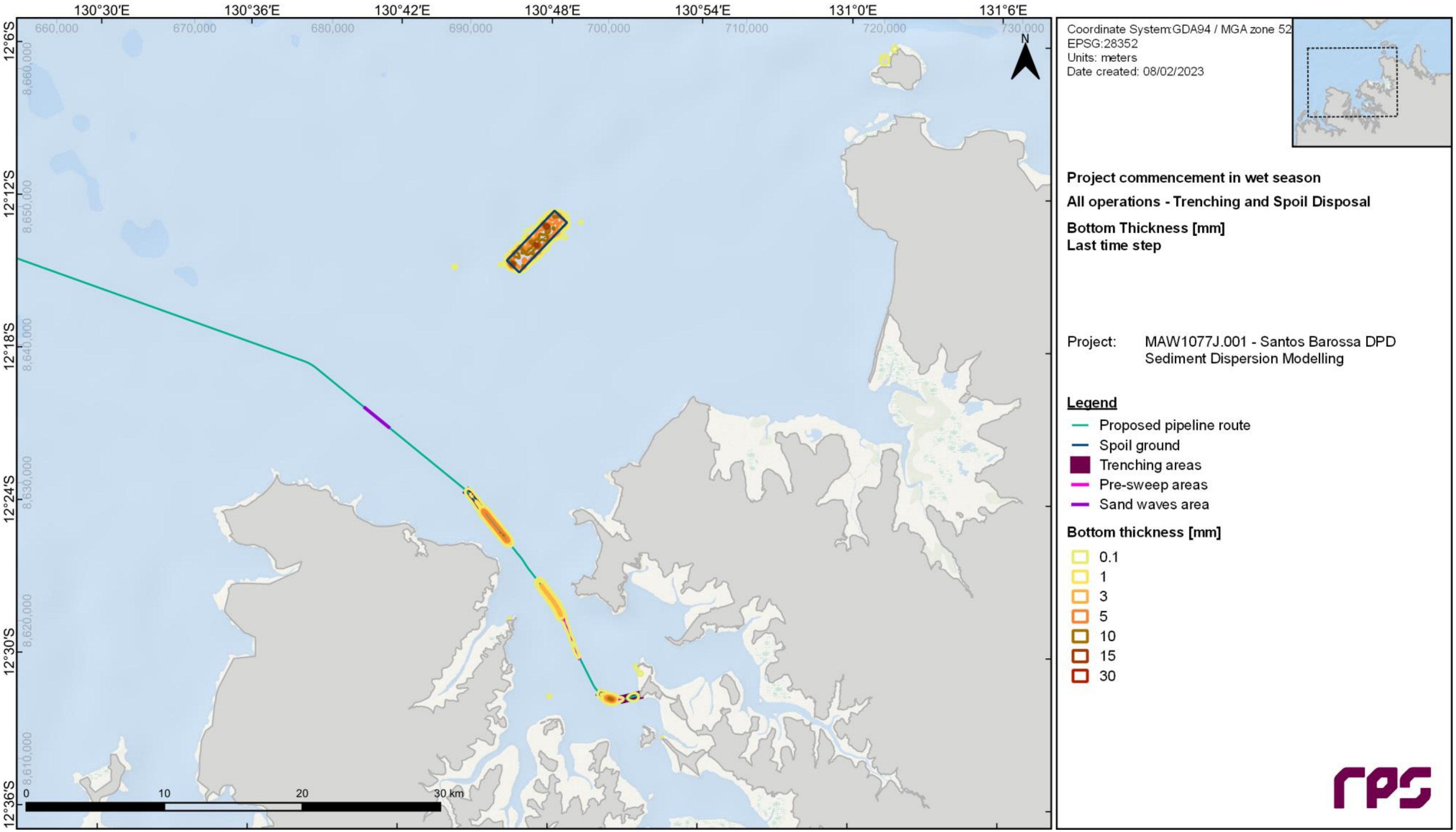

Figure 7.32 **Predicted trenching-excess bottom thickness (mm) at the last time step of the trenching program (not including run-on period) for the summer/wet season scenario (based on 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

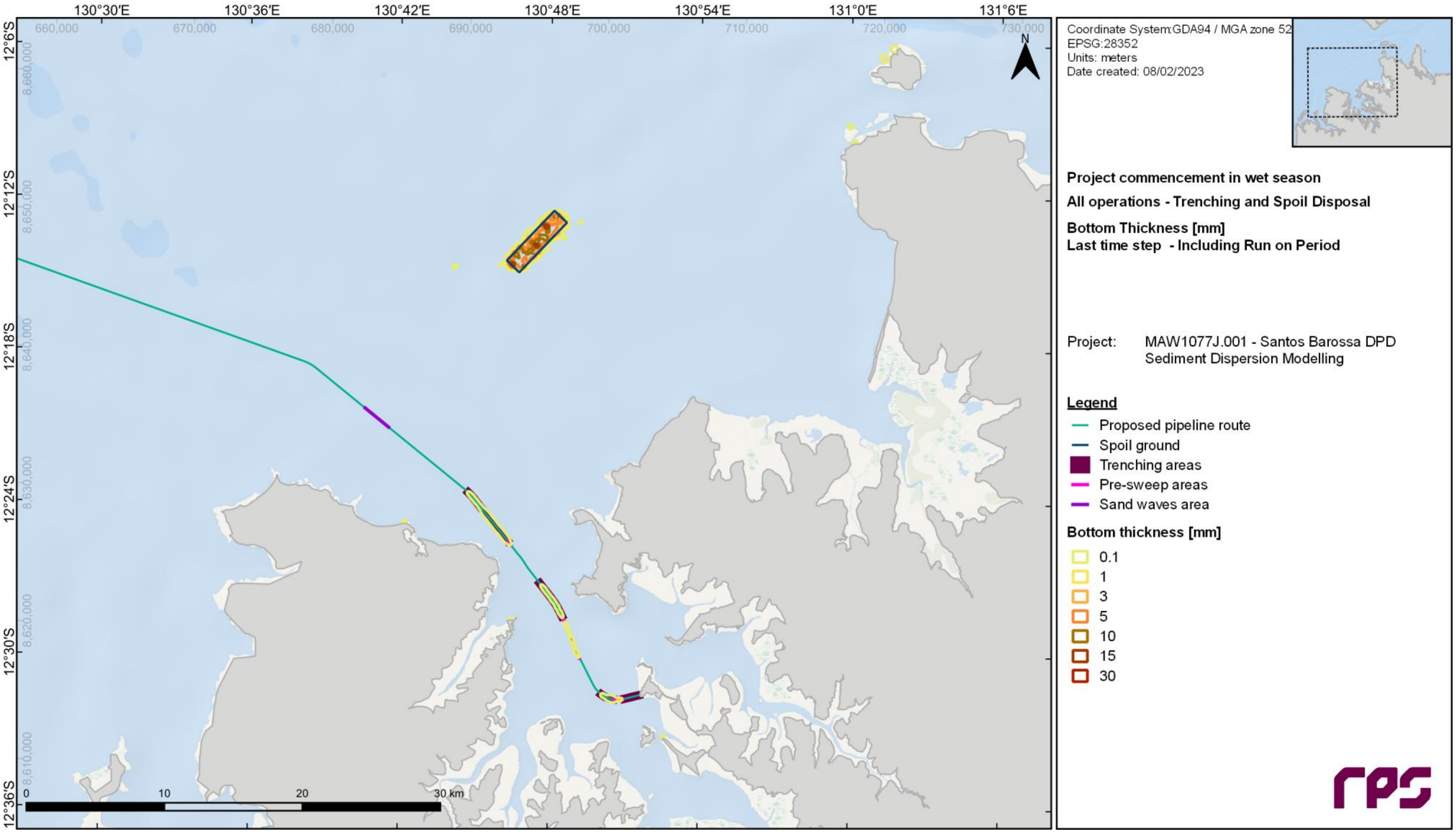

Figure 7.33 Predicted trenching-excess bottom thickness (mm) at the last time step of the simulation (end of run-on period) for the summer/wet season scenario (based on 9 January 2020). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

7.3.2 Temporal Variability of Sedimentation

To explore the temporal exposure of sensitive receptor sites to sedimentation generated by the trenching and disposal operations, a time series analysis at a set of sensitive locations has been conducted to supplement the spatial maps. The set of analysis locations is the same as was used for the time series analysis of SSC (Figure 7.17 and Table 7.1).

As indicated by the spatial maps, the time series analysis shows that the deposition rates at distance from the trenching and disposal areas are low, forming only very thin layers of material. At all sites other than those around the disposal area, the predicted thicknesses remain less than 0.2 mm and those plots have not been included here. The low rates of deposition are due to the magnitude of the tidal currents in the area: material that is suspended is dispersed rapidly and widely, with material deposited at slack tide being typically resuspended on the next tide – or the following spring tide period.

Time series plots showing predicted trenching-excess bottom thickness for each of the offshore disposal area sites are presented for both the winter/dry and summer/wet season scenarios in Figure 7.34 through Figure 7.37. The plots reinforce the finding that deposition beyond the immediate vicinity of the disposal area is very low, with predicted bottom thickness values at *OD1*, *OD5*, *OD6* and *OD9* being less than 0.2 mm at all times, and with corresponding values at *OD7* and *OD8* (on the edge of the disposal area) never exceeding 0.5 mm. At the sites within the disposal area (*OD2*, *OD3* and *OD4*) there are variation in thickness based on their relative proximity to where disposals have occurred in the modelling. Some slight reduction of the predicted bottom thickness can be seen during the run-on periods, but as the deposited material is typically the coarser sediments the sedimentation levels are relatively stable during ambient conditions.

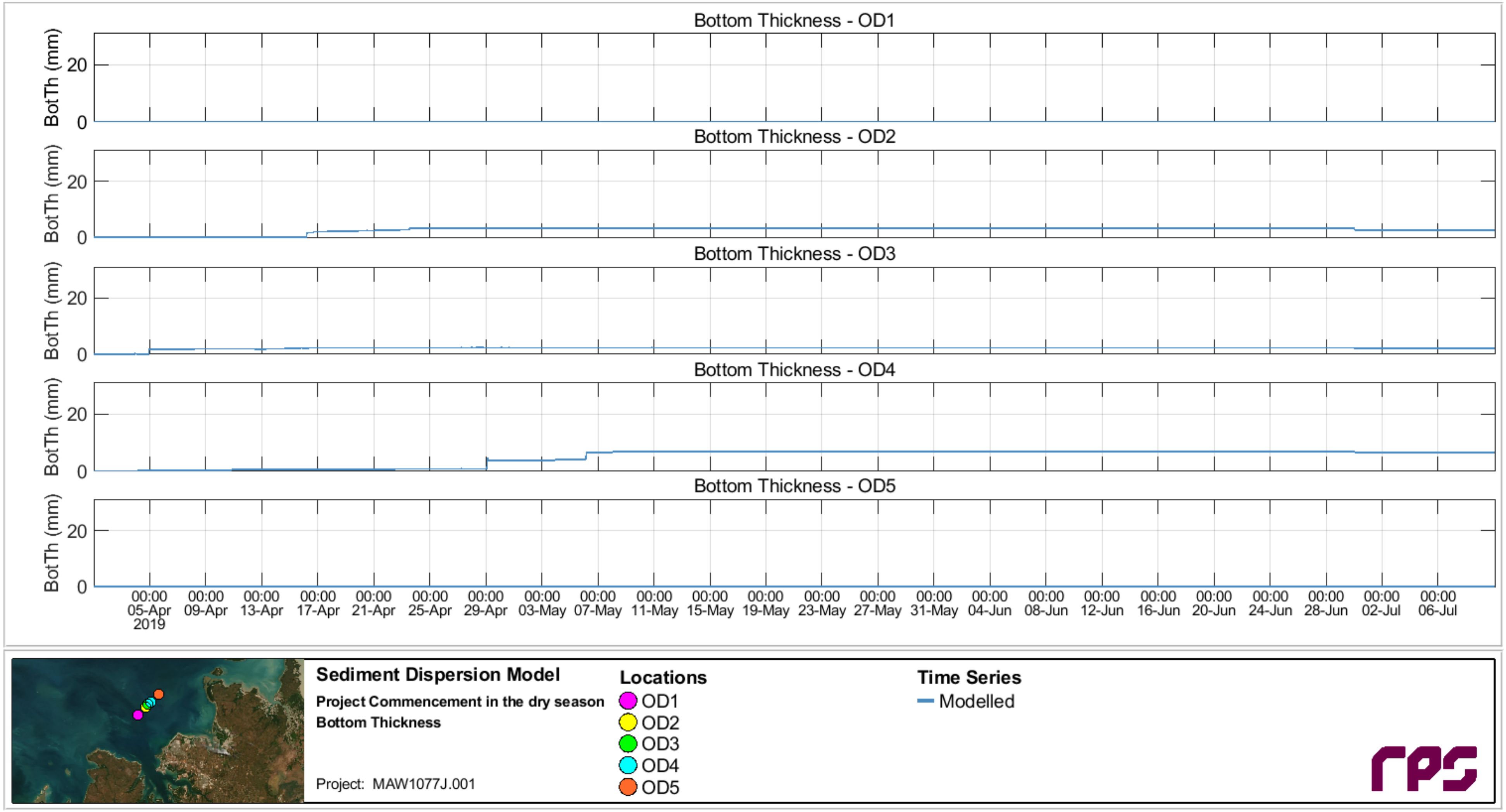

Figure 7.34 **Time series of predicted trenching-excess bottom thickness at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the winter/dry season scenario.**

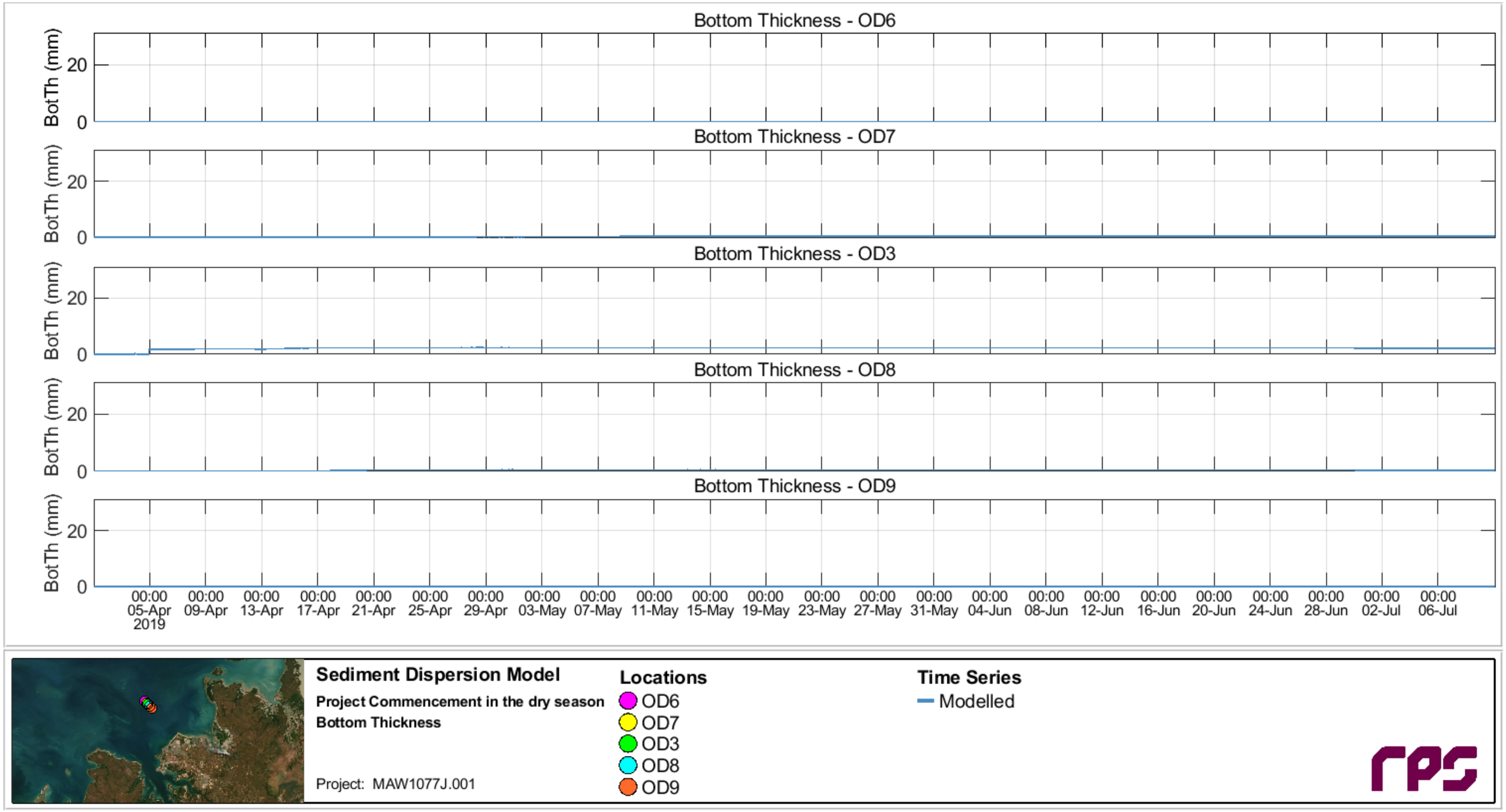

Figure 7.35 Time series of predicted trenching-excess bottom thickness at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

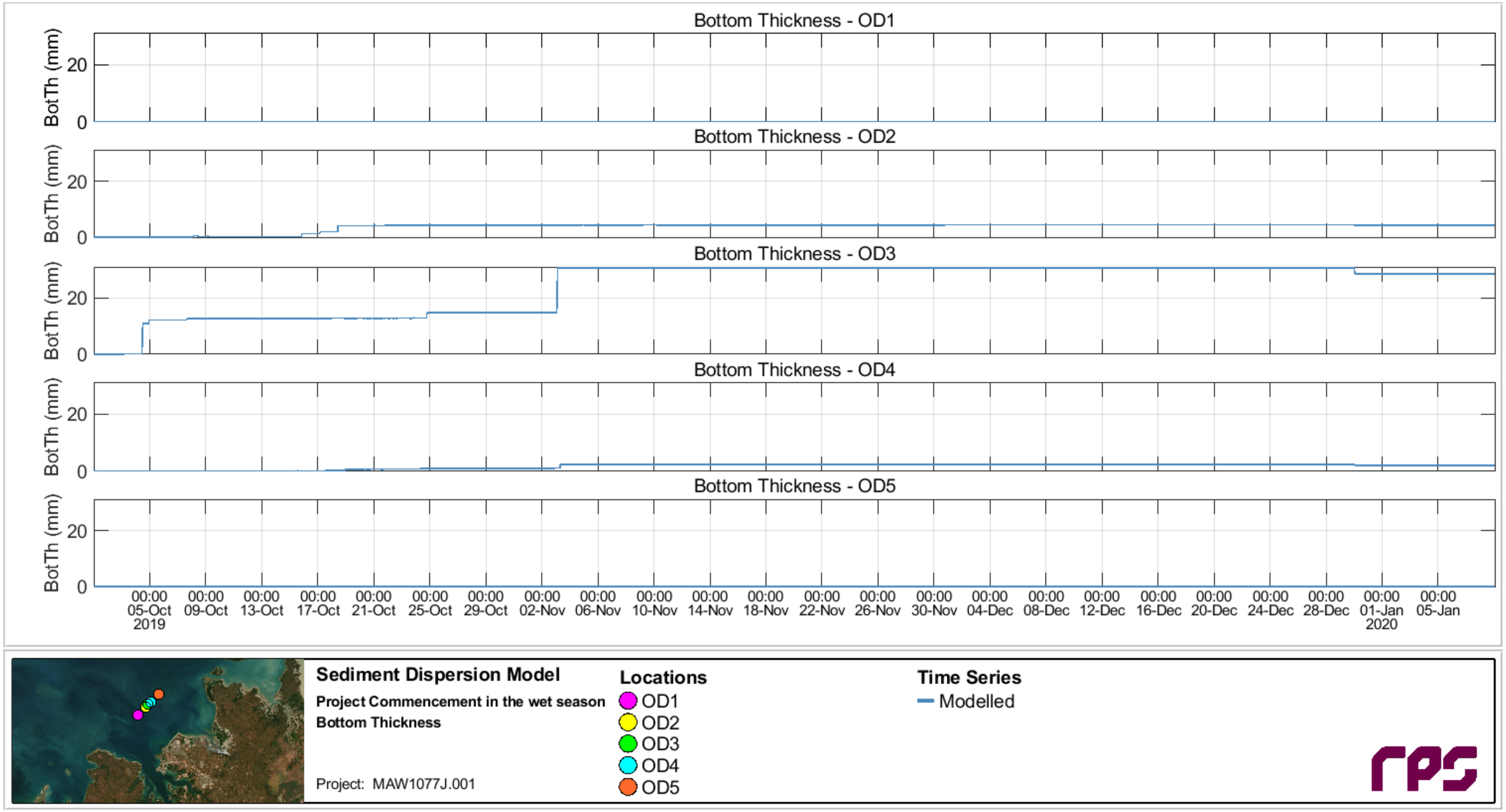

Figure 7.36 **Time series of predicted trenching-excess bottom thickness at the *OD1* to *OD5* sites throughout the entire trenching program and run-on period in the summer/wet season scenario.**

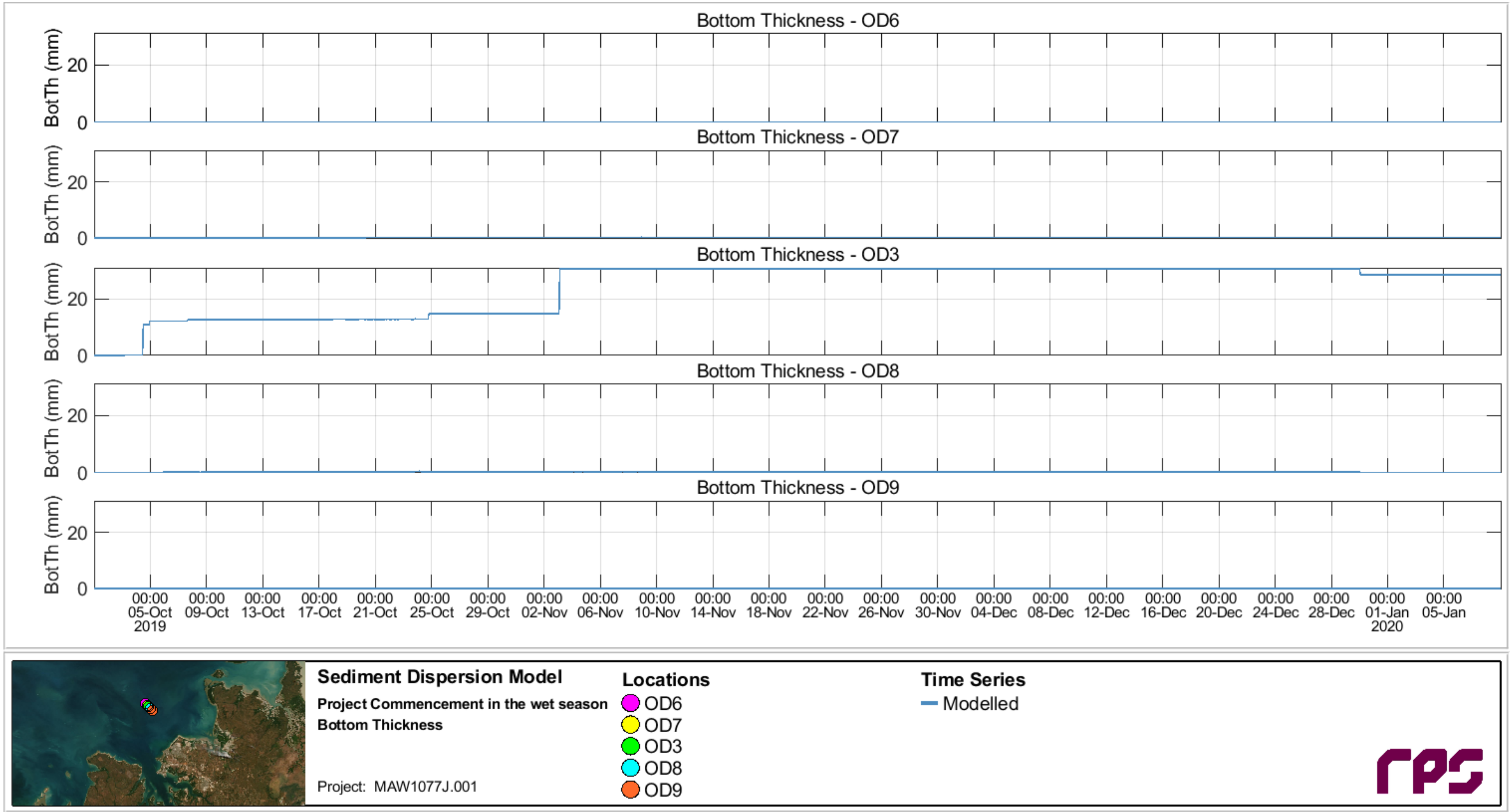

Figure 7.37 **Time series of predicted trenching-excess bottom thickness at the *OD6* to *OD9* (via *OD3*) sites throughout the entire trenching program and run-on period in the summer/wet season scenario.**

7.4 Prediction of Management Zone Extents

The calculated extents of the defined management zones – ZoI and ZoMI – over the entire program of trenching and disposal operations for the winter/dry season scenario are presented in Figure 7.38 and Figure 7.39, and for the summer/wet season scenario the extents are presented in Figure 7.40 and Figure 7.41. From the figures it is evident that the predicted ZoMI for the trenching and disposal operations for both seasonal scenarios is restricted to the trenching and spoil disposal footprints, which are also within the ZoHI as defined in Section 6.2.1.

The predicted ZoI for the trenching and disposal operations for both seasonal scenarios is also generally restricted to within or close to the trenching and spoil disposal footprints, with the exception of a very small patch in the shallows at South West Vernon Island in the summer/wet season scenario. This isolated patch may be attributable to the combined effects of model bathymetry and hydrodynamics, representing sediments that are transported into the shallowest possible grid cells and then trapped upon reversal of the tide. While it is clear that there is a potential for sediments released at the offshore disposal ground to be found in the indicated area, the persistence of material remaining at the water-land boundary in this location may be overstated.

It should be noted that the management zones shown are the result of exceedance of the sedimentation thresholds only; no exceedance of the SSC thresholds occurred at the predicted 90^{th} and 95^{th} percentile depth-averaged SSC levels for both modelled seasonal scenarios (see Figure 7.9 to Figure 7.12).

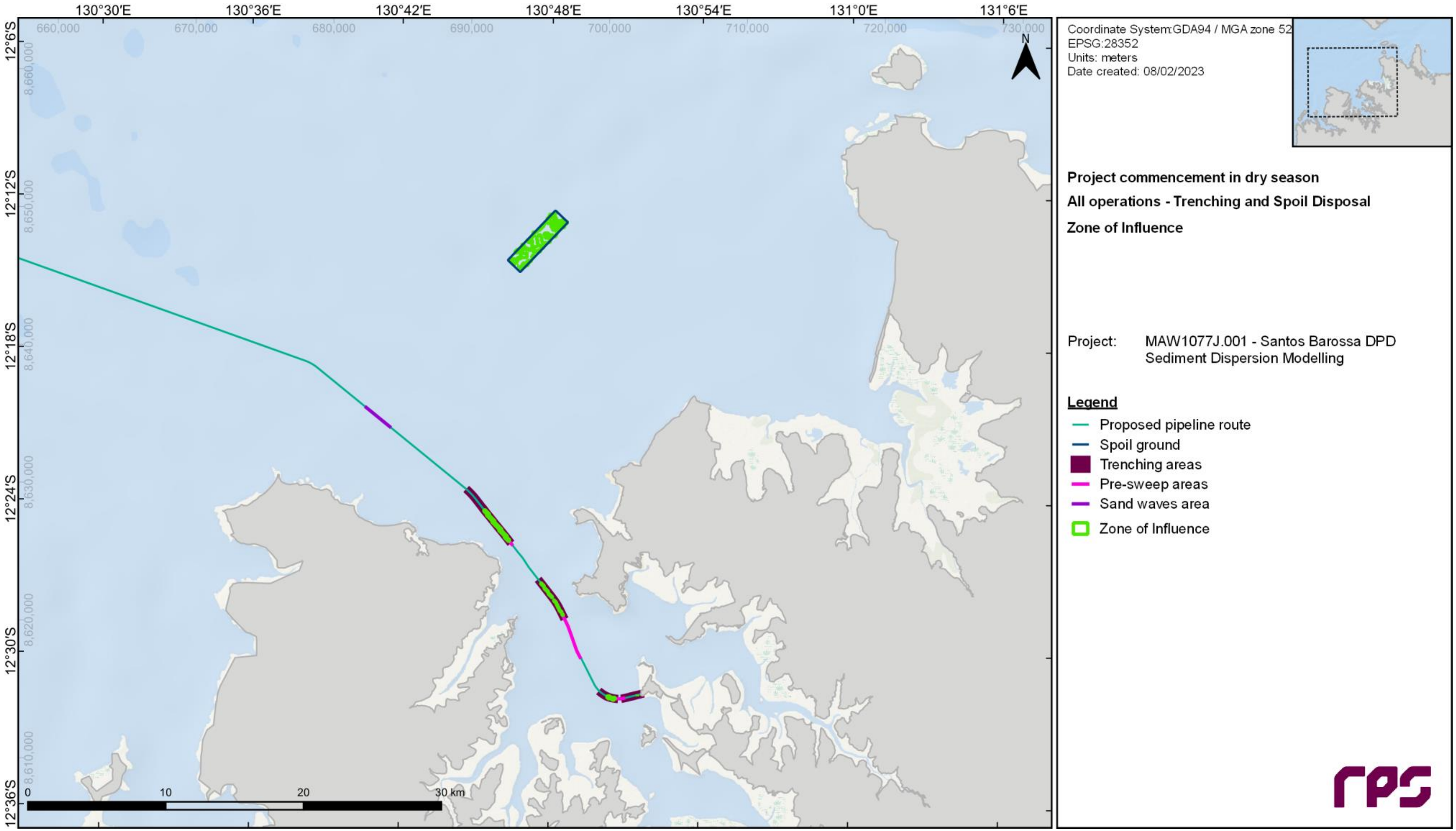

Figure 7.38 Predicted Zone of Influence following application of the appropriate spatial thresholds in Table 6.1 to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

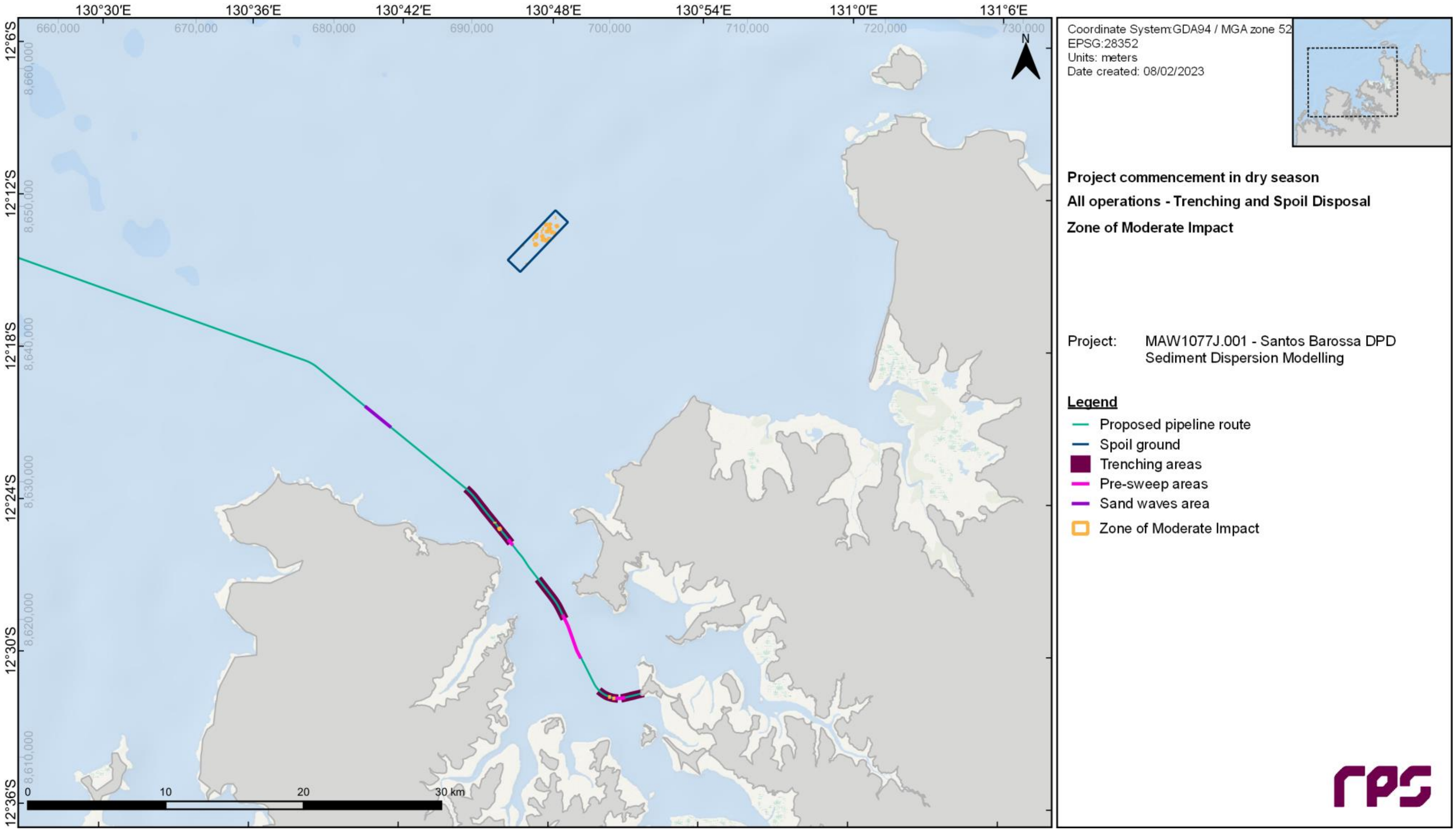

Figure 7.39 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in Table 6.1 to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (based on 1 April to 10 May 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

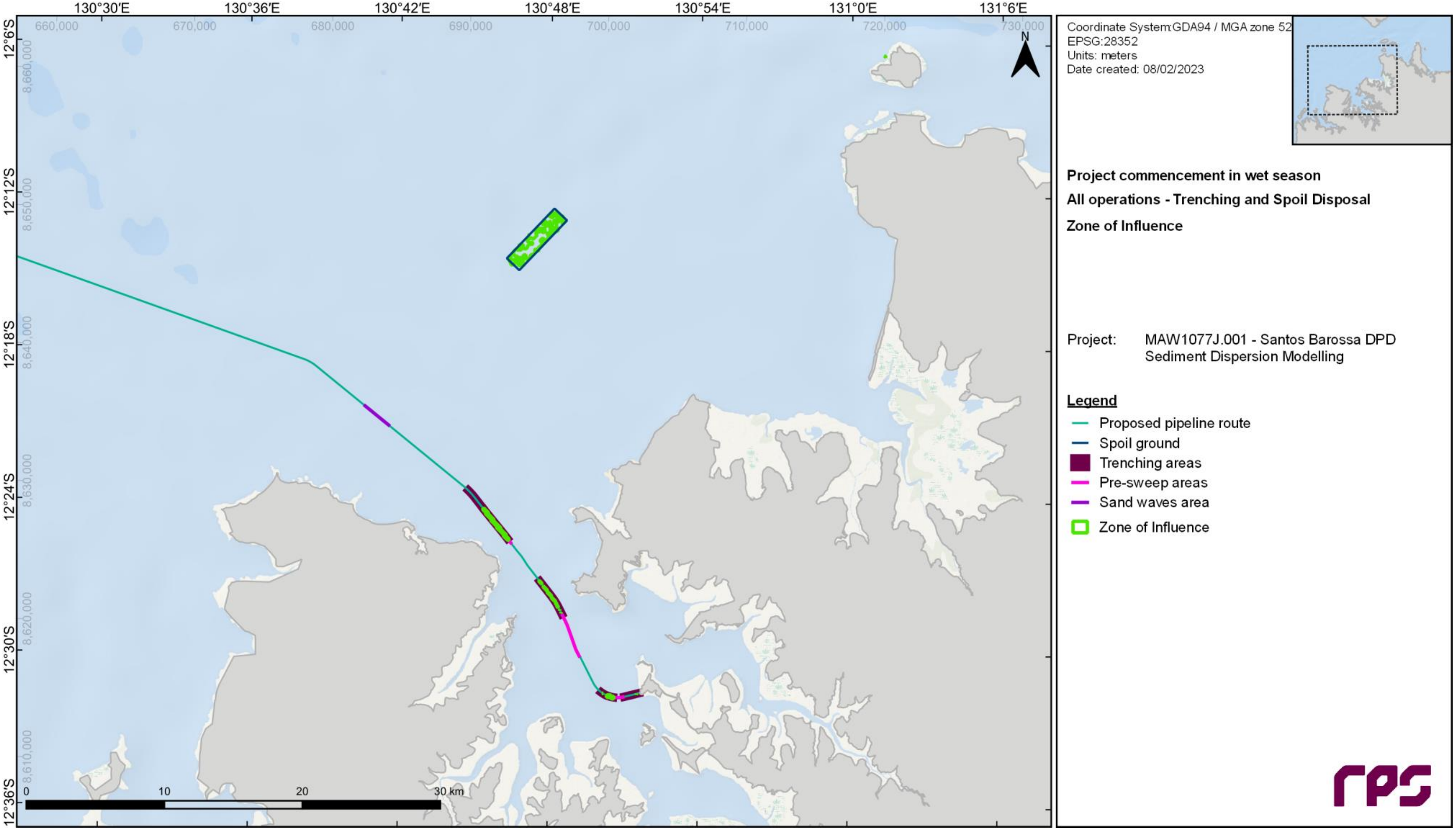

Figure 7.40 Predicted Zone of Influence following application of the appropriate spatial thresholds in Table 6.1 to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

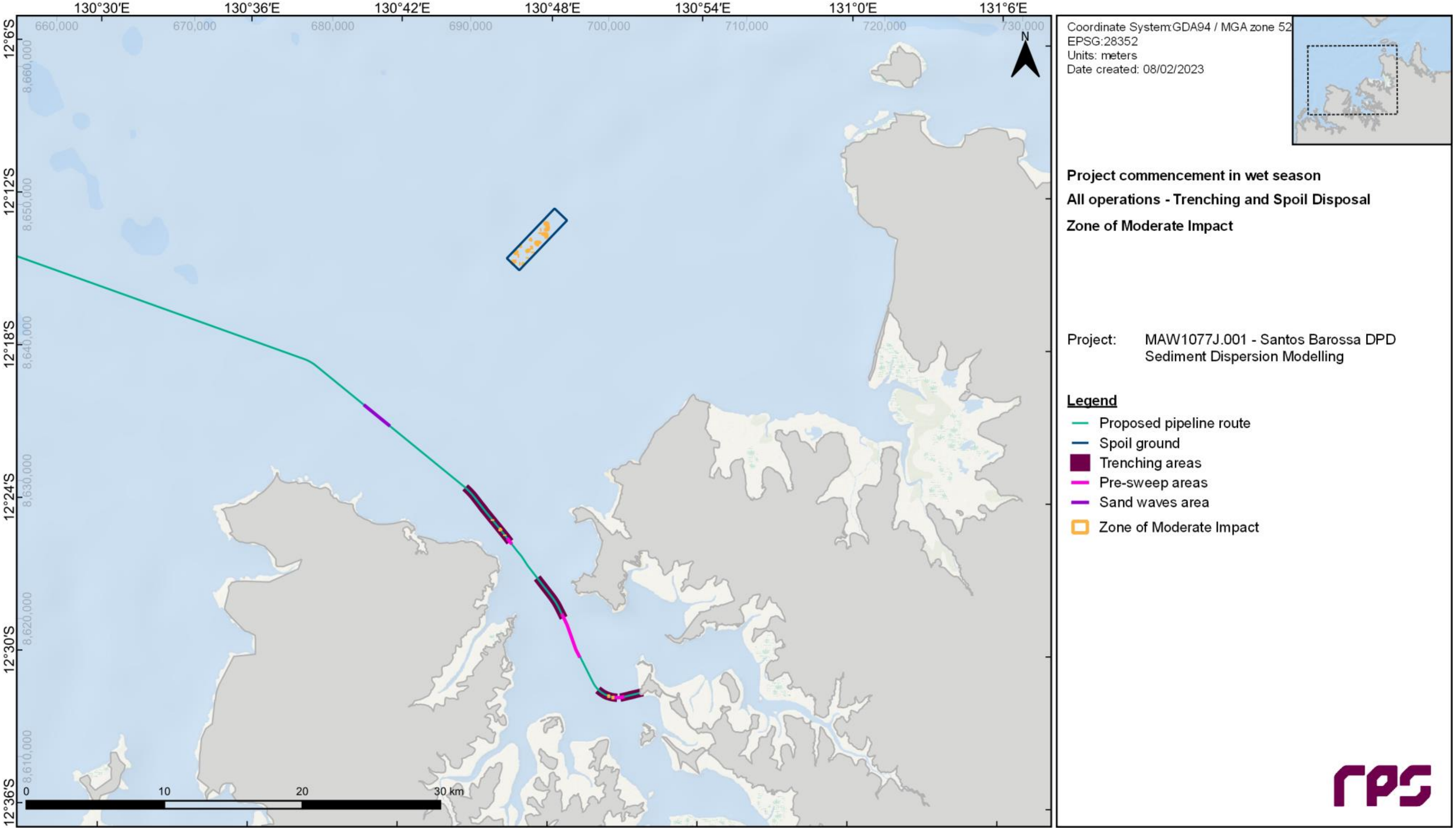

Figure 7.41 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in Table 6.1 to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (based on 1 October to 9 November 2019). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

8 CONCLUSIONS

The main conclusion from the sediment dispersion modelling conducted for the proposed trenching and disposal operations, associated with the Barossa DPD project are outlined in the following sections.

8.1 General Plume Movement

- The localised movement of the trenching-generated suspended sediment is dominated by the ebbing and flooding tidal oscillations, due to the very strong tidal flows in the project area.
- Some slight seasonal differences in the overall drift patterns are evident due to the wind-driven residual currents, with plumes predicted to extend slightly more southwards in the winter/dry season and slightly more northwards during the summer/wet season.
- At the spoil ground the interaction between suspended sediment plumes from consecutive disposals is minimal during spring tide periods, with more potential for interaction between consecutive disposals during neap tide periods, when plume movement is slower, and trajectories are shorter. However, the predicted depth-averaged SSC of the interacting plumes remains relatively low.

8.2 Spatial and Temporal Distributions of SSC

- Forecasts of median depth-averaged SSC values do not exceed 1 mg/L in both seasonal scenarios, while at the 80th percentile values greater than 1 mg/L are forecast in small, isolated patches.
- At the 90th and 95th percentile levels, predicted depth-averaged SSC values do not exceed 5 mg/L in both seasonal scenarios.
- The temporal variation in predicted SSC, reflects the spatial patchiness of the plumes and the oscillations of tidal flows, with rapidly changing (over hourly scales) sharp peaks and troughs in SSC.
- At the sensitive receptor monitoring sites, the duration of the peaks in SSC are predicted to be short (in the order of hours), the 98th percentile SSC is predicted to be less than 7 mg/L at all sites in both seasons.
- At the spoil ground elevated SSC levels (in the order of 100-200 mg/L) occur immediately after disposal events but are rapidly dispersed and do not persist for long periods (scales of hours). The intensity of the modelled SSC values are predicted to reduce significantly within 1-3 km of the spoil ground boundaries.

8.3 Spatial and Temporal Distributions of Sedimentation

- Settlement of coarse material (sand size) is predicted to be rapid and near the trenching and offshore disposal areas, but the fine material is predicted to remain suspended, or will deposit at slack tide only to be resuspended on the following tide, particularly during spring tide periods.
- Suspended sediment plumes are predicted to have long drift trajectories, with sediments dispersed widely but at low concentrations, and with sediments deposited in thin layers.
- Sedimentation of greater than 1 mm thickness is predicted to be limited to the trenching and disposal areas, with a small patch predicted at South West Vernon Island for the summer/wet season scenario.
- Deposition within the spoil ground varies in thickness based on the locations of disposals in the modelling.
- Some slight reduction of the predicted bottom thickness occurs in the run-on periods, but as the deposited material is typically the coarser sediments the thickness is relatively stable during ambient conditions.

8.4 Management Zone Extents

- The predicted management zones are the result of exceedance of the sedimentation thresholds only; no exceedance of the SSC thresholds occurred for both modelled seasonal scenarios.
- The predicted ZoMI for the trenching and disposal operations for both seasonal scenarios is restricted to the trenching and spoil disposal footprints, which are also within the ZoHI as defined in Section 6.2.1.

- The predicted ZoI for the trenching and disposal operations for both seasonal scenarios is also generally restricted to within or close to the trenching and spoil disposal footprints, with the exception of a very small patch in the shallows at South West Vernon Island in the summer/wet season scenario. However, it should be noted that this patch may accentuated due to model limitations.

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Appendix A – Expert Review of Sediment Dispersion Modelling Assessment Report

Australian Government

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Expert Review of Dredge Plume Modelling Assessment Report

Document: MAW1077J.001 - Santos Barossa DPD Sediment Dispersion Modelling Rev0.pdf

prepared for Santos Limited

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"The Australian Institute of Marine Science (AIMS) acknowledges the Traditional Owners as the ongoing custodians of country throughout Australia, and in particular across northern Australia where AIMS operates in partnership with Aboriginal and Torres Strait Islander peoples. AIMS acknowledges and celebrates their continued connection to country, including sea country, and pays respects to all elders past, present and future."

Project Leader shall ensure that documents have been fully checked and approved prior to submittal to client				
Revision History:		Name	Date	Comments
1	Prepared by:	Hemerson Tonin	28/07/2022	
	Reviewed by:	Claire Streten	29/07/2022	
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Cover photo:

Current picture 'RV Solander in Western Australia. Image: N. Thake

Background

In March 2022, the Australian Institute of Marine Science (AIMS) was invited by SANTOS to assist in the Darwin Pipeline Duplication (DPD) plan as an external advisory prior to submission to the Northern Territory – Environmental Protect Agency (NT-EPA). The contribution of AIMS would involve review and provision of advice on source terms to be used for modelling in a workshop organised by Santos and for the numerical modelling provider (RPS) prior to modelling and then further technical review of modelling deliverables, including modelling report, and ad-hoc advice as required. As part of this engagement, the current document is related to a qualitative and quantitative assessment of the component related to the numerical modelling report of the dredging plume (technical review). This assessment by AIMS' team follows the best practices currently employed in Australia and will address the following key points:

- Baseline information on site/environmental conditions: if meteo-oceanographic conditions, as well as if geographic and temporal extension of the numerical modelling were adequate.
- Modelling approach: if the implemented modelling approach was adequate to represent and predict the dredging operation and the discharge of the sediment at specific site. This adequacy should contemplate the dredging plume, sediment suspended concentration, sediment deposition and others significant processes.
- Dredging operation: if the dredging and disposal of sediments were adequately represented numerically in the same context proposal to be carried out *in situ*.
- Model calibration and validation: if the level of accuracy demonstrated through calibration and validation procedures was adequate and reliable to predict sediment transport from the dredging and disposal activity, and,
- If reported results and conclusions could be based on the information contained in the report to be submitted to NT-EPA.

Overall Assessment

The report is prepared with a logical development in order to present the assumptions, modelling and results in a clear manner. However, there are deficiencies and areas for improvement in the report. There is an omission found in the numerical modelling (both hydrodynamics and waves) section that have the potential to impact the quality of the study. For example, the results of the numerical model can, and should, be assessed qualitatively and quantitatively (Williams & Esteves, 2017). There is no statistical analysis of model performance, including biases and errors – as is common in most model validation exercises – and emphasized in the modelling guidelines on dredge plume modelling studies, both by the Northern Territory (NT-EPA, 2013) and others (e.g. GBRMPA, 2012; Sun *et al.*, 2020). Discussion of the performance of the suite of models would benefit from a consistent qualitative approach, beyond a somewhat simplistic discussion as it was sometimes presented in the document.

Another important point that has not received due attention is related to the analysis of residual currents. Such currents are crucial in the transport of fine sediments (Sun *et al*, 2020) even more so when this class of sediment has a high incidence of occurrence in the region to be dredged, and therefore also discharged in the spoil ground. Therefore, the analysis of residual currents and estimation of the respective transport associated with them, in the region of the spoil ground could be better explored to estimate the potential long term transport and fate, particularly of disposal material.

The absence of presentation of results in the form of time series was also observed. The joint analysis of the results in the form of maps and time series form a valuable tool for the analysis of impacts (space-time and intensity exposure; NT-EPA, 2013; GBRMPA, 2012; Sun et al. 2020).

The report presents a comprehensive modelling effort to understand the potential impact of dredging campaign and fate of dredge material.

However noting the limitations and deficiencies listed above, there is opportunity to improve the report. In relation to specific terms of the review:

- The modelling, in general conforms to the NT-EPA and main Australian modelling guidelines,
- The report does not describe observational data that adequately describes the environmental conditions of the dredging and placement locations.
- The modelling approach applies a hierarchy of hydrodynamic, wave and sediment transport models. The models themselves (e.g. Delft3D, SWAN and SSFATE) are suitable and commonly used in similar studies.
- For model validation and calibration, there is a lack a quantitative assessment of model skill (where appropriate) or a consistent qualitative approach to demonstrate model performance.
- A section at the end of the document summarizing the findings (list of dot points referring to the main text) would help the general understanding of the outcomes achieved by the implemented numerical modelling.

Rationale for making Assessment

It is undeniable that there is great complexity in carrying out hydrodynamic modelling to assess coastal processes, including sedimentation and sediment plume analysis. Although the report under review addresses almost all the points recommended by the main Australian guidelines, the most relevant deficiency that the report presents is the lack of quantitative and temporal evaluation/discussion of the implemented modelling suite. We understand the current study serves its purposes, but by making a few changes it will bring the necessary and desired confidence to decision makers.

Key Point's Assessment

- Assessing if the report meets the key point from the main Australian guidelines for the use of hydrodynamic modelling for dredging projects, such as NT-EPA (2013), GBRMPA (2012) and Sun *et al*. (2020).

The report addressed most of the recommendations contained in the guidelines of hydrodynamic modelling for dredging projects and key points for assessment recommendations were met. A relevant point partially addressed in the report is related to the thresholds. Although the threshold for each species found in the region were documented by previous studies by INPEX, the report presents the results on maps at different percentile levels (and only calculated from the average value in the water column; a similar approach should be performed for the maximum values observed in the water column). So, ecological vulnerability is also a function of exposure (intensity and period subject to, Sun *et al.*, 2020; Fraser *et al*., 2017; McCook *et al.*, 2015). In this context, the presentation of time series of suspended sediment and of deposition time series in sensitive regions should be presented to estimate the pressure on marine receptors (GBRMPA, 2012).

- Baseline information on site/environmental conditions

The amount of environmental data available for carrying out the study was adequate, both in spatial and temporal coverage, however, the meteo-oceanographic analyses did not define typical and extreme periods. Although the dredging campaign is suspended during extreme events, numerical simulations for these periods are suggested to evaluate the remobilization of discharged material in the spoil ground. The evaluation of wave modelling also lacks a better qualitative and quantitative discussion of the results obtained. For example, unlike the other comparative graphs, the presentation related to the wave direction is not shown through continuous lines, which makes it difficult to evaluate the implemented model against measured data. The wave modelling showed an almost constant bias over time that is not mentioned also.

In relation to the wind field used as forcing in the model, the same data source used to evaluate the implemented model (for currents and waves) also provides wind measurements, with regular intervals of 10min. Therefore, it would be the opportunity to compare the measured wind with the NCEP-GFS for relevant periods to demonstrate its validity, limitations and possible implications in numerical modelling.

- Modelling approach

Although there are numerical models that are capable of solving hydrodynamic-wave-sediment in a single integrated modelling suite, the numerical modelling methodology used to assess the transport, settlement and resuspension of sediments resulting from dredging used a combination of internationally recognized numerical models (Delft3D, SWAN and SSFATE).

- Dredging and disposal description

The report presents a reliable spatial distribution of the sediment classes in the region of interest (based on surveys and literature). The dredging and disposal scenarios considered presented the necessary exposure to cover possible meteo-oceanographic conditions (wet and dry seasons). However, there is a lack of resuspension scenario of extreme event. In addition, the numerical modelling presented in the report assumed an initial vertical distribution of sediments that does not occur in time and space every time the disposal operation takes place. The discharge of high volume of fine sediments at different times of the day (therefore under different tidal cycle conditions) would transport the sediments according to the instantaneous condition of the tide with different behaviour in the water column, and as consequence, it would be possible an interaction between subsequent disposals, mainly during the operation of TSHD, where its cycles are shorter over time. The report assumes: "Sediments suspended in the water column during previous operations were subject to settlement and progressively-reducing levels of resuspension during this time". Thus, the presentation of the result of the discharge of sediments (mostly fine) in different tidal cycles would be relevant for evaluation (near slack of water and maximum current), as well as the interaction between two consecutive dumps ("best case" and "worst case" scenarios to evaluate the persistence of suspended sediments between disposals of sediments in sequence; GBRMPA, 2012; Sun *et al.*, 2020).

- Model calibration and validation

This is an essential and crucial topic in the analysis of this document on the numerical modelling of Sediment Dispersion Modelling Report. A numerical modelling study including hydrodynamics, waves and sediments with a prognostic focus to support decision-makers must have a level of accuracy, both temporal and spatial, beyond any doubts or possible to quantify its range of variability. The report presents the constant pursuit of this achievement in the hydrodynamic model, in the wave model and in the sediment transport component. However, the models present relevant and systematic weaknesses in the calibration and validation of numerical modelling. The first point to be highlighted is the total lack of statistical metrics of the results of the numerical model (hydrodynamics and waves) compared to the available data (named in the report as validation, there is no calibration presented in this document). These statistical metrics assist in verifying the extent to which the model has been well implemented and is capable of fulfilling its assumptions in a manner appropriate to what it was designed for. A second point about assessing the model results is related to the residual currents. The report made an "in passing" mention on the impacts of residual currents (page 48), but does not present an assessment per se. The computation of residual currents in the sites where the dredging and discharge operations of sediments take place is a valuable tool to evaluate the time-integrated error in the transport of suspended sediments. As for the waves, the report also showed a total lack of metric (quantitative) evaluation.

On a visual inspection, the results of both models (hydrodynamic and waves) show good results, however, there are several methodologies for the quantitative and qualitative evaluation of numerical models used in engineering, and Williams & Esteves (2017) presents a good summary of them. As for the disposal of sediments, some instantaneous maps of the maximum concentration of sediments in the water column could be presented to assess whether plumes resulting from consecutive discharges could interact with each other. A sequence of vertical sections during the disposal and later moments would be valued to evaluate the behaviour of the dynamic of the sediments during its displacement in the water column.

- Results and conclusions

Results for sediment dispersion modelling in the report, for both wet and dry seasons, were presented as “throughout entire trenching program”, were those results related to end of operations (dredging and disposal) or to the end of numerical simulations? In addition, as mentioned before, the presentation of time series in key sites (mainly in the spoil ground, due to the availability of fine materials) would be of great value to observe the temporal behaviour of the SSC until it reaches safe levels (thresholds), or even infer whether there is interaction between consecutive discharges of sediment. An extra point of observation would be to present the snapshot sequence (as shown in figures 5.1. and 5.2) for the wet season too. As a final comment, the presentation of general remarks/conclusions at the end of the document as a list of dot points (referring to the main text) would facilitate the general understanding of the outcome of the study.

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Appendix B – Expert Review AIMS Comments and RPS Response Table Rev 1

Topic	AIMS Expert Review Comment	RPS Response and Report Update
1	The results of the numerical model can, and should, be assessed qualitatively and quantitatively (Williams & Esteves, 2017). There is no statistical analysis of model performance, including biases and errors – as is common in most model validation exercises – and emphasized in the modelling guidelines on dredge plume modelling studies, both by the Northern Territory (NT-EPA, 2013) and others (e.g., GBRMPA, 2012; Sun et al., 2020).	The quantitative statistics have been calculated and added to the report to support the existing time series plots.
2	Another important point that has not received due attention is related to the analysis of residual currents. Such currents are crucial in the transport of fine sediments (Sun et al, 2020) even more so when this class of sediment has a high incidence of occurrence in the region to be dredged, and therefore also discharged in the spoil ground. Therefore, the analysis of residual currents and estimation of the respective transport associated with them, in the region of the spoil ground could be better explored to estimate the potential long-term transport and fate, particularly of disposal material.	Residual currents are included in the hydrodynamic modelling as described in Section 4.1.3. They are also discussed in the results sections (Section 7) where the seasonal differences in SSC drift patterns are attributed to seasonal differences in the direction of the drift currents. Note the differences are small. Some additional discussion of residual currents has been included in Section 2. See also the Comment 4 response.
3	The absence of presentation of results in the form of time series was also observed. The joint analysis of the results in the form of maps and time series form a valuable tool for the analysis of impacts (space-time and intensity exposure; NT-EPA, 2013; GBRMPA, 2012; Sun et al. 2020). So, ecological vulnerability is also a function of exposure (intensity and period subject to, Sun et al., 2020; Fraser et al., 2017; McCook et al., 2015). In this context, the presentation of time series of suspended sediment and of deposition time series in sensitive regions should be presented to estimate the pressure on marine receptors (GBRMPA, 2012).	Time series analysis at a set of 17 points has been included in the results sections (Section 7) and the temporal variation in SSC and sedimentation has been discussed at these sites
4	The report does not describe observational data that adequately describes the environmental conditions of the dredging and placement locations.	A regional metocean conditions discussion has been included at the start of the report (Section 2) with typical wind, wave and current (tides and drift) conditions explained.

5	A section at the end of the document summarizing the findings (list of dot points referring to the main text) would help the general understanding of the outcomes achieved by the implemented numerical modelling.	A conclusions section (Section 8) has been added to the report.
Key Point Assessment		
6	Although the threshold for each species found in the region were documented by previous studies by INPEX, the report presents the results on maps at different percentile levels (and only calculated from the average value in the water column; a similar approach should be performed for the maximum values observed in the water column).	The same percentile levels as used by INPEX have been included. The same percentile analysis was completed for the maximum values and these percentile maps have now been included in the report. Between Santos and RPS it was determined that depth-averaged values were the most relevant for informing the impact of SSC on key benthic habitats that are being assessed (e.g. seagrass and hard corals). This approach is consistent with other dredging proponent referrals in Darwin Harbour that have been recently reviewed and which used depth-averaged results for the threshold analysis. The threshold analysis presented in the report uses the depth-averaged results. Note the same analysis was completed using maximum SSC values in parallel; no thresholds were exceeded for the maximum SSC values either.
7	So, ecological vulnerability is also a function of exposure (intensity and period subject to, Sun et al., 2020; Fraser et al., 2017; McCook et al., 2015). In this context, the presentation of time series of suspended sediment and of deposition time series in sensitive regions should be presented to estimate the pressure on marine receptors (GBRMPA, 2012).	Time series analysis at a set of 17 points has been included in the results sections (Section 7) and the temporal variation in SSC and sedimentation has been discussed at these sites
8	The amount of environmental data available for carrying out the study was adequate, both in spatial and temporal coverage, however, the meteo-oceanographic analyses did not define typical and extreme periods. Although the dredging campaign is suspended during extreme events, numerical simulations for these periods are suggested to evaluate the remobilization of discharged material in the spoil ground.	A separate spoil stability assessment has now been completed with a longer term one-year run-on period, which included a number of storm events. The spoil ground stability study has been included as an addendum to the main report.
9	The evaluation of wave modelling also lacks a better qualitative and quantitative discussion of the results obtained. For example, unlike the	RPS typically always use point markers to plot direction comparisons because the use of continuous lines can make it

	other comparative graphs, the presentation related to the wave direction is not shown through continuous lines, which makes it difficult to evaluate the implemented model against measured data. The wave modelling showed an almost constant bias over time that is not mentioned also.	difficult to distinguish the comparison datasets if/when directional changes cross the 0/360 value and obscure the entire panel at that time step. Quantitative statistics have now been included and discussed the bias in Tp in the modelling.
10	In relation to the wind field used as forcing in the model, the same data source used to evaluate the implemented model (for currents and waves) also provides wind measurements, with regular intervals of 10min. Therefore, it would be the opportunity to compare the measured wind with the NCEP-GFS for relevant periods to demonstrate its validity, limitations and possible implications in numerical modelling.	Comparisons of modelled and measured wind speeds at the NRSDAR station has been conducted and included in the report (Section 4.1.3.3). This section has both time series plots and quantitative statistics. The comparison showed good agreement.
11	Although there are numerical models that are capable of solving hydrodynamic-wave-sediment in a single integrated modelling suite, the numerical modelling methodology used to assess the transport, settlement and resuspension of sediments resulting from dredging used a combination of internationally recognized numerical models (Delft3D, SWAN and SSFATE).	The use of a separate model for the sediment dispersion modelling component is based on the objective of modelling the dredge program in the most time efficient way. Having the wave and hydrodynamic models separate from the dredge dispersion model, allowed the wave and hydrodynamic model to be calibrated/ validated and production runs to be finished upfront, while aspects of the dredge program were being confirmed. In addition, the SSFATE model allows each of the individual dredge operation streams to be modelled and processed individually and cumulatively in a relatively short time frame. This is not practical in a fully coupled Delft3D model, as to assess the effect of individual operations you would essentially have to run the waves and currents multiple times also. This method also allows the dredge program or an individual component of the dredge program to be remodelled relatively quickly without having to rerun the hydrodynamic and wave modelling.

12	The dredging and disposal scenarios considered presented the necessary exposure to cover possible meteo-oceanographic conditions (wet and dry seasons). However, there is a lack of resuspension scenario of extreme event.	A separate spoil stability assessment has now been completed with a longer term one-year run-on period, which included a number of storm events. The spoil ground stability study has been included as an addendum to the main report.
13	The numerical modelling presented in the report assumed an initial vertical distribution of sediments that does not occur in time and space every time the disposal operation takes place. The discharge of high volume of fine sediments at different times of the day (therefore under different tidal cycle conditions) would transport the sediments according to the instantaneous condition of the tide with different behaviour in the water column, and as consequence, it would be possible an interaction between subsequent disposals, mainly during the operation of TSHD, where its cycles are shorter over time. The report assumes: "Sediments suspended in the water column during previous operations were subject to settlement and progressively-reducing levels of resuspension during this time". Thus, the presentation of the result of the discharge of sediments (mostly fine) in different tidal cycles would be relevant for evaluation (near slack of water and maximum current), as well as the interaction between two consecutive dumps ("best case" and "worst case" scenarios to evaluate the persistence of suspended sediments between disposals of sediments in sequence; GBRMPA, 2012; Sun et al., 2020).	Varying the vertical distribution of each disposal based on the tide is not a practical option within the modelling approach. It is theoretically possible but would need a significant amount of time to set up, and given the timings of the disposals in reality will be different to those as-modelled this level of detail would not likely add value or accuracy to the model results. Additionally, the correlation of vertical distributions to tidal states would still have to be justified with reference to literature values, which do not provide the level of detail required to configure a model appropriately. Time series points have been added along two perpendicular cross sections through the disposal ground, zoomed-in snapshot sequences over the disposal ground have been provided to show the interactions between two or more consecutive disposals and the persistence of SSC between them.
14	The models present relevant and systematic weaknesses in the calibration and validation of numerical modelling. The first point to be highlighted is the total lack of statistical metrics of the results of the numerical model (hydrodynamics and waves) compared to the available data (named in the report as validation, there is no calibration presented in this document).	Additional statistical measures of model accuracy have been calculated and added to the report to support the time series plots.
15	A second point about assessing the model results is related to the residual currents. The report made an "in passing" mention on the impacts of residual currents (page 48), but does not present an assessment per se. The computation of residual currents in the sites where the dredging and discharge operations of sediments take place is a	A regional metocean conditions discussion has been added at the start of the report (Section 2) with typical wind, wave and current (tides and drift) conditions explained. Residual currents were included in the hydrodynamic modelling.

	valuable tool to evaluate the time-integrated error in the transport of suspended sediments	
16	As for the disposal of sediments, some instantaneous maps of the maximum concentration of sediments in the water column could be presented to assess whether plumes resulting from consecutive discharges could interact with each other. A sequence of vertical sections during the disposal and later moments would be valued to evaluate the behaviour of the dynamic of the sediments during its displacement in the water column.	An additional section (Section 7.1.2) with discussion of additional hourly mapped snapshots of SSC has been included for typical spring and neap tide sequences, with figures zoomed-in on the disposal area to show the interactions of consecutive disposals at different stages of the tide.
17	Results for sediment dispersion modelling in the report, for both wet and dry seasons, were presented as "throughout entire trenching program", were those results related to end of operations (dredging and disposal) or to the end of numerical simulations?	The percentile results are based on the trenching period only (so not including the run-on period of two months), and the sedimentation results show the maximums throughout the trenching and at the last time-step of trenching (so not considering the run-on period). The presented values are both the more conservative option and thought to be appropriate given the duration of the trenching program period was only ~40 days and the run-on period was 60 days. Comments have been added to the report to make this distinction clearer. We have also added an additional sedimentation map for each scenario, which shows the end of the run-on period (Figures 7.30 and 7.33).
18	In addition, as mentioned before, the presentation of time series in key sites (mainly in the spoil ground, due to the availability of fine materials) would be of great value to observe the temporal behaviour of the SSC until it reaches safe levels (thresholds), or even infer whether there is interaction between consecutive discharges of sediment.	A time series analysis at a set of 17 points has been added to the results sections (Section 7) and the temporal variation in SSC and sedimentation has been discussed at these sites.
19	An extra point of observation would be to present the snapshot sequence (as shown in figures 5.1. and 5.2) for the wet season too.	SSC snapshots for a neap and spring sequence in the summer/wet season scenario have been added to the report (Figures 7.3 and 7.4).
20	The presentation of general remarks/conclusions at the end of the document as a list of dot points (referring to the main text) would facilitate the general understanding of the outcome of the study.	A conclusions section (Section 8) has been added to the report.

SANTOS BAROSSA DPD STUDIES

Sediment Dispersion Modelling Addendum 1 - Spoil Stability Assessment

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Contents

1 INTRODUCTION ... 1
- 1.1 Background ... 1
- 1.2 Additional Modelling Scope ... 1

2 CHARACTERISATION OF METOCEAN CONDITIONS AT THE PROPOSED SPOIL GROUND LOCATION ... 2
- 2.1 Winds at NRSDAR Station ... 2
- 2.2 Waves at Proposed Spoil Ground ... 3
- 2.3 Currents at Proposed Spoil Ground ... 6
- 2.4 Identification of Storm Conditions within the Modelled Period ... 7

3 APPROACH TO SPOIL STABILITY MODELLING ... 10

4 RESULTS OF SPOIL STABILITY MODELLING ... 14
- 4.1 Spatial Distribution of Mobilised Spoil Sediments ... 14
- 4.2 Temporal Variability in Spoil Stability at the Spoil Ground ... 18
- 4.3 Cumulative Mass in Spoil Ground ... 22
- 4.4 Potential for Remobilisation of Deposited Spoil Material ... 22

5 REFERENCES ... 24

Tables

Table 2.1 Annualised joint frequency table of significant wave height and mean wave period predicted at the centre of the spoil ground (January 2019 to December 2020)......................... 5
Table 2.2 Wet-season joint frequency table of significant wave height and mean wave period predicted at the centre of the spoil ground (January 2019 to December 2020)......................... 5
Table 2.3 Dry-season joint frequency table of significant wave height and mean wave period predicted at the centre of the spoil ground (January 2019 to December 2020)......................... 5
Table 3.1 Summary of sediment sources applied in the model. 10
Table 3.3 *In situ* PSDs broken down into the modified SSFATE material classes for each pipeline section to be trenched, derived from available geotechnical information................................ 12
Table 3.4 PSDs broken down into the modified SSFATE material classes for each pipeline section to be trenched, adjusted to remove fines lost during trenching and disposal operations. 12
Table 3.5 Modified PSDs of sediments dumped at the spoil ground by TSHD from the post-sweep of CSD-crushed material. 13

Figures

Figure 2.1 Annualised directional wind speed distribution measured at the NRSDAR station (January 2019 to December 2020). The compass direction shows that from which the wind is blowing. 2
Figure 2.2 Seasonal directional wind speed distributions measured at the NRSDAR station (January 2019 to December 2020). The compass direction shows that from which the wind is blowing. 3
Figure 2.3 Annualised directional wave height distribution predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that from which the waves are flowing. 4
Figure 2.4 Seasonal directional wave height distributions predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that from which the waves are flowing. 4
Figure 2.5 Annualised directional current speed distribution predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that towards which the currents are flowing. 6
Figure 2.6 Seasonal directional current speed distributions predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that towards which the currents are flowing. 7
Figure 2.7 Time series of winds measured at the NRSDAR station and significant wave heights predicted at the centre of the spoil ground (9 November 2019 to 9 May 2020). The red boxes indicate periods of storm conditions. 8
Figure 2.8 Time series of winds measured at the NRSDAR station and significant wave heights predicted at the centre of the spoil ground (9 May 2020 to 9 November 2020). 9
Figure 4.1 Example two-hourly snapshots of modelled bottom thickness during a nominal spring tide cycle (based on 16 November 2019 1pm to 11pm, top-left panel to bottom-right panel). Periods of slack tide occur at approximately 2pm and 7pm. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 15
Figure 4.2 Example two-hourly snapshots of modelled bottom thickness during a nominal spring tide cycle (based on 17 November 2019 1pm to 11pm, top-left panel to bottom-right panel). Periods of slack tide occur at approximately 2pm and 7pm. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 16
Figure 4.3 Progressive snapshots of modelled bottom thickness at the start of the run-on period, half a week, one week, two weeks and three weeks into the run-on period, and at the end of the run-on period (top-left panel to bottom-right panel). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visualisation. 17
Figure 4.4 Time series of predicted disposal-excess SSC at the *OD1* to *OD5* sites throughout the one-year run-on period. 20
Figure 4.5 Time series of predicted disposal-excess SSC at the *OD6* to *OD9* (via *OD3*) sites throughout the one-year run-on period. 21

1 INTRODUCTION

1.1 Background

Santos is exploring options for the Darwin pipeline duplication (DPD) project associated with development of the Barossa gas field in northern Australia. The proposed pipeline would run from the offshore point where the Barossa gas export pipeline (GEP) reaches the existing Bayu-Undan pipeline to the Darwin LNG (DLNG) plant at Wickham Point in Darwin Harbour. Sections making up approximately 16 km of the proposed pipeline within the harbour will require trenching using dredge vessels, with the remaining sections – including the section offshore from the harbour – laid on the seabed. Trenched material is proposed to be disposed of at an offshore disposal site adjacent to the existing INPEX spoil ground. Pipeline burial where required is proposed using quarry rock material. Suspended sediment generated during these activities has a potential to cause environmental impacts which must be identified, quantified, mitigated and managed to acceptable levels.

RPS was commissioned by Santos to undertake sediment dispersion modelling of the trenching and disposal operations associated with the Barossa DPD project in support of environmental approvals documentation and the development of the trenching and spoil disposal monitoring and management plan (TSDMMP) for the project. The sediment dispersion modelling has quantified the potential magnitude, intensity and spatial distribution of suspended sediment concentrations (SSC) and sedimentation that would be expected for the trenching and disposal operations proposed for the project. The predicted outcomes are to be used to inform the assessment of the potential for influence or impact upon water quality and benthic habitats in the region.

The sediment fate model inputs, methodologies and assumptions, and the model outcomes following analysis against specified threshold criteria are reported in RPS (2022).

1.2 Additional Modelling Scope

Following the reported outcomes of the sediment dispersion modelling study, Santos and RPS engaged in a peer review process through the Australian Institute of Marine Science (AIMS) and held discussions with the Northern Territory (NT) Department of Environment Parks and Water Security (DEPWS). During this process, queries were raised about the longer-term stability of the trench spoil at the proposed offshore spoil ground – in particular, during storm events. Santos commissioned RPS to conduct an additional spoil stability assessment, which focused on potential remobilisation of the material in the spoil ground after the trenching and disposal operations were complete, over a longer-term (one-year) period, with particular focus on non-cyclonic extreme events that occurred within the modelled period. The spoil stability assessment has quantified the potential magnitude and spatial distribution of sedimentation/deposition that would be expected in the longer term at the spoil ground and surrounding areas for the disposal operations proposed for the project.

This document is presented as an addendum to our previous report (RPS, 2022).

2 CHARACTERISATION OF METOCEAN CONDITIONS AT THE PROPOSED SPOIL GROUND LOCATION

Regional metocean conditions affecting the wider project area have been described in RPS (2022). However, in order to assess the potential for remobilisation of settled material at the spoil ground and identify periods of storm conditions, the winds, waves and currents at the proposed spoil ground area needed a specific analysis. The analysis has been based on data extracted from the validated hydrodynamic and wave model framework at a point in the centre of the proposed spoil ground, and measured wind data at Australia's Integrated Marine Observing System (IMOS) national reference station Darwin (NRSDAR).

2.1 Winds at NRSDAR Station

Measured wind data at the NRSDAR location for the period January 2019 to December 2020 (inclusive) was sourced to provide wind forcing validation for the hydrodynamic and wave model framework (RPS, 2022), and is the closest measured wind data to the offshore disposal ground (~20 km away). A wind rose for the complete two-year dataset is presented in Figure 2.1 and seasonal wind roses are presented in Figure 2.2.

The roses show that winds near the proposed spoil ground have a distinct seasonal pattern, reflecting the dominant south-east trade winds in the region during the dry season, with west to north-westerlies dominant during the wet season. Ambient wind magnitudes vary up to 14 m/s, however these are less than 8 m/s for the majority of the time (>94%). Wind magnitudes are shown to be higher on average in the wet season, which is most likely associated with the formation of mid-to-late afternoon storm cells, and the presence of tropical lows and cyclones in the region during this time of the year.

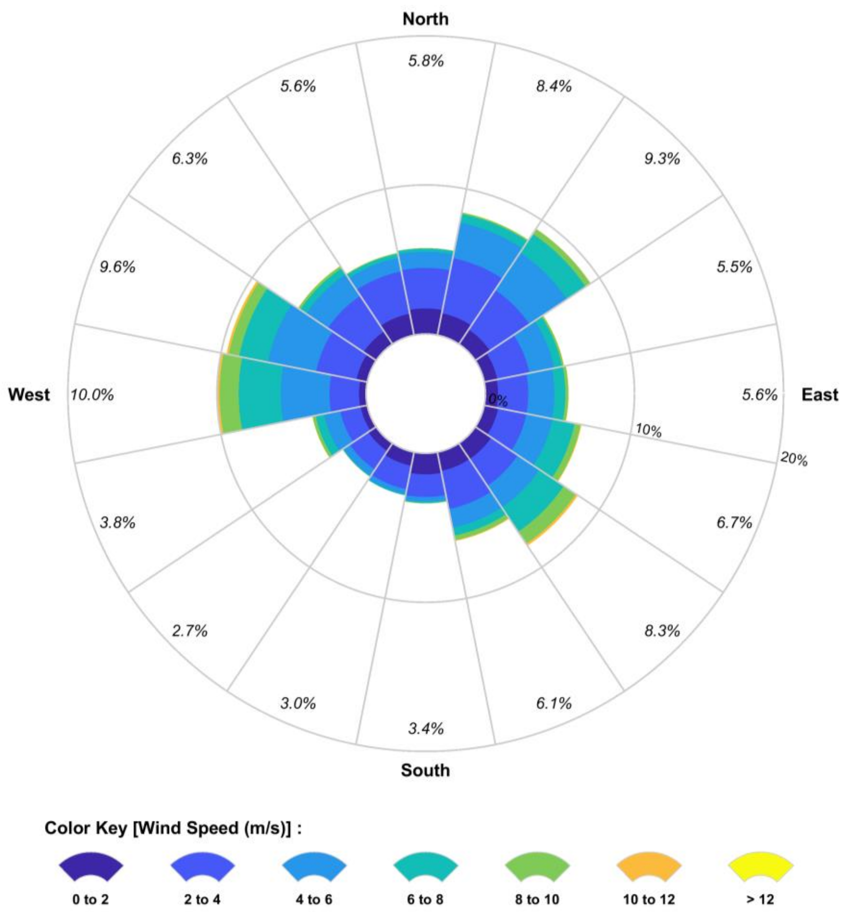

Figure 2.1 Annualised directional wind speed distribution measured at the NRSDAR station (January 2019 to December 2020). The compass direction shows that from which the wind is blowing.

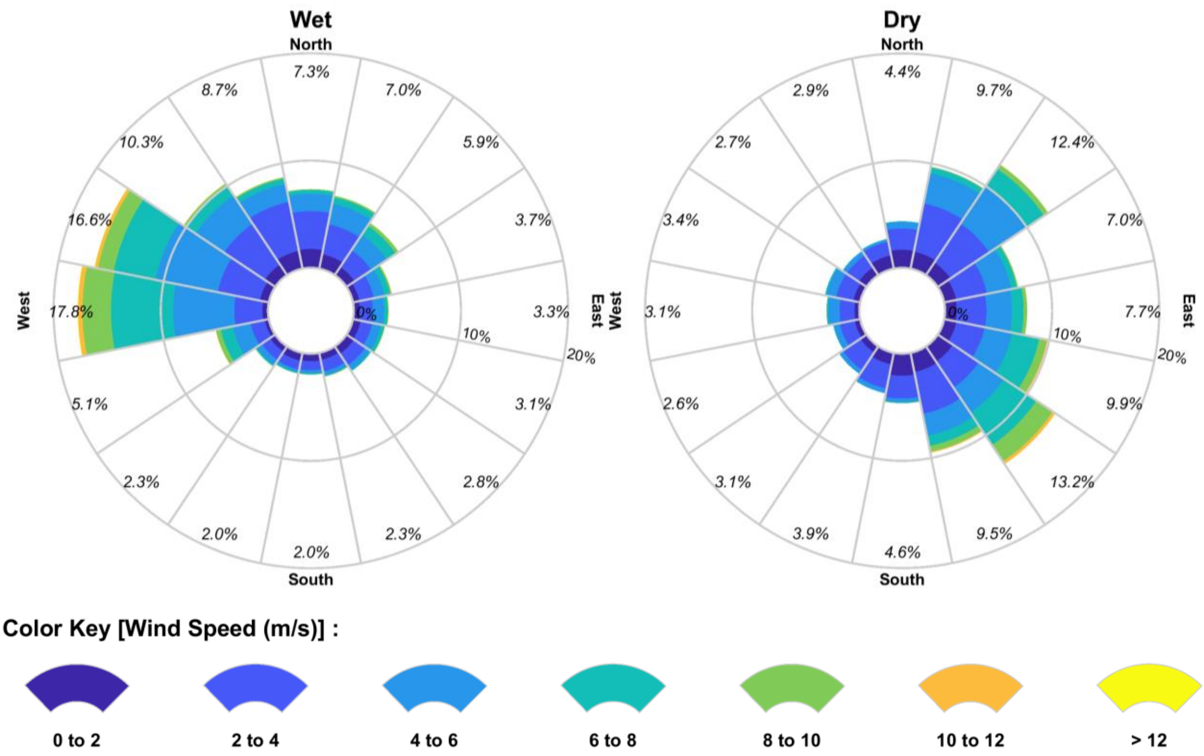

Figure 2.2 Seasonal directional wind speed distributions measured at the NRSDAR station (January 2019 to December 2020). The compass direction shows that from which the wind is blowing.

2.2 Waves at Proposed Spoil Ground

Wave conditions were extracted from the validated wave model framework at a point in the centre of the proposed spoil ground for the period 2019-2020 (inclusive). A wave rose of significant wave height (H_s) and mean wave direction (θ_m) for the complete two-year dataset is presented in Figure 2.3 and seasonal wave roses are presented in Figure 2.4. Joint frequency tables of significant wave height and mean wave period (T_m) for the complete dataset (Table 2.1), the wet season (Table 2.2) and the dry season (Table 2.3) are also presented.

The roses and joint frequency tables show that the wave climate at the spoil ground is strongly seasonal, mirroring the seasonality in the wind climate of the region. The seasonal difference is more accentuated in the wave climate due to the uninterrupted fetch for winds from the west-north-westerly direction which are dominant in the wet season, and the relatively short fetch for the south-easterly winds dominant during the dry season.

Therefore, waves at the spoil ground during the dry season are generally low energy sea waves with significant wave heights below 1.0 m almost all (99%) of the time, and mean wave periods between 2-4 s most (~92%) of the time. In the wet season wave heights are generally larger, being less than 1.6 m almost all (99%) of the time and ranging up to 2.2 m during the passage of storm cells and tropical lows within the modelled time period. The mean wave periods are also slightly higher in the wet season, however they remain within the range of sea waves, being between 2-5 s almost all (98%) of the time. The lack of swell wave periods at the spoil ground is expected as Beagle Gulf is sheltered from ocean swell waves by the Tiwi Islands and coastline configuration.

It should be noted that the modelled period included non-cyclonic storms and the passage of tropical lows within the region, but did not include any tropical lows or tropical cyclones whose paths led directly over Beagle Gulf and Darwin Harbour. Therefore, the maximum significant wave heights that may occur at the spoil ground may be larger than was predicted within the modelled period. Wave height measurements from the IMOS NRSDAR station near the entrance to Darwin Harbour (~20 km away) recorded significant wave heights exceeding 3.5 m during the passage of tropical lows in 2012, with peak periods of wave energy also increasing to between about 6-8 seconds (Nicholas *et al.*, 2019).

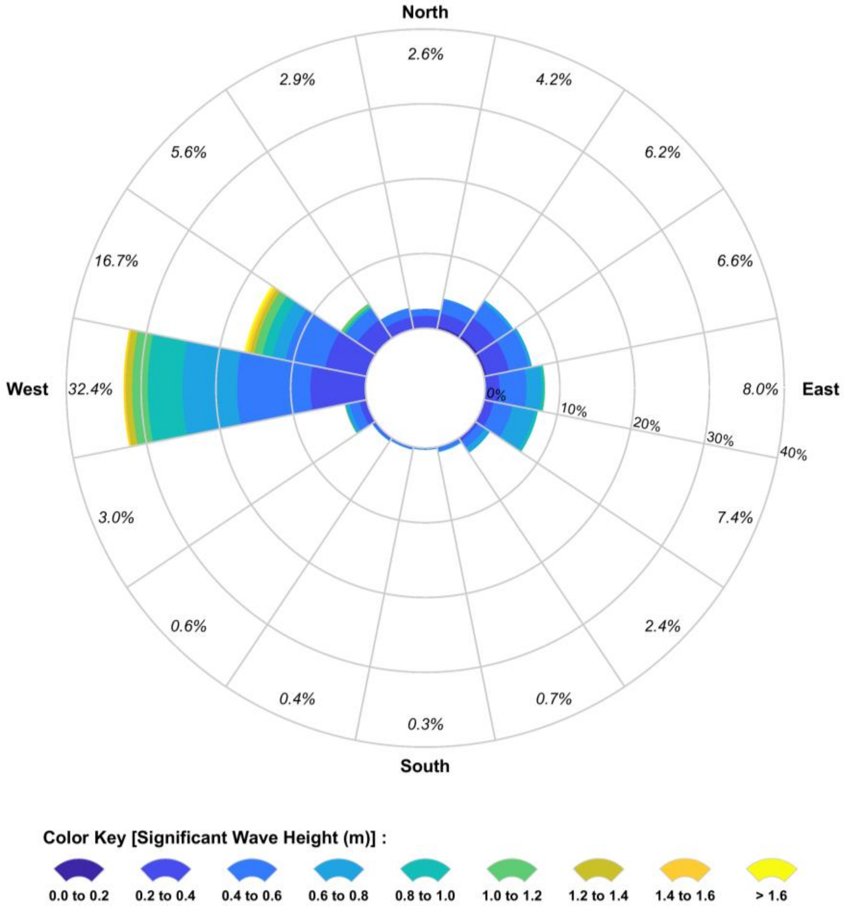

Figure 2.3 **Annualised directional wave height distribution predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that from which the waves are flowing.**

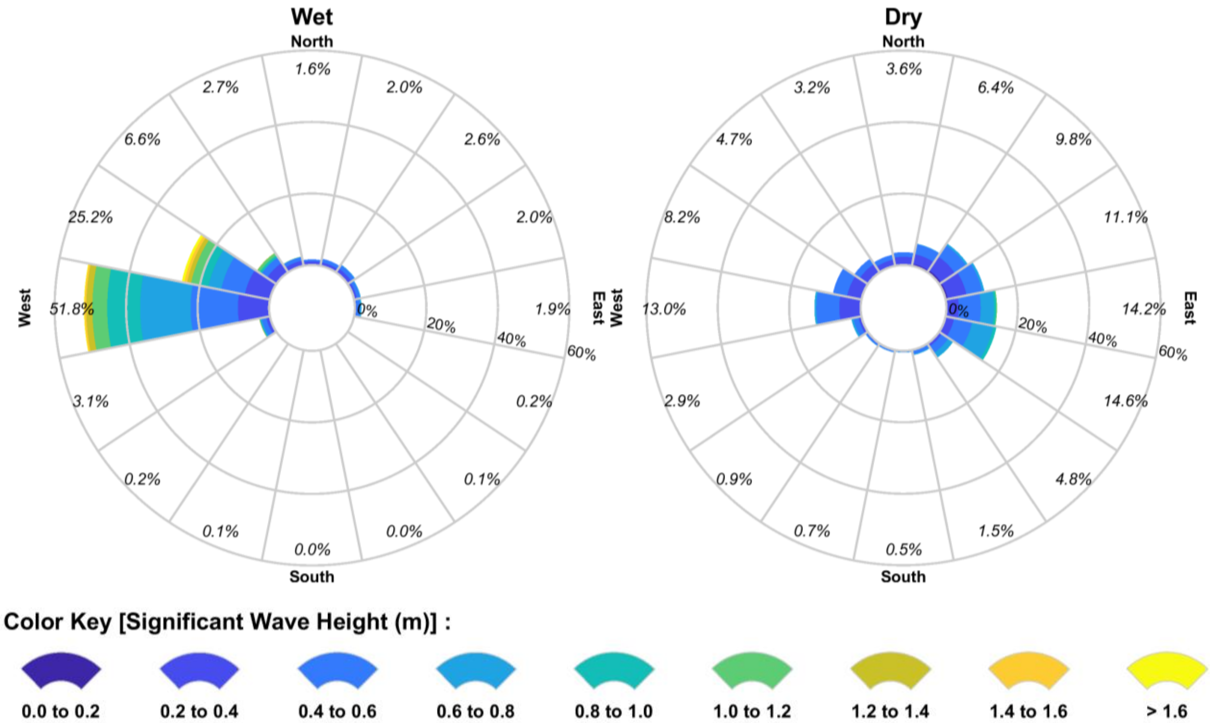

Figure 2.4 **Seasonal directional wave height distributions predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that from which the waves are flowing.**

Table 2.1 Annualised joint frequency table of significant wave height and mean wave period predicted at the centre of the spoil ground (January 2019 to December 2020).

H_s (m)	T_m (s)								
	1.0 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	5.0 - 6.0	6.0 - 7.0	>7.0	Sum	Cum.
0.00 - 0.20	1.0	0.4	0.03	0.01				1.5	1.5
0.20 - 0.40	1.3	16.8	12.6	1.1	0.2	0.1		32.1	33.6
0.40 - 0.60		13.7	21.1	1.2	0.01			36.1	69.7
0.60 - 0.80		3.8	9.2	3.3	0.4			16.8	86.4
0.80 - 1.00		0.2	5.1	1.9	0.05			7.2	93.6
1.00 - 1.20			1.6	2.2	0.05			3.8	97.4
1.20 - 1.40				1.5	0.02			1.5	98.9
1.40 - 1.60				0.7				0.7	99.6
>1.60				0.3	0.2			0.4	100
Sum	2.3	35.0	49.6	12.2	0.9	0.1			
Cum.	2.3	37.2	86.8	99.0	99.9	100	100		

Table 2.2 Wet-season joint frequency table of significant wave height and mean wave period predicted at the centre of the spoil ground (January 2019 to December 2020).

H_s (m)	T_m (s)								
	1.0 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	5.0 - 6.0	6.0 - 7.0	>7.0	Sum	Cum.
0.00 - 0.20	0.4	0.05						0.5	0.5
0.20 - 0.40	0.5	14.3	10.7	0.6				26.2	26.6
0.40 - 0.60		11.2	16.9	1.0				29.0	55.7
0.60 - 0.80		1.2	10.5	6.7	0.8			19.1	74.7
0.80 - 1.00			8.8	3.8	0.09			12.7	87.4
1.00 - 1.20			2.9	4.4	0.09			7.4	94.8
1.20 - 1.40				3.0	0.05			3.0	97.8
1.40 - 1.60				1.3				1.3	99.1
>1.60				0.6	0.3			0.9	100
Sum	0.9	26.8	49.8	21.2	1.3				
Cum.	0.9	27.7	77.5	98.7	100	100	100		

Table 2.3 Dry-season joint frequency table of significant wave height and mean wave period predicted at the centre of the spoil ground (January 2019 to December 2020).

H_s (m)	T_m (s)								
	1.0 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	5.0 - 6.0	6.0 - 7.0	>7.0	Sum	Cum.
0.00 - 0.20	1.6	0.8	0.07	0.02				2.5	2.5
0.20 - 0.40	2.0	19.3	14.5	1.6	0.43	0.25		38.1	40.5
0.40 - 0.60		16.3	25.3	1.53	0.02			43.1	83.7
0.60 - 0.80		6.4	8.0	0.02				14.4	98.1
0.80 - 1.00		0.4	1.3					1.7	99.7
1.00 - 1.20			0.3					0.3	100
1.20 - 1.40									100
1.40 - 1.60									100
>1.60									100
Sum	3.6	43.1	49.4	3.2	0.5	0.3			
Cum.	3.6	46.7	96.1	99.3	99.8	100	100		

2.3 Currents at Proposed Spoil Ground

Current conditions were extracted from the validated hydrodynamic model framework at a point in the centre of the proposed spoil ground for the period 2019-2020 (inclusive). The bottom-layer currents are presented as this layer is important for bottom shear stress and sediment resuspension. A current rose for the complete two-year dataset is presented in Figure 2.5 and seasonal current roses are presented in Figure 2.6.

The roses reveal the tide is the dominant influence on currents at the spoil ground, which are oriented along the tidal axis approximately east-west and show minimal seasonal differences. The predicted current speeds in the bottom layer (which are slightly lower than those in the surface layer) are relatively strong, ranging up to 0.95 m/s, and are strongly correlated with the rise and fall of the tide.

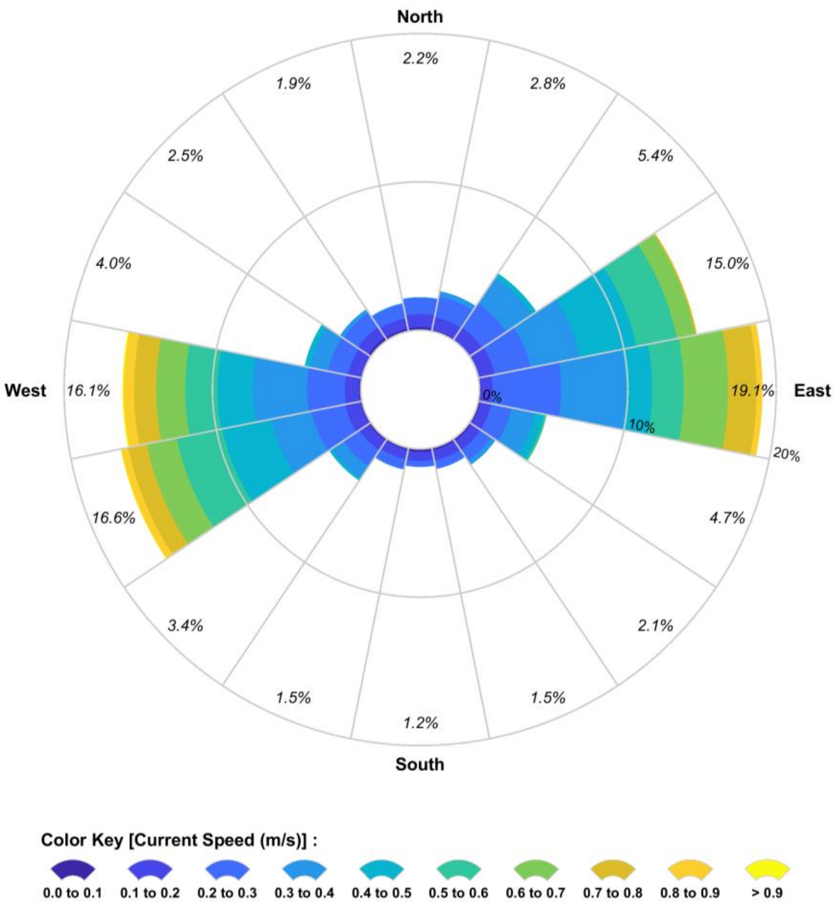

Figure 2.5 Annualised directional current speed distribution predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that towards which the currents are flowing.

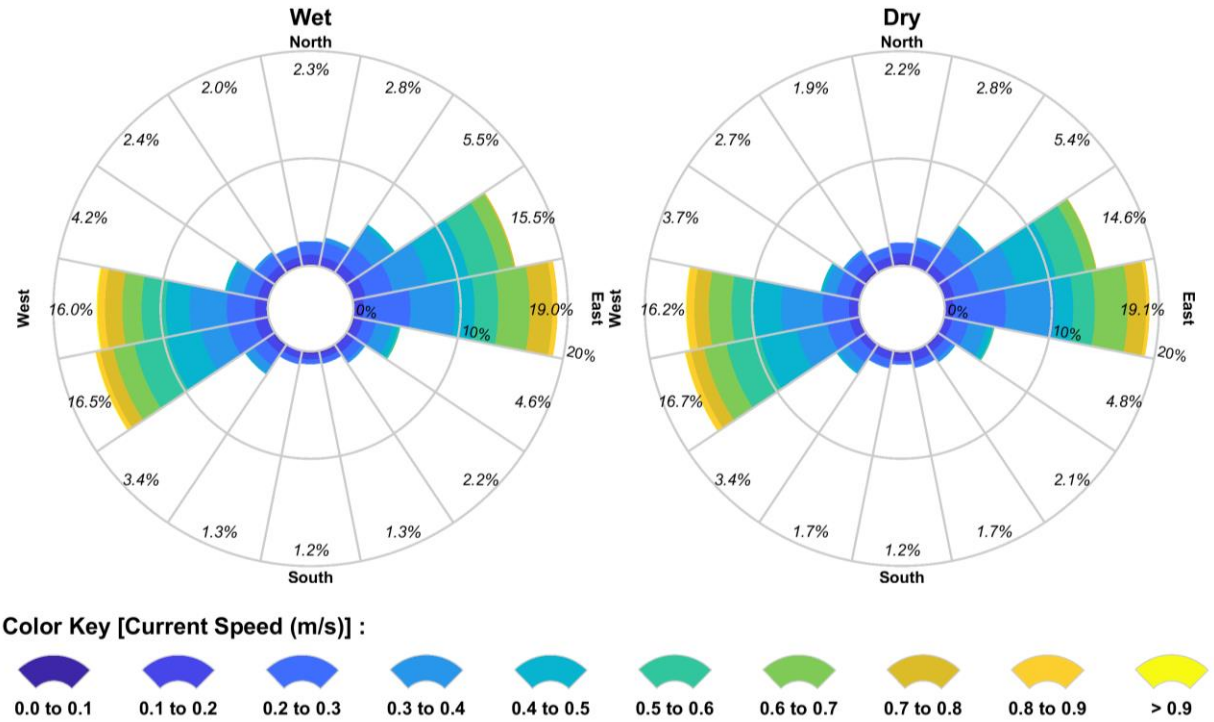

Figure 2.6 **Seasonal directional current speed distributions predicted at the centre of the spoil ground (January 2019 to December 2020). The compass direction shows that towards which the currents are flowing.**

2.4 Identification of Storm Conditions within the Modelled Period

The wind speed and significant wave height were assessed to identify periods of storm events over the one-year run-on period for the spoil stability assessment. Figure 2.7 and Figure 2.8 present time series of the wind speed measured at the NRSDAR station and the significant wave height predicted at the proposed spoil ground location, for two six-month periods spanning 9 November 2019 to 9 November 2020. From the plots it is evident that the wind speeds and significant wave heights mirror each other, which is to be expected given the dominance of sea waves and minimal swell in the region. Periods with sustained elevation in both the wind and wave magnitudes have been identified and are marked by red boxes on Figure 2.7. Note that no periods of sustained elevated wave magnitudes (H_s >1 m) were identified during the dry season. While the wind magnitudes showed periods of elevation, the limited fetch distance from the dominant south-easterly wind direction means wave magnitudes remained low.

Four storm periods were identified within the modelled scenario:

1. 25 to 29 December 2019.
2. 7 to 13 January 2020. This correlates with dates reported by the Bureau of Meteorology (BoM) for the evolution of Tropical Cyclone Claudia (5 to 16 January 2020).
3. 19 to 25 January 2020.
4. 21 February to 6 March 2020. This correlates with dates reported by the BoM for the evolution of Tropical Cyclone Esther (21 February to 4 March 2020).

Of the four identified storm periods, two were associated with the passage of tropical lows or ex-tropical cyclones within the region, and the other two are likely due to local thunderstorm activity.

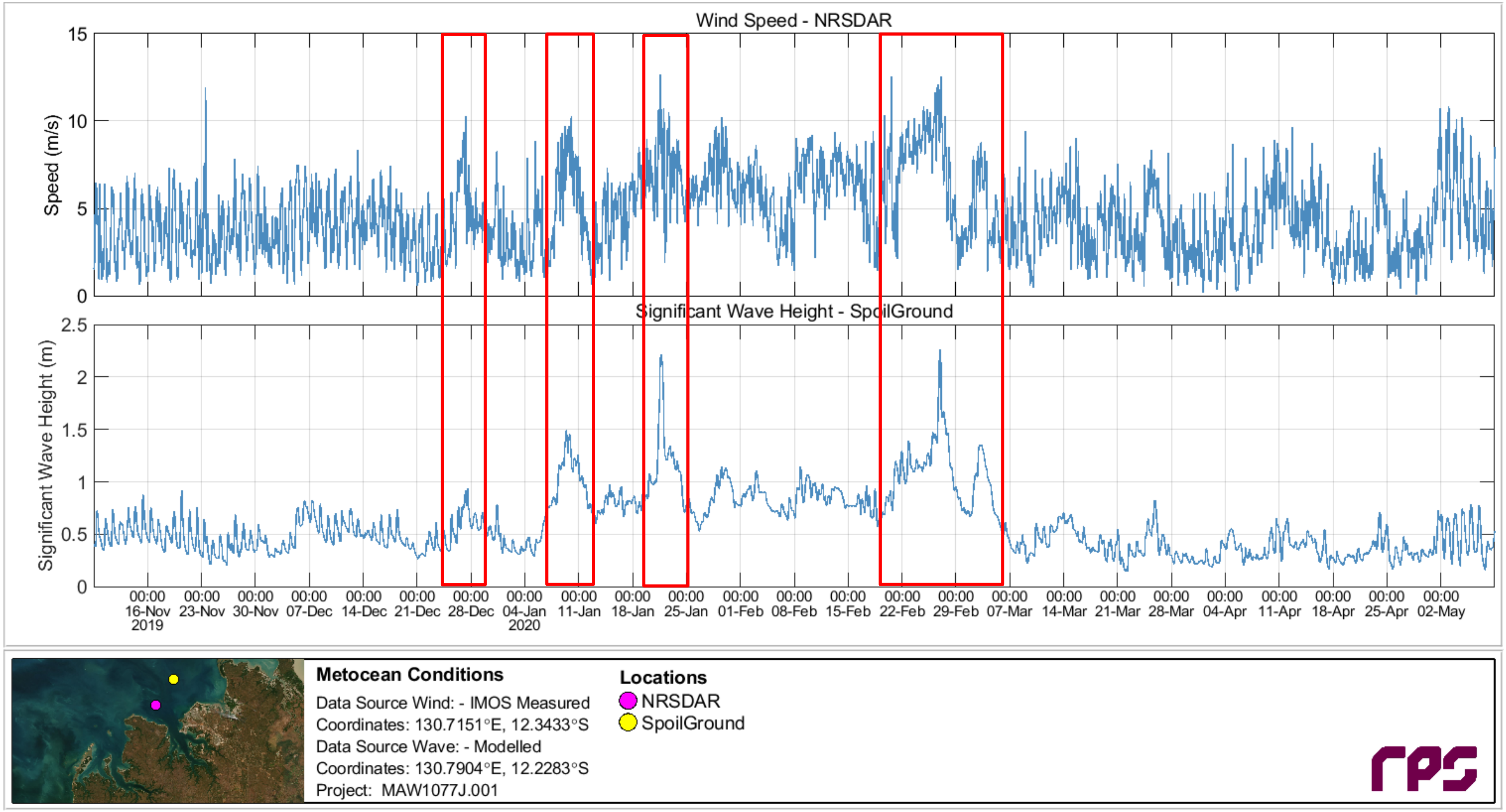

Figure 2.7 Time series of winds measured at the NRSDAR station and significant wave heights predicted at the centre of the spoil ground (9 November 2019 to 9 May 2020). The red boxes indicate periods of storm conditions.

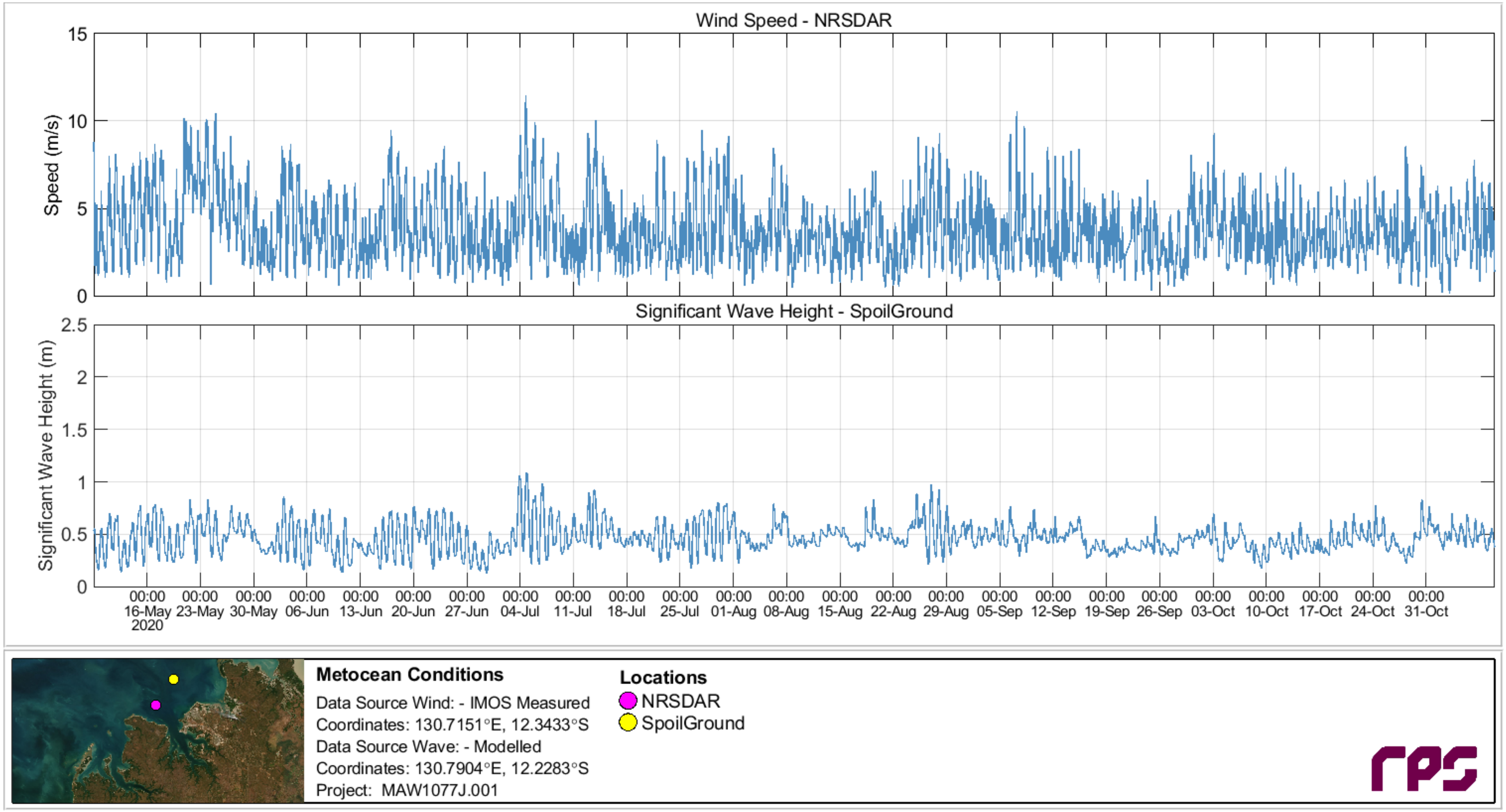

Figure 2.8 **Time series of winds measured at the NRSDAR station and significant wave heights predicted at the centre of the spoil ground (9 May 2020 to 9 November 2020).**

3 APPROACH TO SPOIL STABILITY MODELLING

Following (and during) the trenching and disposal program, energy from wave and current action can exceed that required for mobilisation and resuspension of the previously settled material. To investigate the longer-term stability of the proposed spoil ground, simulation of sediment transport of the material within the spoil ground was conducted in SSFATE for a one-year run-on period, following completion of trenching and disposal operations. The assessment used spatially-varying current and wave data, spanning the period of October 2019 to November 2020, taken from the hydrodynamic and wave model framework developed for the project. Only the wet season scenario has been modelled in the spoil stability assessment, as the subsequent run-on period covered an entire year and all seasonal conditions were represented. Additionally, most of the identified storms fell in the wet season and followed on from the end of trenching and disposal operations in this scenario.

The methodology applied for the sediment dispersion modelling of the trenching and disposal operations has been applied to the spoil stability assessment, with some modifications as outlined in this section. For details of the modelling methodology – including the model used, details of the hydrodynamic and wave model framework, model domain and bathymetry, overview of the trenching and disposal operations program, and how the sources of suspended sediment were represented in the model – please refer to our sediment dispersion modelling report (RPS, 2022).

The proposed spoil ground was pre-filled with the material from the TSHD and BHD disposal loads in the same pattern as modelled for the trenching and disposal activities (RPS, 2022). The disposal operations were assumed to have the broad aim of evenly distributing the total volume of allocated material across the entire spoil ground area by the conclusion of all activities. The main difference applied in the spoil stability assessment rests in the volume of disposed material that was assumed to be available for resuspension.

In the modelling of trenching and disposal activities it was assumed that 5% of the deposited mass – representing the volume of the upper surface layer of the spoil mound – would be available for resuspension. This was done to account for the natural sediment capping in the surface layer of the mound that will occur as the smaller-sized particles (silts and clays) are resuspended, leaving the larger particles to act as armouring against bottom shear stress. While the model maintains mass balances of each sediment size class within each grid cell to derive an estimate of the median particle size, and uses this to calculate the potential for ongoing resuspension of fines, it does not precisely represent the process of sediment capping. As such, the assumption that only a proportion of the mound is available for resuspension is necessary so that overestimates of resuspension and in turn SSC do not occur in the modelling.

However, to conduct the spoil stability assessment it was necessary to model the total volume of material that will be placed on the seabed within the spoil ground. It was assumed that 95% of the total disposed volume, rather than 5%, would be placed on the seabed and assumed to be available for resuspension. This assumes that 5% of the material would have been lost to the water column during the disposal operations. It should be noted that this approach may result in overestimation of resuspension and as such the outcomes should be viewed as a guide to the potential for resuspension of the mound, and the stability of the mound, during storm conditions.

The volumes of material placed on the seabed in the spoil ground during disposal operations are outlined in Table 3.1. The surface area of the proposed spoil ground is approximately 6,290,000 m^2; given the volume of material to be placed there, a theoretical thickness of 4-17 cm (depending on depositional density) is expected if the spoil is evenly distributed.

Table 3.1 Summary of sediment sources applied in the model.

Operation	Source Rate (% Disposed Volume)	Trenched Volume (m^3)	Trenching Volume Loss (m^3)	Disposal Volume Loss (m^3)	Spoil Volume (m^3)
Disposal SHB	95 (seabed; potential)	22,220	511	1,085	20,623
Disposal TSHD	95 (seabed; potential)	281,725 *	6,004	13,786	261,935
	Totals	**303,945 ***	**6,515**	**14,871**	**282,558**

* Note these volumes include the proportion of material that has been crushed by CSD and subsequently picked up by TSHD.

The standard particle classes used in SSFATE are set according to the typical size ranges of material that are found within suspended sediment plumes, whereas the grain size of the sediment that remains in disposal areas is typically greater than that which dispersed during the initial trenching and disposal activities. For the assessment of the long-term stability of the spoil material a modified set of grain classes, weighted more towards coarser material, was applied. Table 3.2 shows the modified material classes used in SSFATE for the spoil stability assessment.

Table 3.2 Material size classes used in SSFATE.

Material Class Description	Particle Size Range (µm)
Fines – Clay and Silt	<75
Fine to Medium Sand	75-300
Medium Sand	300-600
Coarse Sand to Pebble	600-10,000
Pebble/Rubble	>10,000

The PSDs that were applied in the sediment dispersion modelling of trenching and disposal activities were based on available geotechnical information for each pipeline section (RPS, 2022). These PSDs have been redistributed to match the modified material size classes used in SSFATE for the spoil stability assessment, as shown in Table 3.3. It is assumed that the material lost during trenching and disposal operations is made up of the finer sediment proportions that are more likely to be suspended into the water column. As such, the PSDs used to represent the material remaining in the spoil ground have been adjusted to remove 5% of the fines and redistribute this proportionally across the four other size classes, as shown in Table 3.4. The modified PSDs applied to the material placed in the spoil ground by TSHD from the post-sweep of CSD-crushed material are outlined in Table 3.5.

Table 3.3 ***In situ*** **PSDs broken down into the modified SSFATE material classes for each pipeline section to be trenched, derived from available geotechnical information.**

Sediment Grain Size Class	Size Range (µm)	Trench Zones 1-2 (%)	Pre-Sweep Area 1 (%)	Trench Zone 3 (%)	Trench Zone 4 (%)	Pre-Sweep Area 2 (%)	Trench Zone 5 (%)	Pre-Sweep Area 3 (%)	Trench Zone 6 (%)	Trench Zone 7 (%)	Sand Waves Area (%)
Fines – Clay and Silt	<75	20.7	21.7	20.0	28.3	16.0	11.1	25.0	26.2	23.8	5.9
Fine to Medium Sand	75-300	22.7	11.6	8.7	11.4	10.9	6.6	11.4	11.2	10.0	11.4
Medium Sand	300-600	6.7	4.0	3.4	5.5	6.9	3.3	4.0	4.5	7.6	16.3
Coarse Sand to Pebble	600-10,000	47.1	33.3	31.2	37.9	54.7	59.0	52.8	52.0	49.5	66.1
Pebble/Rubble	>10,000	2.9	29.3	36.8	16.9	11.5	19.9	6.9	6.2	9.1	0.3

Table 3.4 **PSDs broken down into the modified SSFATE material classes for each pipeline section to be trenched, adjusted to remove fines lost during trenching and disposal operations.**

Sediment Grain Size Class	Size Range (µm)	Trench Zones 1-2 (%)	Pre-Sweep Area 1 (%)	Trench Zone 3 (%)	Trench Zone 4 (%)	Pre-Sweep Area 2 (%)	Trench Zone 5 (%)	Pre-Sweep Area 3 (%)	Trench Zone 6 (%)	Trench Zone 7 (%)	Sand Waves Area (%)
Fines – Clay and Silt	<75	15.7	16.7	15.0	23.3	11.0	6.1	20.0	21.2	18.8	0.9
Fine to Medium Sand	75-300	24.1	12.4	9.2	12.2	11.5	7.0	12.2	12.0	10.6	12.0
Medium Sand	300-600	7.1	4.2	3.6	5.9	7.4	3.5	4.2	4.8	8.1	17.2
Coarse Sand to Pebble	600-10,000	50.0	35.5	33.1	40.5	57.9	62.4	56.4	55.5	52.8	69.6
Pebble/Rubble	>10,000	3.1	31.2	39.1	18.1	12.2	21.0	7.3	6.6	9.7	0.3

Table 3.5 Modified PSDs of sediments dumped at the spoil ground by TSHD from the post-sweep of CSD-crushed material.

Sediment Grain Size Class	Size Range (µm)	PSD (%) for Sediment Disposal – Trench Zone 3	PSD (%) for Sediment Disposal – Trench Zone 4	PSD (%) for Sediment Disposal – Trench Zone 5	PSD (%) for Sediment Disposal – Trench Zone 6	PSD (%) for Sediment Disposal – Trench Zone 7
Fines – Clay and Silt	<75	10.6	10.6	5.5	10.0	10.7
Fine to Medium Sand	75-300	10.8	10.8	11.1	11.4	10.7
Medium Sand	300-600	26.2	26.2	27.8	26.2	26.2
Coarse Sand to Pebble	600-10,000	26.2	26.2	27.8	26.2	26.2
Pebble/Rubble	>10,000	26.2	26.2	27.8	26.2	26.2

4 RESULTS OF SPOIL STABILITY MODELLING

Simulation of spoil stability at the proposed spoil ground over the one-year run-on period showed that settlement of the finer spoil material is minimal and there is potential for significant resuspension of the finer proportions. The localised movement and dispersion of the disposal-generated and resuspended sediment is governed by the tide, with very strong tidal flows at the spoil ground.

Coarse material (coarse sand size and above) is predicted to settle rapidly, while available fine material in the spoil is predicted to be continuously resuspended on each tide, particularly during spring tide periods where even fine to medium sand size material is predicted to be resuspended. Deposition is forecast to occur at slack tide, however much of this settled material is resuspended on the following tide. This results in suspended sediment plumes having long drift trajectories, with sediments dispersed widely but at low concentrations, and with sediments deposited in thin layers. Drift trajectories from the spoil ground are predicted to be longest to the north-east towards the Clarence Strait and Van Diemen Gulf.

There is significant variability in the predicted vertical distributions of SSC in the water column at the proposed spoil ground, with a distinct increase in concentration towards the seabed. The higher SSC concentrations near the seabed are due to the resuspended material typically being mixed to the lower reaches (1-3 m) of the water column.

4.1 Spatial Distribution of Mobilised Spoil Sediments

In order to map the area of influence of the mobilised sediment and show how it evolves over the one-year run-on period, sequences of snapshots of sedimentation thickness throughout the simulation period were plotted. Figure 4.1 and Figure 4.2 show example two-hourly snapshot sequences of predicted bottom thickness over successive tidal cycles on 16 and 17 November 2019, to illustrate how the sedimentation changes over the short term (12 hours). The snapshots clearly show the deposition of sediment at slack tide and the resuspension of the deposited sediment on the following tide. These sequences were selected early in the run-on period to show the dispersion of the finer sediment as it is resuspended and moved on each tidal cycle progressively further away from the spoil ground.

Figure 4.3 shows progressive snapshots of bottom thickness at the start of the run-on period, half a week, one week, two weeks and three weeks into the run-on period, and at the end of the run-on period to present the evolution of the area of influence over time. In the longer term, significant sedimentation is shown to generally be limited to the vicinity of the spoil ground (within 9-10 km), while sediment that has dispersed and settled further away has typically been subsequently resuspended and dispersed to very low thicknesses (<1 mm). Some isolated patches of longer-term sedimentation are predicted in the shallows around the Vernon Islands and Glyde Point. These patches may be attributable to the combined effects of model bathymetry and hydrodynamics, representing sediments that are transported into the shallowest possible grid cells and then trapped upon reversal of the tide. While it is clear that there is potential for sediments released at the spoil ground to be found in the indicated areas, the persistence of material remaining at the water-land boundary in these locations may be overstated.

The maximum bottom thickness within the spoil ground over the simulation period was predicted to be approximately 400 mm during the disposal operations period, with the maximum longer-term bottom thickness being approximately 240 mm. The average bottom thickness over the spoil ground in the long term is approximately 50 mm.

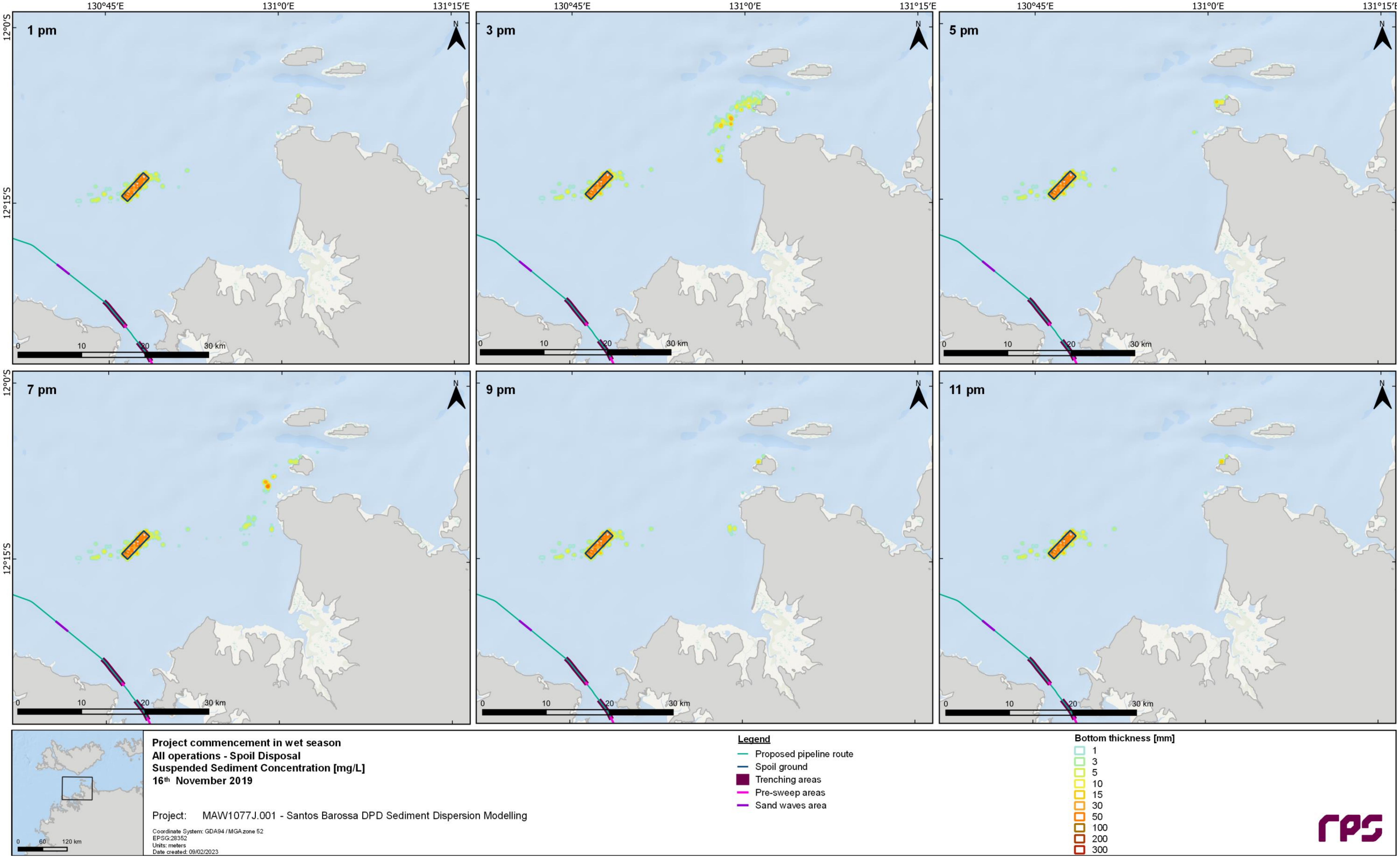

Figure 4.1 **Example two-hourly snapshots of modelled bottom thickness during a nominal spring tide cycle (based on 16 November 2019 1pm to 11pm, top-left panel to bottom-right panel). Periods of slack tide occur at approximately 2pm and 7pm. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.**

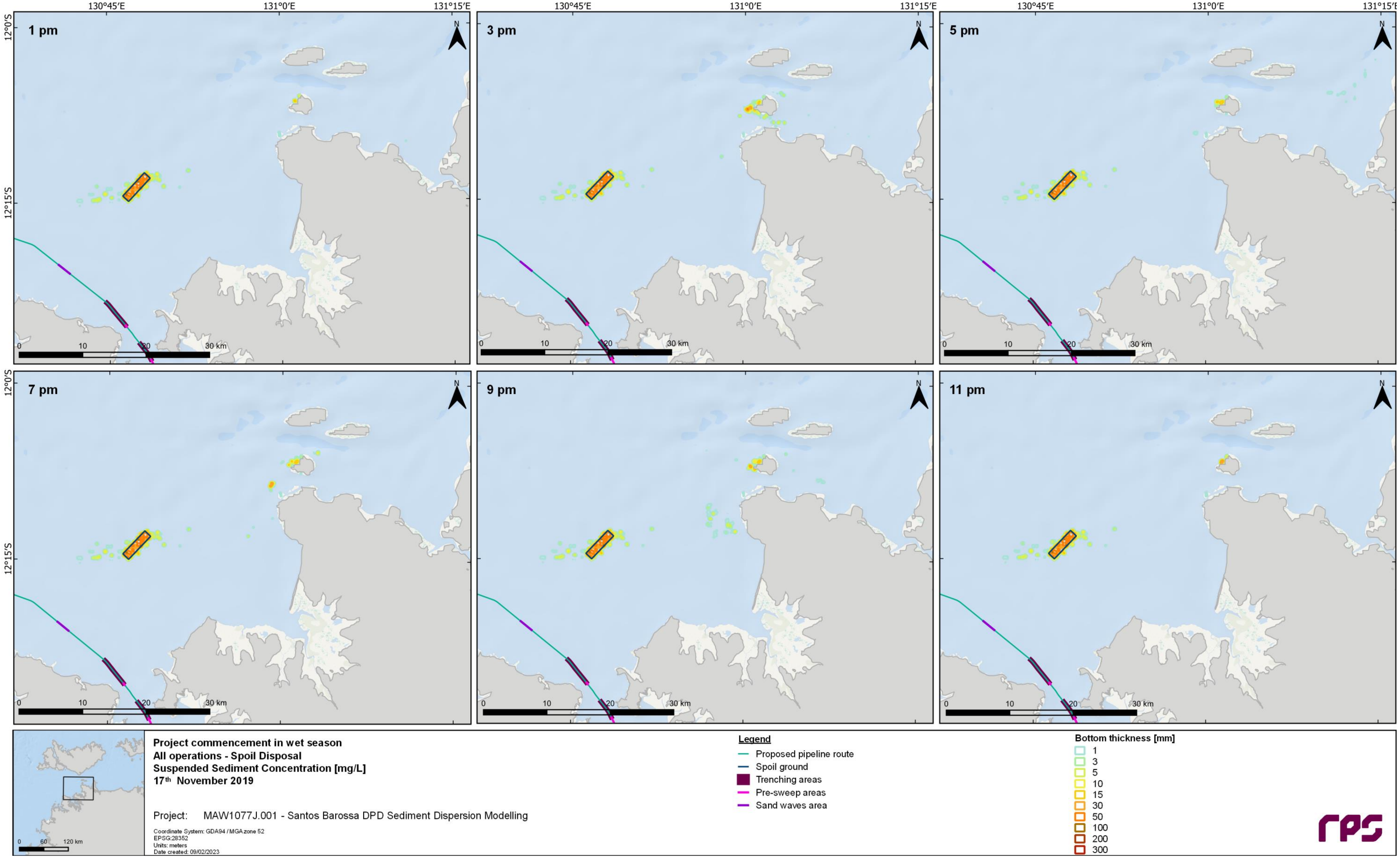

Figure 4.2 Example two-hourly snapshots of modelled bottom thickness during a nominal spring tide cycle (based on 17 November 2019 1pm to 11pm, top-left panel to bottom-right panel). Periods of slack tide occur at approximately 2pm and 7pm. Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

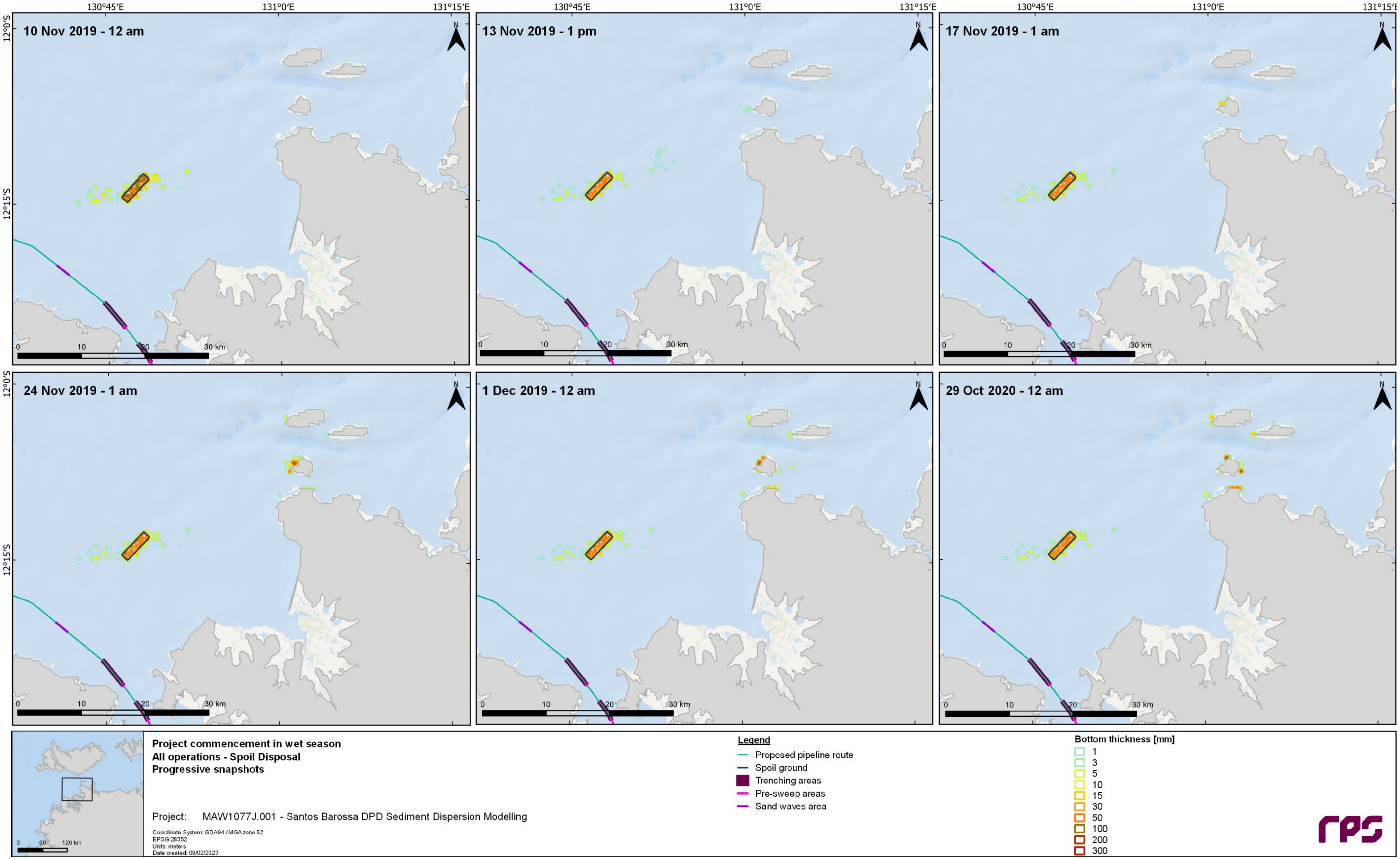

Figure 4.3 Progressive snapshots of modelled bottom thickness at the start of the run-on period, half a week, one week, two weeks and three weeks into the run-on period, and at the end of the run-on period (top-left panel to bottom-right panel). Note the trenching area widths shown on this and other Figures in this report are exaggerated to aid visual clarity.

4.2 Temporal Variability in Spoil Stability at the Spoil Ground

To explore the temporal variability of spoil stability at the proposed spoil ground, time series analysis of the predicted SSC and sedimentation at a set of locations previously defined at the proposed offshore disposal area (RPS, 2022) has been conducted. Table 4.1 presents the locations of the time series points used. Time series plots showing predicted depth-averaged and maximum-in-water-column disposal-excess SSC for each of the selected locations are presented in Figure 4.4 and Figure 4.5. The sedimentation time series plots for these points have not been included as they show very little change over the majority of the simulated period at the scales required to plot the thickness. In place of plots, Table 4.2 shows the median, maximum and last-time-step sedimentation values for each point.

Table 4.1 Time series analysis point locations.

Point Name	Point Abbreviation	Longitude (°)	Latitude (°)
Offshore Disposal Area Point 1	OD1	130.7553	-12.26529
Offshore Disposal Area Point 2	OD2	130.7814	-12.23756
Offshore Disposal Area Point 3	OD3	130.7904	-12.22830
Offshore Disposal Area Point 4	OD4	130.8001	-12.21846
Offshore Disposal Area Point 5	OD5	130.8253	-12.19286
Offshore Disposal Area Point 6	OD6	130.7773	-12.21576
Offshore Disposal Area Point 7	OD7	130.7869	-12.22465
Offshore Disposal Area Point 8	OD8	130.7952	-12.23249
Offshore Disposal Area Point 9	OD9	130.8036	-12.23999

The time series analysis indicated that there will be significant temporal variability in the distribution of SSC at the proposed spoil ground during disposal operations and in the initial 1-2 weeks following the end of disposal operations. This is due to resuspension of the available finer material within the spoil. Following this, the SSC in the vicinity of the spoil ground reduces significantly with only patchy short-lived spikes evident throughout the remaining run-on period. Additionally, the sedimentation values after the first 1-2 weeks of the run-on period at all points assessed show very little change, indicating that significant resuspension of the material in the mound at the disposal site has mostly ceased to occur.

Sediment thicknesses at the points within the spoil ground are predicted to range from 24 mm up to a maximum of 140 mm during the disposal operations period, with the long-term thickness ranging up to 96 mm.

The time series analysis shows no significant change in SSC or sedimentation at the proposed spoil ground during the four identified storm periods (refer Section 2.4). This indicates that once the finer proportions of the spoil material have dispersed away from the spoil ground in the initial 1-2 weeks after disposal operations cease, the mound is predicted to be relatively stable.

Table 4.2 Median, maximum and last-time-step bottom thickness values at each time series analysis point throughout the disposal program and one-year run-on period.

Point	Median Sedimentation (mm)	Maximum Sedimentation (mm)	Sedimentation at Last Time Step (mm)
OD1	0	0.01	0
OD2	47	101	47
OD3	41	68	41
OD4	96	139	96
OD5	0	0.2	0
OD6	0	3	0
OD7	52	66	52
OD8	24	42	24
OD9	0	9	0

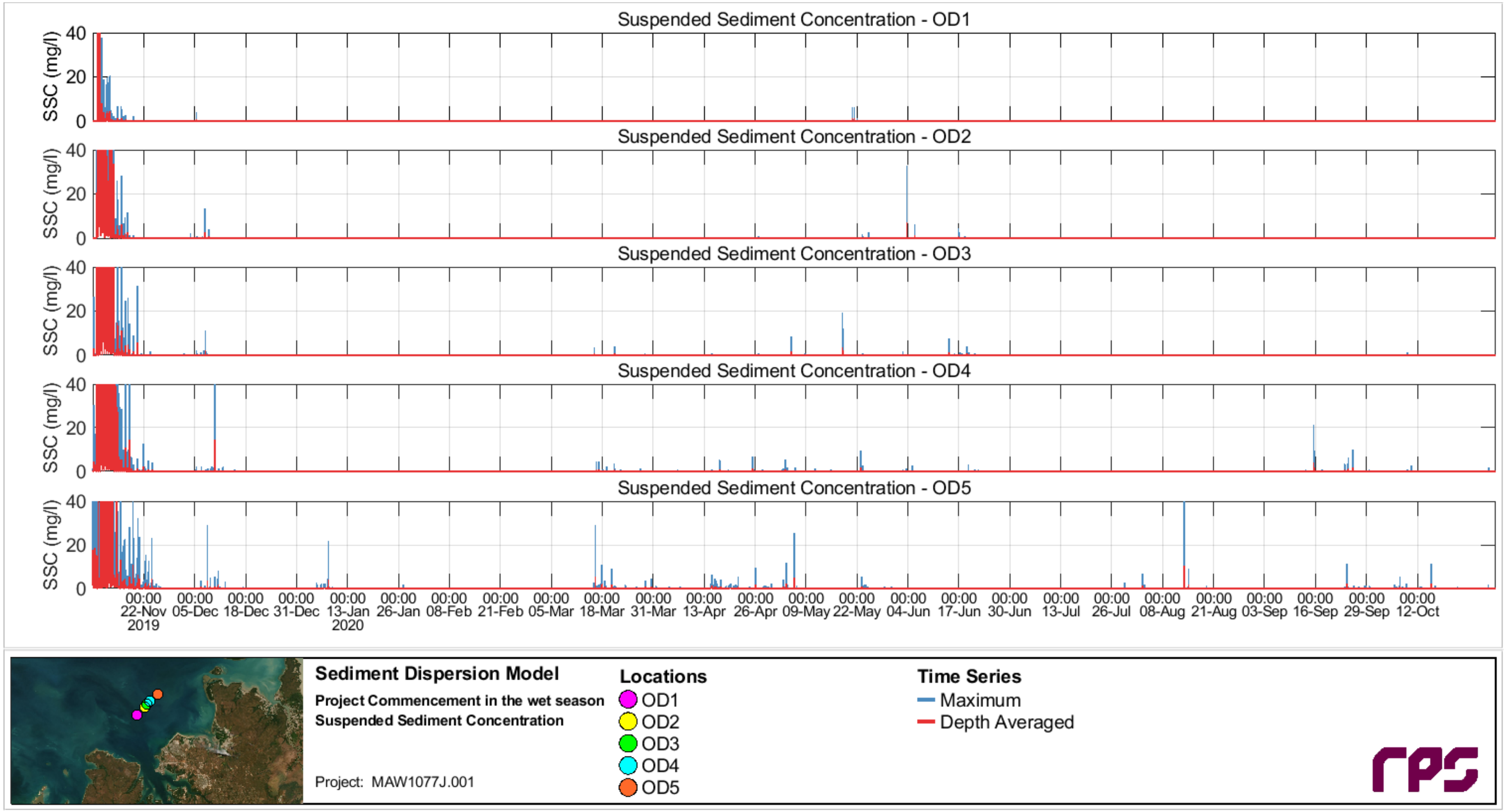

Figure 4.4 Time series of predicted disposal-excess SSC at the *OD1* to *OD5* sites throughout the one-year run-on period.

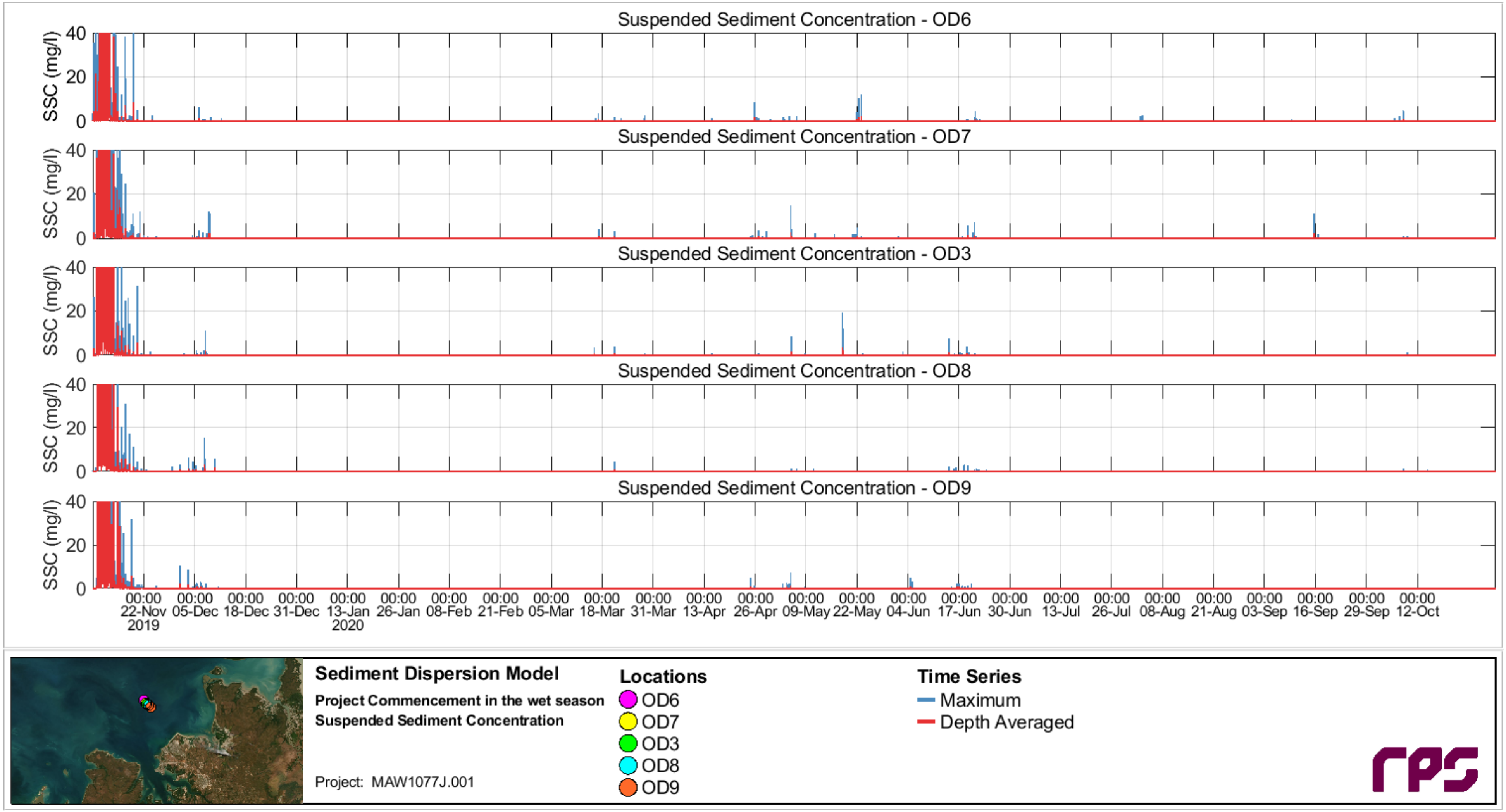

Figure 4.5 Time series of predicted disposal-excess SSC at the *OD6* to *OD9* (via *OD3*) sites throughout the one-year run-on period.

4.3 Cumulative Mass in Spoil Ground

The model results were assessed at the end of each simulated week to calculate the predicted mass inside the proposed spoil ground, and the percentages of the disposed mass remaining were used to assess the stability over time. Table 4.3 presents the cumulative mass remaining in the proposed spoil ground throughout the disposal operation and one-year run-on period. From the cumulative masses remaining, it is evident that a significant proportion of the spoil material has the potential to be dispersed away from the spoil ground during disposal operations and within the initial 1-2 weeks following the end of disposal operations. After the available finer proportion of the spoil material has been dispersed away from the spoil ground, the mass remaining becomes stable and is predicted to change very little, even during the non-cyclonic storm conditions which occur during the simulation period (refer Section 2.4).

It should be noted that the proportion of the spoil material that is available for resuspension, and hence dispersed away from the spoil ground, is overestimated in the model as the natural sediment capping that will occur in the mound is not precisely accounted for. Therefore, in reality the volumes of spoil material lost from the spoil ground are expected to be less than quoted in this addendum. However, this does not change the finding that once the mound surface layer has lost the finer material that is available to resuspend – within the first 1-2 weeks after cessation of disposal operations – it will be relatively stable during ambient and non-cyclonic storm conditions.

Table 4.3 Cumulative mass remaining in spoil ground over the disposal and one-year run-on period.

Weeks from Start of Disposal Operations	Cumulative Mass Remaining (% of Disposal Mass)
1	11.3
2	23.1
3	40.2
4	54.4
5	66.0
6 (disposal operations have finished)	50.1
7	50.1
8	50.1
12	50.1
16	50.1
56	50.1

4.4 Potential for Remobilisation of Deposited Spoil Material

Given the predicted rapid dispersion of the finer proportion of the material from the spoil ground and the predicted volume of spoil lost, a cross-check of the model findings against the calculated potential for resuspension due to the metocean conditions experienced at the spoil ground was conducted.

The effect that the wave and current forcings have on sediment dynamics/resuspension is through the friction that they exert on the seabed, which is expressed as the bed shear stress (frictional force exerted by the flow per unit area). A time series of bed shear stress due to predicted waves and currents, as extracted at the spoil ground, was calculated. To determine an estimate of the potential for remobilisation of spoil material under ambient and non-cyclonic storm conditions at the site, the time series data was compared to the critical bed shear stress required to mobilise the range of grain sizes modelled for the spoil material (Soulsby, 1997; van Rijn, 2005).

The calculations showed that the ambient currents at the spoil ground were strong enough to potentially resuspend material of up to 1.5 mm grain size, and to potentially resuspend the proportions of the sediments in the finer three modelled size classes for 60%, 38% and 27% of the time, respectively. The wave orbital velocities were calculated to rarely be large enough to resuspend sediments within the spoil ground, with the critical shear stress exceeded less than 1% of the time even for the finest material class modelled. This is due to the depth of the spoil ground, the relatively small magnitude of the wave heights, and the relatively short wave periods resulting in low orbital velocities at the seabed – predicted to be always less than 0.18 m/s even during the modelled storm events. Note that during tropical cyclone events – which have not been modelled in this study – wave heights and wave periods may be larger, resulting in larger orbital velocities that have greater potential to resuspend material.

The calculations showed that tidal currents are the main force driving resuspension at the spoil ground and confirmed that the current magnitudes are strong enough for a significant proportion of the time to resuspend the finer proportions of the material from the spoil ground. This confirms the model findings that dispersion/loss of the available finer components of the spoil material will be rapid, that there is potential to resuspend a large proportion of the spoil material if it is available, and that once the finer proportions of the spoil material are dispersed away from the spoil ground the mound will be relatively stable during non-cyclonic storm events.

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Appendix 4: Trenching and Spoil Disposal Management and Monitoring Plan

BAS-210 0023

Santos

Darwin Pipeline Duplication (DPD) Project – Trenching and Spoil Disposal Management and Monitoring Plan (TSDMMP)

PROJECT / FACILITY	Barossa DPD Project
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	**Owner**	**Reviewer/s** Managerial / Technical / Site	**Approver**
	Project Environmental Lead	Project HSE Manager	Project Director
E			

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Rev	Rev Date	Author / Editor	Amendment
A	2/09/2022	RPS	Issued for Santos review
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C	23/01/2023	RPS	Issued for Santos review
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Contents

Abbreviations, acronyms, glossary and units of measurements 10

1 Introduction 15

1.1 Project overview 15
1.2 Purpose 17
1.3 Scope 17
1.4 Plan structure 18
1.5 Proponent 19
1.5.1 Details of the proponent 19
1.5.2 Details of nominated liaison person 20
1.5.3 Notification procedure in the event of changed details 20
1.6 Plan availability, review, and revision 21

2 Trenching and Spoil Disposal Methodology 22

2.1 Overview 22
2.2 Project area 22
2.2.1 Trenching areas 22
2.2.2 Spoil disposal ground 22
2.3 Trench designs 24
2.4 Equipment 26
2.4.1 Backhoe dredger 26
2.4.2 Trailing suction hopper dredge 26
2.4.3 Cutter suction dredger 27
2.4.4 Split hopper barge 28
2.4.5 Excavator 29
2.5 Work method 29
2.5.1 Trenching method 29
2.5.2 Spoil disposal method 33
2.6 Indicative dredging and disposal schedule 33

3 Legal and other obligations 34

3.1.1 Commonwealth environmental approval 34
3.1.2 Northern Territory environmental approvals 34
3.1.3 Aboriginal Areas Protection Authority certificates 35
3.2 Legislative framework 35
3.2.1 Key legislation 35
3.2.2 Other relevant legislation 36
3.2.3 International conventions and agreements 39
3.2.4 Standards, codes and guidelines 40

4	**Environmental management framework**	**41**
4.1	Santos Management System (SMS)	41
4.2	Santos' Environment, Health, and Safety Policy	41
4.3	DPD Project Environmental Management Plans	41
4.4	Supporting management processes and procedures	41
4.4.1	Contractor health, safety and environment requirements	41
4.4.2	Santos marine vessel vetting process	42
4.4.3	Santos waste management process	43
4.4.4	Ballast water management	43
4.4.5	Biofouling management	44
5	**Existing Environment**	**48**
5.1	Physical environment	48
5.1.1	Meteorological conditions	48
5.1.2	Coastal morphology	49
5.1.3	Oceanography	50
5.1.4	Water quality	51
5.1.5	Sediment quality	52
5.1.6	Underwater noise	54
5.2	Benthic habitats	54
5.2.1	Offshore Northern Territory waters	54
5.2.2	Darwin Harbour	55
5.2.3	Hard Coral	60
5.2.4	Filter Feeders	60
5.2.5	Seagrass	60
5.2.6	Macroalgae	60
5.2.7	Soft-bottom benthos	61
5.3	Terrestrial ecosystems	61
5.3.1	Flora	61
5.3.2	Mangroves	61
5.4	Fauna	61
5.4.1	Marine mammals	62
5.4.2	Marine reptiles	62
5.4.3	Fish and sharks	62
5.4.4	Seabirds and shorebirds	63
5.4.5	Phytoplankton	63
5.5	Parks, reserves and reef protection areas	63
5.6	Socio-economic environment	67
5.6.1	Commercial fishing and aquaculture	68
5.6.2	Shipping	68
5.6.3	Recreational activities and tourism	69

5.6.4 Traditional fishing 69
5.7 Cultural environment 69
5.7.1 Aboriginal sacred sites 69
5.7.2 Non-Indigenous heritage sites 70
5.8 Windows of sensitivity 70

6 Sediment Dispersion Modelling and Water Quality/Benthic Habitat Impact Predictions 72

6.1 Introduction 72
6.2 Dredge plume sources 72
6.3 Tolerance limits for habitats 73
6.4 Modelled scenarios 74
6.5 Results 75
6.5.1 Sediment fate modelling results 75
6.5.2 Spoil stability modelling 94
6.5.3 Zones of impact and influence 94
6.6 Predicted habitat impacts 101

7 Impact and Risk Assessment 102

7.1 Conceptual site model 102
7.2 Impact and Risk assessment methods 102
7.2.1 Identification of environmental hazard 102
7.2.2 Standard controls 102
7.2.3 Impact and risk assessment 102
7.3 Residual impacts and risks 106
7.3.1 Planned events 106
7.3.2 Unplanned events 107
7.4 Demonstration of ALARP 107
7.5 Impact/risk assessment summary 107
7.6 Assessment of potential for cumulative impacts 115
7.6.1 Marine Environmental Quality 115
7.6.2 Marine Ecosystems 121

8 Environmental Management Strategies 123

8.1 NT EPA environmental management hierarchy 123
8.2 Management of trenching-related water quality and benthic habitat impacts 123
8.2.1 Environmental performance objectives, performance criteria and management actions 124
8.2.2 Adaptive monitoring/management strategy 128
8.3 Management of impacts and risks 136
8.3.1 Other planned events impacts 136
8.3.2 Unplanned events risks 149

9 Environmental Monitoring 163
9.1 Overview 163
9.2 Monitoring objectives 163
9.3 Environmental monitoring program 164
9.3.1 Monitoring site selection 167
9.3.2 Methods and QAQC 169
10 Implementation Strategy 172
10.1 Leadership, accountability and responsibility 172
10.2 Workforce training and competency 176
10.2.1 Inductions 176
10.2.2 Training and competency 176
10.2.3 Workforce involvement and communication 176
10.3 Audits and inspections 177
10.3.1 Environmental Incident Reporting Internal incident reporting 177
10.3.2 External incident reporting 177
10.3.3 Corrective actions 179
10.3.4 Continuous improvement 179
10.4 Emergency preparedness and response 180
10.4.1 Contractor emergency and oil spill response plans 180
10.4.2 Santos incident management and oil spill response arrangements 180
10.5 Reporting and notifications 181
10.5.1 Internal reporting 181
10.5.2 External reporting 182
10.5.3 Summary of reporting 182
10.6 Document management 187
10.6.1 Information management and document control 187
10.6.2 Management of change 187
10.6.3 Reviews 187
11 Stakeholder Engagement and Communications 188
12 References 192

Figures

Figure 1-1: DPD Project Location 16
Figure 1-2: Conceptual model of management plan geographical scopes 18
Figure 2-1: Proposed trenching and spoil disposal locations 23
Figure 2-2: Indicative trenching designs – Note these are not actual project specifications but included for descriptive purposes only 25
Figure 2-3: Typical Backhoe Dredgers (Dredging, Environmental and Marine Engineering (DEME) Offshore & Van Oord JV, 2022) 26

Figure 2-4: Trailer Suction Dredger's Bonny River (left) and Vox Amalia (right) (Allseas, 2022) 27
Figure 2-5: Main features of a Trailing Suction Hopper Dredger (TSHD) (Allseas, 2022) 27
Figure 2-6: Cutter Suction Dredger's Ambiorix (left) and Anthena (right) (Allseas, 2022) 28
Figure 2-7: Schematic diagram of CSD Anthena (Van Oord, 2017) 28
Figure 2-8: Proposed trenching locations 31
Figure 4-1: Generic biofouling risk assessment process (from Department of Agriculture, Fisheries and Forestry, 2009) 47
Figure 5-1: RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021) 57
Figure 5-2: RPS surveys habitat mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021) 58
Figure 5-3: RPS surveys habitat mapping along offshore pipeline route 59
Figure 5-4: Charles Point Wide and Lorna Shoals reef fish protection areas 66
Figure 6-1: Predicted 90th percentile trenching-excess SSC throughout the entire trenching program for the winter/dry season scenario (1st April to 10th May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 77
Figure 6-2: Predicted 95th percentile trenching-excess SSC throughout the entire trenching program for the winter/dry season scenario (1st April to 10th May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 78
Figure 6-3: Predicted 90th percentile trenching-excess SSC throughout the entire trenching program for the summer/wet season scenario (1st October to 9th November). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 79
Figure 6-4: Predicted 95th percentile trenching-excess SSC throughout the entire trenching program for the summer/wet season scenario (1st October to 9th November). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 80
Figure 6-5: Time series analysis point locations. Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 83
Figure 6-6: Time series of predicted trenching-excess SSC at the Woods Inlet South, Weed Reef 1 and Channel Island sites throughout the entire trenching program and run-on period in the winter/dry season scenario 84
Figure 6-7: Time series of predicted trenching-excess SSC at the Woods Inlet South, Weed Reef 1 and Channel Island sites throughout the entire trenching program and run-on period in the summer/wet season scenario 85
Figure 6-8: Time series of predicted trenching-excess SSC at the Charles Point Wide 1, Mandorah and Charles Point sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 86
Figure 6-9: Time series of predicted trenching-excess SSC at the Charles Point Wide 1, Mandorah and Charles Point sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 87
Figure 6-10: Time series of predicted trenching-excess SSC at the Varanus Island S and Varanus Island E sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 88
Figure 6-11: Time series of predicted trenching-excess SSC at the Varanus Island S and Varanus Island E sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 89

Figure 6-12: Time series of predicted trenching-excess SSC at the Offshore Disposal 1 to Offshore Disposal 5 sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 90
Figure 6-13: Time series of predicted trenching-excess SSC at the Offshore Disposal 6 to Offshore Disposal 9 (via Offshore Disposal 3) sites throughout the entire trenching program and run-on period in the winter/dry season scenario. 91
Figure 6-14: Time series of predicted trenching-excess SSC at the Offshore Disposal 1 to Offshore Disposal 5 sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 92
Figure 6-15: Time series of predicted trenching-excess SSC at the Offshore Disposal 6 to Offshore Disposal 9 (via Offshore Disposal 3) sites throughout the entire trenching program and run-on period in the summer/wet season scenario. 93
Figure 6-16: Predicted Zone of Influence following application of the appropriate spatial thresholds in **Table 6-1** to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (1 April to 10 May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 97
Figure 6-17: Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in **Table 6-1** to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (1 April to 10 May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 98
Figure 6-18: Predicted Zone of Influence following application of the appropriate spatial thresholds in **Table 6-1** to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (1 October to 9 November 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 99
Figure 6-19: Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (1 October to 9 November 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1** 100
Figure 7-1: Projects and activities considered for cumulative impacts 116
Figure 8-1: Decision tree outlining practise for turbidity triggers 129
Figure 9-1: DPD Trench Monitoring sites. Note the number and locations of monitoring sites may be subject to change based on final route alignment and trenching methods 168

Tables

Table 1-1: Trenching and Spoil Disposal Monitoring and Management Plan structure 19
Table 1-2: Proponent details for Barossa DPD Project's Pipeline licences 20
Table 2-1: Trench sections, locations, equipment proposed, and estimated volume of dredged material 32
Table 2-2: Preliminary pre-lay, construction, installation, and pre-commissioning schedule for DPD 33
Table 3-1: Other commonwealth legislation relevant to DPD trenching activities. 36
Table 3-2: Other Northern Territory legislation relevant to the Santos Barossa DPD pipeline project 37
Table 3-3: International agreements and conventions relevant to the activity 39
Table 4-1: Biofouling mitigation measures 45

Table 5-1:	Average monthly and annual mean, max and min rainfall from 1941 to 2021 for Darwin International Airport (mm)	49
Table 5-2:	Summary of processes affecting water quality in Darwin Harbour	52
Table 5-3:	Marine reptile conservation status	62
Table 5-4:	Parks and reserves in the Darwin area	64
Table 5-5:	Summary of socio-economic activities that may overlap with the Project Area	67
Table 5-6:	Windows of sensitivity for environmental receptors in the vicinity of the Project Area	71
Table 6-1:	Tolerance limits for excess SSC and sedimentation (INPEX, 2018)	74
Table 6-2:	Percentiles (95th and 98th) and maximum predicted trenching-excess SSC (mg/L) (depth-averaged and maximum-in-water-column) for each time series analysis location, throughout the entire trenching program and run-on period for the winter/dry and summer/wet season scenarios. Values presented are rounded to the nearest whole number	82
Table 6-3:	Summary of the areal overlap of Project trenching zone and spoil ground Zones of High Impact (ZoHI) with different benthic habitats. Areal extent of benthic habitat impacted by different activities was calculated by overlaying DPD Project infrastructure over the combined AIMS 2019 and 2021 habitat mapping	101
Table 7-1:	NT EPA consequence descriptors	104
Table 7-2:	Summary environmental consequence descriptors	106
Table 7-3:	Likelihood description	106
Table 7-4:	Risk assessment matrix	106
Table 7-5:	Summary of the residual consequence levels associated with planned impacts	107
Table 7-6:	Summary of the residual risk level associated with unplanned risks	107
Table 7-7:	Summary of risk assessment outcomes	108
Table 7-8:	Potential for cumulative impacts from marine dredging from proposed dredge programs in Darwin Harbour	117
Table 8-1:	Environmental management strategy template derived from the NT EPA Draft Guideline for the Preparation of an Environmental Plan (NT EPA, 2022)	123
Table 8-2:	Seabed and benthic habitat disturbance EPOs and associated performance criteria	124
Table 8-3:	Management action for trenching related seabed and benthic habitat disturbance	126
Table 8-4:	Additional management action not adopted for trenching related seabed and benthic habitat disturbance	127
Table 8-5:	Level 1 and 2 turbidity management trigger criteria for trenching related seabed and benthic habitat disturbance	131
Table 8-6:	Adaptive Management Mechanism for trenching related seabed and benthic habitat disturbance following trigger exceedance	133
Table 8-7:	Interaction with other marine users (including construction activities and Project infrastructure) EPOs and associated performance criteria	136
Table 8-8:	Management actions for trenching vessel interaction with other marine users	138
Table 8-9:	Noise emissions EPOs and associated performance criteria	139
Table 8-10:	Management actions for noise emissions during routine construction including the use of an Xcentric Ripper tool	140
Table 8-11:	Additional environmental management actions for contingency rock breaking using hydraulic hammer	141
Table 8-12:	Additional (ALARP) management actions not adopted for noise emissions	141
Table 8-13:	Light emissions EPOs and associated performance criteria	143

Table 8-14: Management actions for trenching and spoil disposal related light emissions 144
Table 8-15: Additional management actions not adopted for trenching and spoil disposal related light emissions 144
Table 8-16: Routine vessel discharges EPOs and associated performance criteria 145
Table 8-17: Management actions for routine vessel discharges 146
Table 8-18: Additional management action not adopted for routine vessel discharges 146
Table 8-19: Atmospheric emissions EPOs and associated performance criteria 147
Table 8-20: Management actions for atmospheric emissions 148
Table 8-21: Dropped objects (including accidental release of non-hazardous waste) EPOs and associated performance criteria 149
Table 8-22: Management actions for release of dropped objects 150
Table 8-23: Introduction of invasive marine species EPOs and associated performance criteria 151
Table 8-24: Management actions for introduction of invasive marine species 152
Table 8-25: Additional management actions not adopted for invasive marine species 152
Table 8-26: Unplanned marine fauna interactions EPOs and associated performance criteria 153
Table 8-27: Management actions for marine fauna interaction 154
Table 8-28: Additional management actions not adopted for marine fauna interaction 155
Table 8-29: Release of hazardous liquids EPOs and associated performance criteria 156
Table 8-30: Management actions for hazardous liquids releases 157
Table 8-31: Hydrocarbon and marine diesel release (offshore vessel bunkering or vessel tank rupture) EPOs and associated performance criteria 158
Table 8-32: Management actions for hydrocarbon release (offshore bunkering incident or vessel fuel tank rupture) 159
Table 8-33: Additional management actions not adopted for hydrocarbon release (offshore bunkering incident or vessel fuel tank rupture) 160
Table 8-34: Release of dry natural gas environmental performance objectives and associated performance criteria 161
Table 8-35: Management actions for release of dry natural gas 162
Table 9-1: Overview of proposed monitoring program 165
Table 9-2: Proposed water quality parameters and units 170
Table 10-1: Chain of command, key leadership roles and responsibilities 173
Table 10-2: Trigger exceedance notification and reporting summary 182
Table 10-3: Summary of reporting requirements. 183
Table 11-1 Sections of the SEP specific to the lead-up to and execution of trenching activities 189

Appendices

Appendix 1: Santos Environment, Health and Safety Policies
Appendix 2: Summary of Management Actions

Abbreviations, acronyms, glossary and units of measurements

Abbreviations and acronyms

Abbreviation/acronym	Definition
AAPA	Aboriginal Areas Protection Authority
ABWM	Australian Ballast Water Management
AFANT	Amateur Fishing Association for the Northern Territory
AFZ	Australian Fishing Zone
AIMS	Australian Institute of Marine Science
ALARP	As low as reasonably practicable
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
ASS	Acid sulphate soils
ASSDMP	Acid Sulphate Soils and Dewatering Management Plan
ARMCANZ	Australian and Resource Management Council of Australia and New Zealand
AWR	Air Weapons Range
BHD	Backhoe dredge
BIA	Biologically Important Area
BOM	Bureau of Meteorology
BTEXN	Benzene, toluene, ethylbenzene, xylenes and naphthalene
CAMBA	China-Australia Migratory Bird Agreements
CCS	Carbon Capture Storage
CEMP	Construction Environmental Management Plan
CHI	Channel Island
CHP	Charles Point
CMID	Common Marine Inspection Document
CMT	Crisis Management Team
CPRFPA	Charles Point Reef Fish Protection Area
CPW	Charles Point Wide
CSD	Cutter suction dredge
CSS	Cargo Stowage and Securing

Abbreviation/acronym	Definition
CTD	Conductivity, temperature, and dissolved oxygen
DAWE	Department of Agriculture, Water and the Environment
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEME	Dredging, Environmental and Marine Engineering
DEPWS	Northern Territory Department of Environment, Parks and Water Security
DGV	Default guideline value
DHAC	Darwin Harbour Advisory Committee
DIPL	Department of Infrastructure, Planning and Logistics
DITT	Northern Territory Department of Industry, Tourism and Trade
DLNG	Darwin Liquefied Natural Gas
DLRM	Department of Land Resource Management
DP	Dynamic positioning
DPD	Darwin Pipeline Duplication
DPIR	Department of Primary Industry and Resources
DPIRD	Department of Primary Industry and Regional Development
DSDMP	Dredging and Spoil Disposal Management Plan
EAAS	Environmental Assurance Activities Schedule
ECAP	Environmental Compliance Assurance Plan
ECNT	Environment Centre NT
EHS	Environment, Health, and Safety
EIS	Environmental Impact Statement
EMS	Environmental Management Strategy
ENVID	Environmental Impact Identification
EPA	Environmental Protection Agency
EP Act	Environmental Protection Act 2019
EPBC	Environment Protection and Biodiversity Conservation Act 1999
EPO	Environmental performance objective
EPS	Environmental performance standards
FCGT	Flood, clean, gauge and testing
GEP	Gas export pipeline

Abbreviation/acronym	Definition
GHG	Greenhouse gas
GIS	Geographic Information System
GOMO	Guide for Offshore Marine Operations
HAB	Habitat
HAT	Highest astronomical tide
HFO	Heavy Fuel Oil
HSE	Health, safety and environment
HSEQ	Health, safety, environment and quality
HSEQ-MS	Health, safety, environment and quality management system
IACS	International Association of Classification Societies
ILT	Inline tee
ITF	Indonesian Through Flow
IMS	Introduced marine species
KP	Kilometre point
LAT	Lowest astronomical tide
LTS	Listed threatened species
LoR	Limits of Reporting
MA	Management actions
MDO	Marine diesel oil
MGO	Marine gas oil
MMNMP	Marine Megafauna Noise Management Plan
MoC	Management of changes
NTU	Nephelometric turbidity units
NT	Northern Territory
Offshore CEMP	Offshore Construction Environment Management Plan
Onshore CEMP	Onshore Construction Environmental Management Plan
PAH	Polynuclear aromatic hydrocarbons
PAR	Photosynthetically active radiation
PASS	Potential acid sulphate soils
PLET	Pipeline end termination
PLRS	Pig launcher/receiver

Abbreviation/acronym	Definition
PPT	Parts per thousand
PSV	Platform supply vessel
PTS	Permanent threshold shift
Q1, Q2, Q3 and Q4	Quarter 1, 2, 3 and 4
TBT	Tributyltin
TSDA	Trench spoil disposal area
TSHD	Trailing suction hopper dredge
TSDMMP	Trenching and Spoil Disposal Management and Monitoring Plan
TPH	Total petroleum hydrocarbons
TRH	Total recoverable hydrocarbons
TTS	Temporary threshold shift
SER	Supplementary Environmental Report
SHB	Split hopper barge
SSC	Suspended sediment concentration
UXO	Unexploded ordnance

Glossary

Term	Definition
Biologically important area	Areas spatially defined and mapped by the Commonwealth Department of Environment (DoE) where aggregations of individuals of a species are known to display a biologically important behaviour such as breeding, foraging, resting or migration.
Consequence	Impact of an even or incident e.g., a loss, injury or concern. May be expressed qualitatively or quantitatively.
Environmental Performance Standard	A statement of performance required of a management action.
Environmental Performance Objective	Measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks are of an acceptable level.
Impact	A positive or negative effect the DPD Project would have on the environment (including physical, ecological and socio-economic environments).
Measurement Criteria	A system of measurements that define whether a project is successful.
Non-Indigenous	Refers to heritage artefacts or sites that are not deemed “sacred sites” per the Northern Territory Aboriginal Sacred Sites Act or deemed

Term	Definition
	Aboriginal archaeological sites or artefacts per the *Heritage Act 2011* (NT).
Performance Criteria	he standards by which success of management actions is evaluated.
Project Area	Project Area is an area extending 500 m either side of the Pipeline, within which the Construction Activity will take place.
Residual risk	Risk remaining after implementation of mitigation measures
Risk	A combination of the potential consequence of an event occurring and the likelihood of the consequence occurring.
Sensitive receptor	A receptor that could be subject to adverse impacts from the DPD Project
Shore pull onshore termination point	The point (KP 122.484, approximately 2 m above highest astronomical tide) to which the pipeline will be pulled ashore to by the shore-pull activity
Target	Specific and measurable performance requirements to achieve Environmental Performance Objectives.

Units of measurement

Unit	Definition
°	degrees
µS	micro Siemens
MA	centimetre
dB	decibels
dB(A)	A-weighted sound pressure level in decibels
kHz	kilohertz
km	kilometre
km2	square kilometre
m	metre
m2	square metre
mg/L	milligrams per litre
nm	nautical mile (1.856 km)

1 Introduction

1.1 Project overview

Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the existing Bayu-Undan to Darwin Gas Export Pipeline (GEP) in the Timor Sea. The Bayu-Undan to Darwin GEP is a dry natural gas export pipeline transporting gas from the Bayu-Undan Field located in Timor-Leste waters to the Darwin liquefied natural gas (DLNG) Facility at Wickham Point peninsula near Darwin, Northern Territory (NT), Australia. The Bayu-Undan to Darwin GEP has been operational since 2005. In anticipation of the end of the Bayu-Undan Field's commercial production in 2022 – 2023, the Barossa Field is being developed to supply gas to the DLNG facility. The supply of backfill gas to the DLNG facility was originally planned to be achieved through the installation of a 262 kilometre (km) Barossa GEP to a tie-in point on the existing Bayu-Undan to Darwin GEP

In recognition of potential Carbon Capture and Storage opportunities at the Bayu-Undan Field, Santos has approved an alternative solution to transport backfill gas to the DLNG facility through the construction of an additional segment of pipeline to extend the Barossa GEP to the DLNG facility, instead of tying into the Bayu-Undan to Darwin GEP. Construction of this segment of pipeline is referred to as the Darwin Pipeline Duplication (DPD) Project, as it will be installed parallel to the existing Bayu-Undan to Darwin GEP. The effective 'duplication' of the existing Bayu-Undan to Darwin GEP is considered the optimal route to minimise potential environmental and social impacts.

The pipeline will run from the point where the Barossa GEP reaches the existing Bayu-Undan pipeline and continue through Darwin Harbour to the beach valve location at the DLNG facility at Wickham Point (**Figure 1-1**). Santos' DPD Project includes a ~23 km segment in Commonwealth waters and ~100 km segment in NT waters and lands adjacent to the existing Bayu-Undan to Darwin pipeline route. This Trenching and Spoil Disposal Monitoring and Management Plan (TSDMMP) will only cover activities in NT waters. The DPD Project pipeline will be located for the most part ~100 m from the existing Bayu-Undan to Darwin pipeline, to minimise potential environmental and social impacts. The Project Area for the DPD Project includes a 2 km buffer around the pipeline route in NT waters, the onshore construction area at the DLNG facility and an offshore spoil disposal ground for the trench spoil disposal (**Figure 1-1**).

Pre-lay trenching is required to meet a number of objectives, including providing pipeline protection and stability (in combination with rock installation), reducing pipeline spanning and ensuring compliance with shipping channel clear water requirements. Sections of the pipeline route within the harbour, with a combined length of up to ~12.8 km, will be trenched using various equipment with the remainder of the pipeline laid directly on the seabed. Rock sourced from a local quarry will be used to backfill in some areas where anchor protection or additional stabilisation is required.

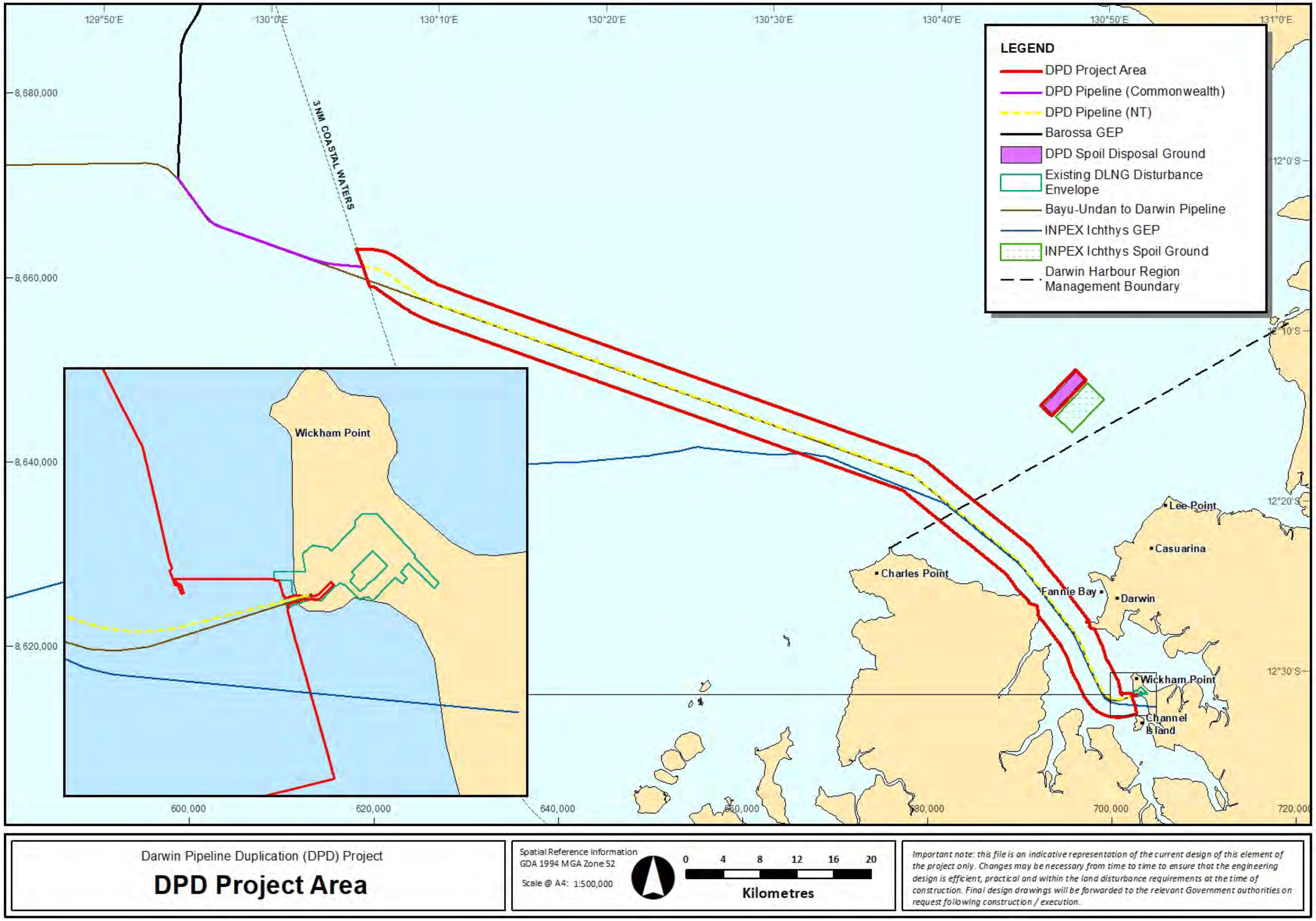


Figure 1-1: DPD Project Location

1.2 Purpose

This TSDMMP outlines the environmental impacts and risks arising from the trenching and spoil disposal activities associated with the DPD Project, within Darwin Harbour and offshore within NT waters and details how these impacts and risks will be monitored and managed.

The purpose of this TSDMMP is to:

+ Demonstrate that all measures deemed reasonable and practicable will be implemented to manage risks associated with, and potential environmental impacts arising from, the proposed trenching and spoil disposal activities
+ Prior to finalisation, demonstrate how the requirements of relevant conditions of approvals under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the NT *Environment Protection Act 2019* (EP Act) will be met.
+ Satisfy the Northern Territory Environmental Protection Authority (NT EPA) requirement for a TSDMMP for subsea trenching activities that includes:
+ baseline (pre-construction) condition of habitats within the zone of influence of the proposal and relevant parameters to be monitored to detect impacts
+ trigger levels for relevant parameters (and description of their derivation) corresponding to actions that must be taken should monitoring indicate trenching activities are likely to impact sensitive receptors
+ management actions to be applied if triggers are exceeded in accordance with the environmental decision-making hierarchy.
+ a communications strategy for engaging with government and other proponents undertaking or proposing dredging in the harbour;
+ a monitoring program for the assessment of cumulative impacts from concurrent or consecutive dredging programs not related to the proposal; and
+ a proposed approach to managing dredging in coordination with other proponents/dredging projects to avoid significant cumulative impacts to Darwin Harbour from dredging activities.

Note, as final decision is yet to be made as to the exact trenching methodology, the monitoring programme presented herein should be considered as a draft at this stage and may be adapted to reflect the final trenching methodology selected.

1.3 Scope

This TSDMMP has been prepared to allow for a maximum volume of 750,000 m^3 to be trenched within a 15-month construction period. This includes over-trenching and contingency trenching, therefore the actual volume to be trenched based on trench designs is expected to be much less at ~255,000 m^3.

This TSDMMP addresses trenching activities that will be undertaken within the proposed trench and pre-sweep areas between the pipeline shore pull onshore termination point to the Commonwealth/NT waters boundary and the disposal of trenched material at the proposed spoil disposal ground within NT waters.

This TSDMMP forms part of a suite of environmental management plans under an overarching Santos DPD Project Offshore Construction Environmental Management Plan (Offshore CEMP; BAS-210 0024) which covers all construction activities from the Commonwealth/NT waters boundary to the shore pull onshore termination point. The construction of the remaining section of pipeline between the onshore termination point and the upstream weld of the beach valve will be subject to the DPD Project Onshore CEMP (BAS-210 0025; Onshore CEMP) (**Figure 1-2**).

In addition to this TSDMMP, there are two further EMPs under the Offshore CEMP that address specific activities during construction (**Figure 1-2**). These are the:

+ Acid Sulphate Soil and Dewatering Management Plan (ASSDMP) (BAS-210 0049) that addresses all activities associated with acid sulphate soils (ASS) from lowest astronomical tide (LAT) to the upstream weld of the beach valve
+ Marine Megafauna Noise Management Plan (MMNMP) (BAS-210 0022) that addresses all activities associated with noise impacts to marine megafauna from the Commonwealth/NT waters boundary to the onshore termination point.

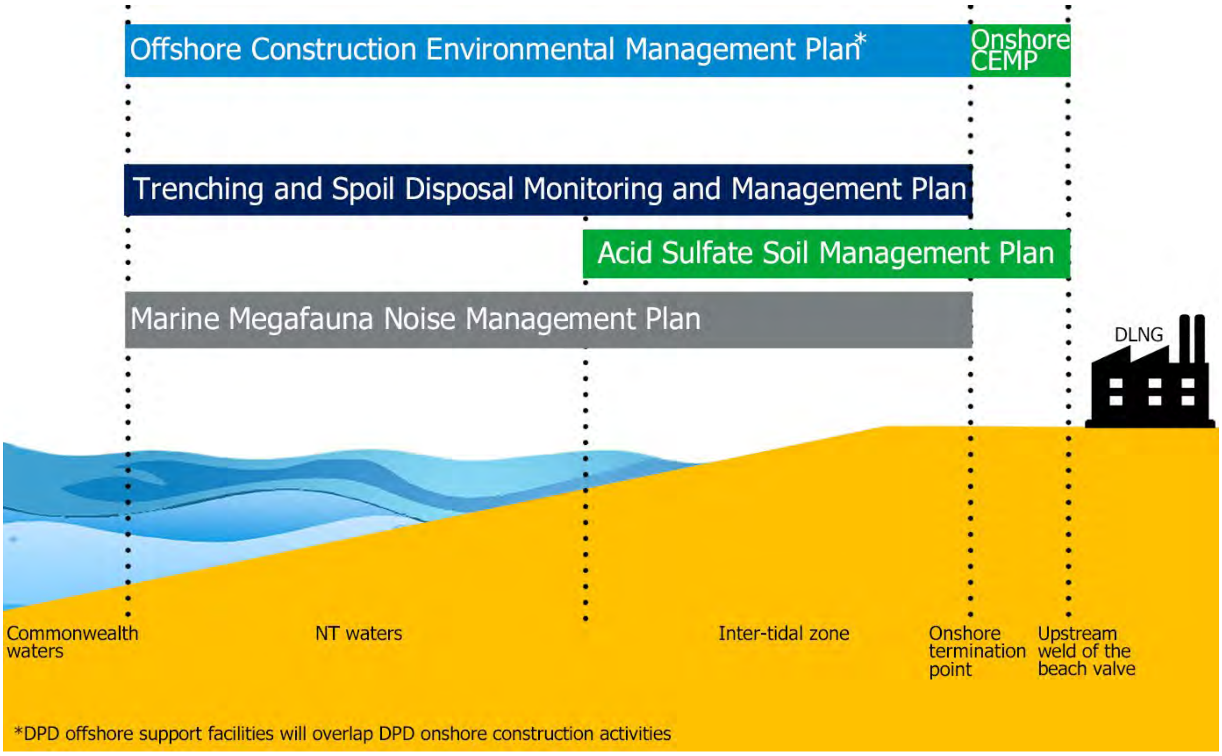


Figure 1-2: Conceptual model of management plan geographical scopes

1.4 Plan structure

This TSDMMP has been prepared and structured in accordance with the NT EPA: Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015) and the NT EPA: Draft Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA, 2013) as indicated in **Table 1-1**.

Table 1-1: **Trenching and Spoil Disposal Monitoring and Management Plan structure**

Regulatory requirement		**Relevant TSDMMP Section**
NT EPA: Draft Guideline for the Preparation of an Environmental Management Plan 2015	**NT EPA: Draft Guideline for the Environmental Assessment of Marine Dredging in the Northern Territory**	
Project Overview Proponent details Key contacts	-	**Section 1**: Introduction
Clear and comprehensive project description	-	**Section 2**: Detailed Activity Description
Legal and other obligations	Legislation	**Section 3**: Legal and Other Obligations
Environmental management framework		**Section 4:** Environmental Management Framework
Existing environment	Describing benthic habitats Background environmental data Critical windows of environmental sensitivity	**Section 5**: Existing Environment
Conceptual Site Model Environmental risk assessment	Environmental Impact Assessment	**Section 6:** Sediment Dispersion Modelling and Water Quality /Benthic Habitat Impact Predictions **Section 7**: Risk Assessment The requirement for a conceptual site model is addressed within the risk assessment.
Environmental Management Strategies	Environmental Management Plan Risk-based environmental management framework	**Section 8**: Environmental Management Strategies
Monitoring	Environmental Management Plan Risk-based environmental monitoring	**Section 9**: Environmental Monitoring
Corrective actions and contingencies	-	**Section 10**: Implementation Strategy

Regulatory requirement		Relevant TSDMMP Section
NT EPA: Draft Guideline for the Preparation of an Environmental Management Plan 2015	**NT EPA: Draft Guideline for the Environmental Assessment of Marine Dredging in the Northern Territory**	
Auditing Reporting and Review Training and awareness		
Communication	Public notification and engagement	**Section 11:** Stakeholder Engagement and Communications

1.5 Proponent

1.5.1 Details of the proponent

Santos, as the operator of the Barossa Joint Venture, has applied to the NT Department of Industry Tourism and Trade (DITT) for two pipeline licences for the DPD pipeline (NT):

+ Coastal and Territorial Waters Licence for the section of the pipeline under the jurisdiction of the *Petroleum (Submerged Lands) Act 1981* (NT) (i.e., between the NT Coastal Waters Limit and the Territorial Sea Baseline)
+ Inland Waters Licence for the section of Pipeline under the jurisdiction of the *Energy Pipelines Act 1981* (NT) (i.e., between the Territorial Sea Baseline and the onshore beach valve).

Both licences are applicable to the section of pipeline within the scope of the Barossa CEMP although the trenching activities covered under this TSDMMP will only be required for the section of pipeline covered by the licence under the *Energy Pipelines Act 1981*. The proposed proponent details are provided in **Table 1-2**, with the nominated operator shown in bold.

Table 1-2: Proponent details for Barossa DPD Project's Pipeline licences

Title	Proponent (nominated operator in bold)	ABN	Interest	Titles
+ Coastal and Territorial Waters Licence + Inland Waters Licence	Santos NA Barossa Pty Ltd	44 109 974 932	25.0%	Business Address: Level 7, 100 St Georges Terrace, Perth, Western Australia, 6000 Telephone number: (08) 6218 7100 Fax number: (08) 6218 7200 Email address: barossa.regulatory@santos.com
	Santos Offshore Pty Ltd	38 005 475 589	25.0%	
	SK E&S Australia Pty Ltd	55 158 702 071	37.5%	Business Address: Level 6, 60 Martin Place, Sydney NSW 2000, Australia Telephone number: (02) 21213304 Fax number: None Email address: hyunjoon-kim@sk.com
	JERA Barossa Pty Ltd	18 654 004 387	12.5%	Business Address: Level 9 Brookfield Place, 125 St Georges Tce, PERTH, WA, 6000

1.5.2 Details of nominated liaison person

Name: Dr Lachlan MacArthur

Title: Environmental Approvals Adviser

Business address: Level 7, 100 St Georges Terrace, Perth, WA 6000

Telephone number: (08) 6218 7100

Email: Barossa.regulatory@santos.com

1.5.3 Notification procedure in the event of changed details

If there is a change in the nominated operator, or a change in the contact details for the operator or liaison person, Santos will notify the NT DITT and provide the updated details.

1.6 Plan availability, review, and revision

Santos is responsible for submitting this TSDMMP alongside its Supplementary Environmental Report (SER) for the DPD Project to the NT EPA and DITT for comment and final approval. This plan will also be provided to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) in support of Santos' Preliminary Documentation (EPBC 2022-9372) submission for assessment under the

EPBC Act. Santos will review and update the document as required based on regulatory feedback and any regulatory conditions on DPD Project approval as applicable. The final TSDMMP will be made publicly available on an Australian website.

2 Trenching and Spoil Disposal Methodology

The following sections provide an overview of the proposed trenching and spoil disposal activity, including work sites and methods.

2.1 Overview

This TSDMMP has been prepared to allow for a maximum of 750,000 m^3 of material to be trenched. This maximum volume is considered a worst-case scenario that incorporates over-trenching and contingency trenching and a volume of ~255,000 m^3 (up to ~245,000 m^3 for trenching including pre-sweep areas; and 10,000 m^3 for the onshore and shore pull works) of material is expected to be dredged. This figure includes volume for pre-sweep areas and for maintenance trenching. The trenching campaign is expected to commence in Q1 2024 and is expected to continue for 2 – 3 months, with any contingency trenching taking place at a later date for a period of ~2 weeks. The potential for natural events such as cyclones, tropical storms and flooding to cause deposits of large amounts of sediment within the Project Area means maintenance or contingency trenching may be required to ensure the trench is in specification for the pipelay.

2.2 Project area

2.2.1 Trenching areas

The trenching areas are located along the DPD Project pipeline route, parallel to, and approximately 50 – 100 m from, the existing Bayu-Undan to Darwin pipeline. The trench design width is up to 40 m (with a 20 m buffer either side) along the DPD Project pipeline route. Trenching will only occur in NT waters. Trenching will occur along pipeline route sections between a point approximately 34 km offshore (KP92.2) to the shore pull onshore termination point (KP122.5). Specific locations of proposed trenching along the project pipeline route are shown in **Figure 2-1**.

2.2.2 Spoil disposal ground

The spoil disposal ground is located north of the Darwin Harbour Region Management Boundary, within Beagle Gulf, adjacent to the spoil ground used by INPEX for the Ichthys Gas Field Development Project (**Section 2.2.2**). Water depths at the site are between 15 m and 20 m below lowest astronomical tide (LAT). The site was selected with consideration of technical, environmental, cost and safety aspects. The site is 6.25 km^2 and is to be filled progressively so that the full volume of dredged material can be accommodated. The site is located within NT waters.

Material excavated via land-based plant (refer to **Section 2.4**) will be placed as close to LAT as possible adjacent to the trench to be subsequently removed by a dredge vessel and disposed to the offshore spoil disposal ground.

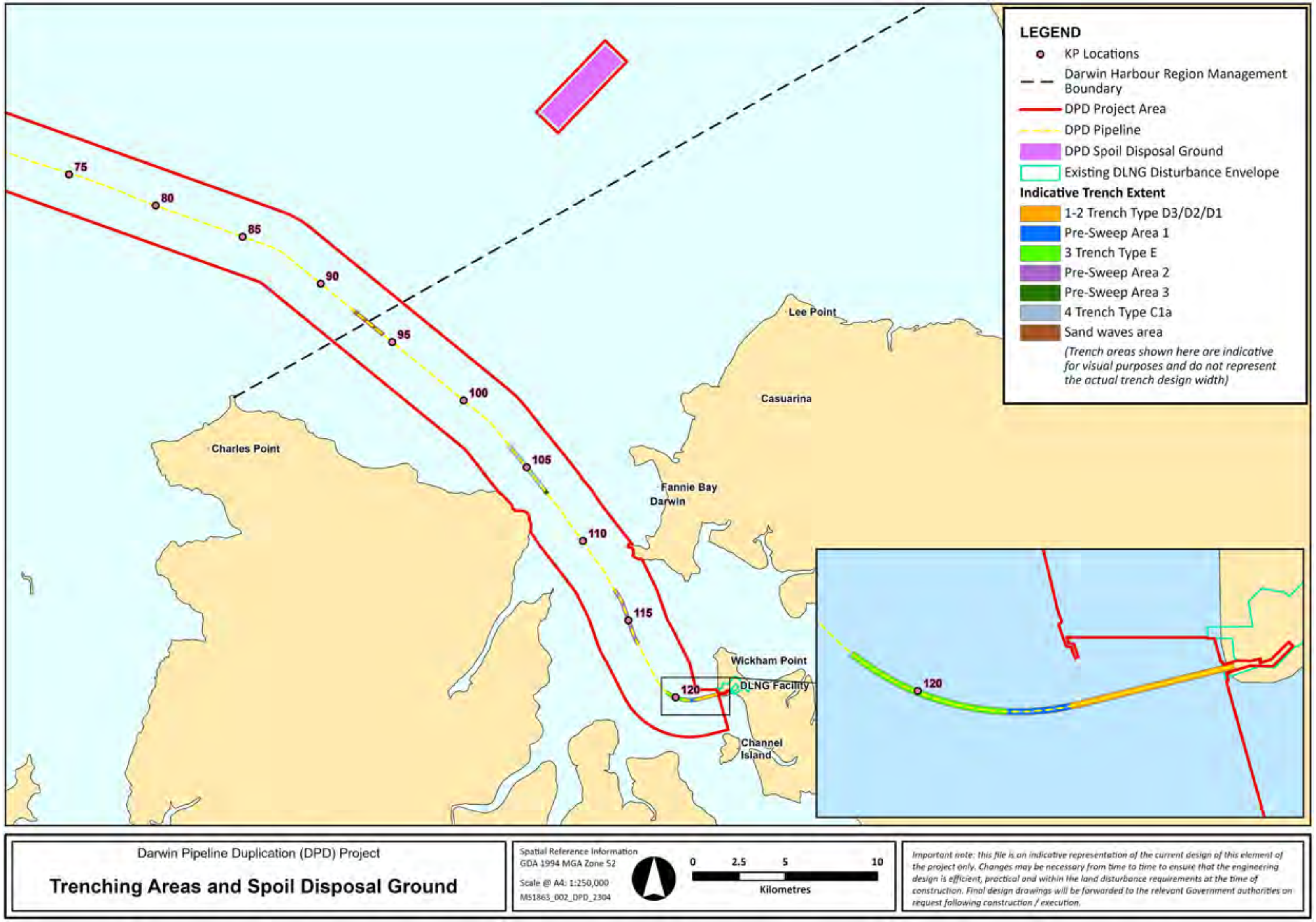


Figure 2-1: Proposed trenching and spoil disposal locations

2.3 Trench designs

Trench design, including trench depth and presence/type of rockfill will vary between trenching locations depending on the specific trench objectives. Indicative trench designs are shown in **Figure 2-2**, with corresponding locations shown in **Figure 2-8,** however specifications of trench design may alter slightly as they are finalised.

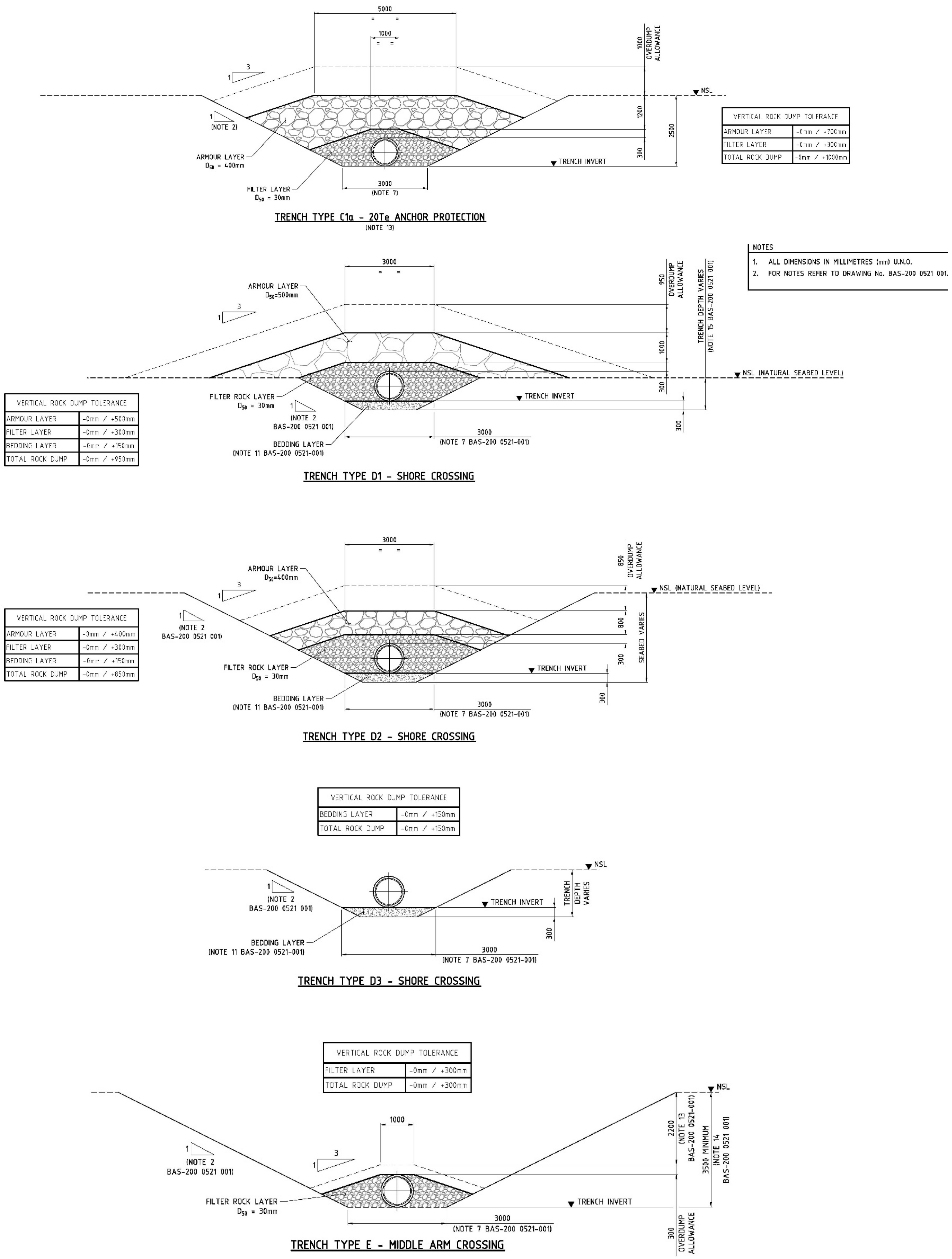


Figure 2-2: Indicative trenching designs – Note these are not actual project specifications but included for descriptive purposes only

2.4 Equipment

Trenching and spoil disposal for the DPD Project will require the use of specialised equipment and vessels. Equipment and vessels used for the trenching and spoil disposal activities are list below:

- Backhoe Dredge (BHD): Type “Nulla Nulla /Razende Bol”, or similar; with mounted hydraulic tools if required (**Section 2.4.1**).
- Trailing Suction Hopper Dredge (TSHD): Type “Bonny River/Vox Amalia”, or similar (**Section 2.4.2**)
- Cutter Suction Dredge (CSD): Type “Ambiorix/Athena”, or similar (**Section 2.4.3**)
- Split Hopper Barges (SHB): Type “Johannes de Rijke”, or similar (**Section 2.4.4**).
- Excavator (refer to Section 2.4.5)

2.4.1 Backhoe dredger

A BHD is a type of mechanical dredging equipment (**Figure 2-3**), consisting of a hydraulic arm and bucket system mounted on a turntable at the front of the pontoon with attached spud legs. Spud legs are driven into the seabed preventing movement due to wind, waves, and currents. BHDs can achieve a precise finished level and therefore are especially suitable for working in confined spaces in the presence of obstacles such as jetties or pipelines and are mainly utilised in shallow or confined waters.

A BHD will be used to trench shallower sections of the DPD pipeline route near the shore crossing. The BHD will be towed to location and will begin operations once positioned and stationary. Trenched material will be lifted by the BHD bucket to an SHB for transport to the spoil disposal ground.

Figure 2-3: Typical Backhoe Dredgers (Dredging, Environmental and Marine Engineering (DEME) Offshore & Van Oord JV, 2022)

The use of hydraulic tools is required for hard material that the BHD cannot cut through. Hydraulic tools may include an Xcentric Ripper or a hydraulic hammer which will be used to fracture rock as required. Once fractured the bucket is reattached to the BHD and the broken of fractured strata is dredged by the BHD and loaded into the SHB for transport to and discharge at the spoil disposal ground. This method will only be used when required at specific locations and is a discontinuous process.

2.4.2 Trailing suction hopper dredge

A TSHD is a type of hydraulic dredger that is a self-propelled sea-going vessel equipped with a hopper that can be loaded or emptied via a dredging arm. Dredging via TSHD is a cyclical process of loading (dredging), transporting, and discharging. TSHD hoppers vary in volume from a few hundred m^3 up to 33,000 m^3. TSHDs are the only non-stationary dredger and are not anchored by spud poles or anchors.

At the trenching location the TSHD vessel slows to approximately 2 to 3 knots, then one or more suction tubes with dragheads (suction mouths) are lowered to the seabed. Whilst on the seabed swell compensators control the contact between the draghead and the seabed. Pumps then dredge the material (a mixture of soil and water) from the seabed into the hopper located within the TSHD.

TSHD overflow devices discharge water from the hopper when it has reached a certain level within the hopper. If the slurry dredged is a settling slurry, then water is discharged via the overflow while sediment settles in the hopper. However, if the dredged slurry contains fine sediment and is a non-settling slurry, then water and fine sediment is discharged. This can increase turbidity in the near- and far-field of the dredging operations.

After the hopper is filled with dredged material, the pumps are stopped, the suction pipes and draghead lifted on deck and the TSHD will sail to the spoil disposal ground. At the spoil disposal ground the dredged material will be discharged by opening the bottom doors of the hopper.

Figure 2-4: Trailer Suction Dredger's Bonny River (left) and Vox Amalia (right) (Allseas, 2022)

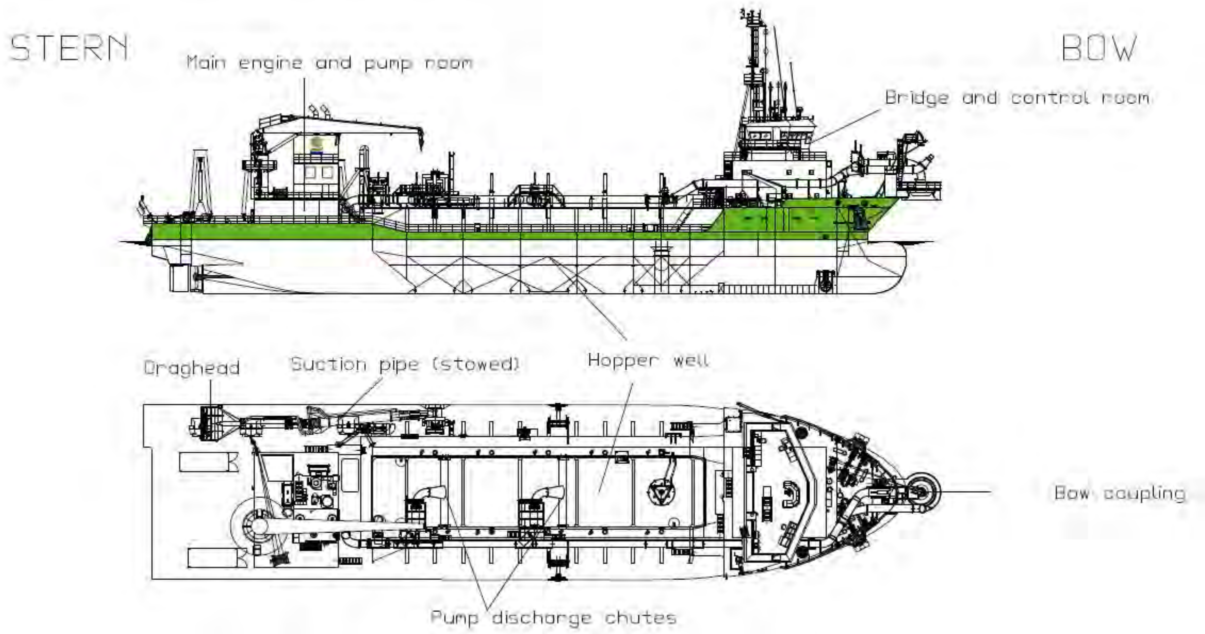


Figure 2-5: Main features of a Trailing Suction Hopper Dredger (TSHD) (Allseas, 2022)

2.4.3 Cutter suction dredger

CSDs are stationary hydraulic dredgers that are equipped with a cutter head (**Figure 2-6** and **Figure 2-7**). The cutter head rotates excavating the seabed which can then be sucked up by dredge pumps as a mixture of water and sediment (slurry). CSDs can also be used to break up harder material which is left in-situ for subsequent removal by a TSHD; this will be the mode of operation used for the DPD Project. Whilst operating the dredger moves around the spud pole via the pulling and slacking of two fore sideline wires. CSDs can excavate and then dredge all types of material, with accuracy due to the precise movement around the spud leg.

The CSDs utilised for this project will have self-propulsion, which will only be used during mobilisation between trench locations. Maximum dredge depth ranges between 31 m (Anthena) and 35 m (Ambiorix).

Figure 2-6: Cutter Suction Dredger's Ambiorix (left) and Anthena (right) (Allseas, 2022)

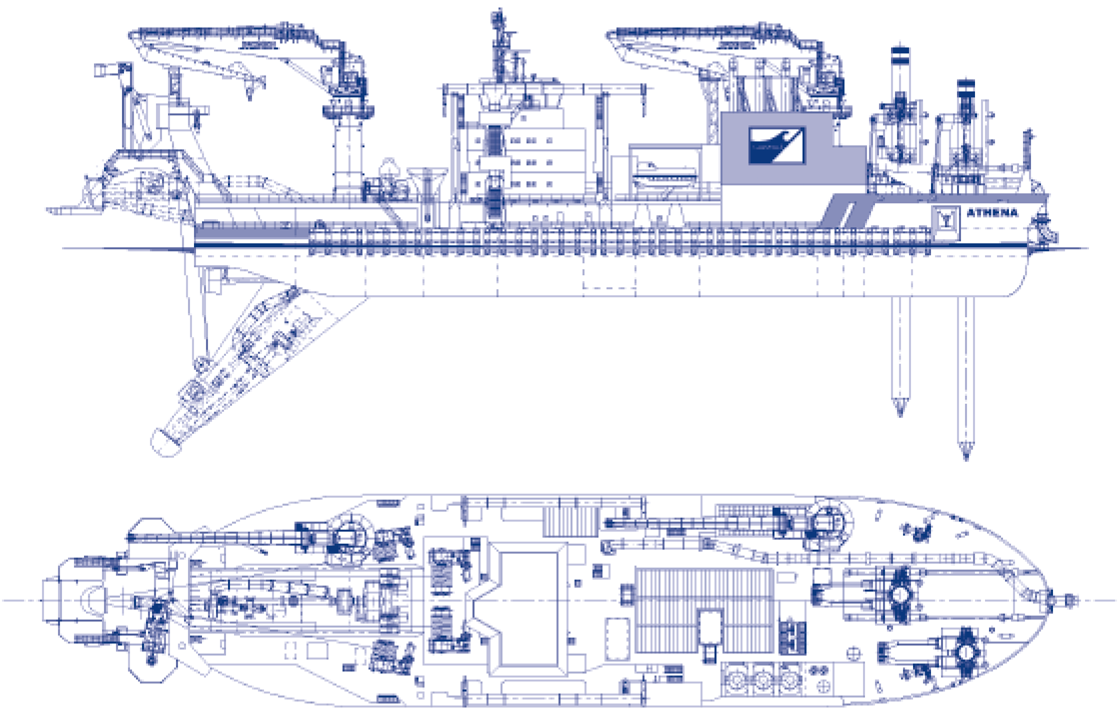


Figure 2-7: Schematic diagram of CSD Anthena (Van Oord, 2017)

2.4.4 Split hopper barge

SHBs are utilised for transporting and discharging of material dredged by the BHD. For this project, it is expected that two SHBs will be used to maximise efficiency and will be either self-propelled, towed or pushed by barges. A third barge may be used to further increase efficiency. SHBs are positioned and secured parallel to the BHD for loading. SHBs are loaded equally across the hopper area and once filled SHBs will sail to the disposal area. Once at the disposal area the load is discharged, by either opening the bottom doors or splitting the hopper well, depending on the type of barge.

2.4.5 Excavator

An excavator/s will be utilised to excavate material within the intertidal area and up to the shore pull onshore termination point. Excavators and the BHD will both work in the intertidal zone with operations dictated by tidal state. Material excavated will be deposited adjacent to the trench as close to LAT as possible.

2.5 Work method

2.5.1 Trenching method

The DPD trenching work can be divided into the following sections:

- Intertidal zone
- Nearshore trenching zones
- Trenching zones
- Pre-sweep areas (3 areas)
- Sand waves area

The trenching operations for the pipeline route have been divided into eight sections made up of four trenching zones, three pre-sweep areas and a sand waves area outlined in **Table 2-1** and **Figure 2-8**. The pre-sweep areas and single sand waves area only require sediments to be removed, while the trenching zones require the removal of both sediment and rock material. Pre-sweep areas are only potential trench areas and will only be trenched in targeted areas if pre-lay span rectification is required.

Trenching equipment will excavate a trench that is, at its maximum, approximately 3 m wide at the base and up to 9 m in depth, resulting in an approximate width of 40 m along the pipeline route at distinct sections shown in **Figure 2-8** with the corresponding trench designs and kilometre points defined in **Section 2.3** and **Table 2-1**

Trenching in the intertidal area will be completed via land-based excavators at low tide with material placed adjacent to the trench as close to LAT as possible but below mean sea level (MSL). This will minimise potential for soil oxidation and reduce acid sulfate soil risk (ASSDMP [BAS-210 0049]) and facilitate natural dispersion with tidal action. To assist with the pre-lay trenching at the shore crossing, Santos will require the use of temporary rock causeway/s. These structures will be located at the shore crossing. No blasting or rock fragmentation is proposed for the activity, however there may be some requirement for mechanical rock breaking using a BHD mounted hammer or Xcentric ripper at localised rock outcrops.

During periods above low tide, the BHD will excavate the trench with material placed into the SHBs for transport to the spoil disposal ground, the BHD will also remove any remaining material placed below MSL by the onshore excavator where accessible. Trenching in the nearshore trench zones will also be completed via BHD with material transported to the spoil disposal ground via the SHB/s.

Trenching in the pre-sweep areas and the sand wave area will be completed by TSHD. Material dredged via TSHD will be transported within the internal hopper to the spoil disposal ground where it will be discharged.

The remainder of the trench zones will be trenched using a three-step process:

1. The TSHD will pre sweep the zone removing sand and small material until rock is reached
2. The rock will be crushed using the CSD with material left in place
3. The TSHD will return to pick up the material for disposal at the spoil ground.

Estimated volumes of material to be removed through trenching are presented in **Table 2-1**.

Depending on the final construction schedule maintenance dredging may be required prior to pipelay activities in isolated pockets along the entire trench corridor to ensure the trench remains in specification for pipelay. Sediment mobility within the harbour over the wet season, may result in material being deposited within the bottom of the trenches whilst they lay open for pipelay to begin. Bathymetry surveys will be undertaken typically by multi-beam echosounder (MBES) following cyclone events prior to the pipelay campaign to determine the level of sediment build up, indicating whether maintenance trenching is required. It would be expected that maintenance trenching will be completed via TSHD and/or BHD as the material is anticipated to be soft and unconsolidated. Maintenance trenching would be primarily completed by TSHD, with the BHD only used if the shore crossing site was impacted. A towed plough may be deployed to remove any localised high spots from sediment infill prior to pipelay. The plough will be surface deployed and towed from a suitable vessel and only be used within areas that have been previously trenched minimising impact to benthic habitats. Sediment mobility is difficult to determine, however, conservative estimates indicate that no more than 80,000 m^3 of additional trench material will be removed. This would occur over a short timeframe due to the likelihood of only soft material being present post-wet season, with an expected timeframe of no longer than two weeks. If required, this would likely occur at the end of the cyclone season in April/May 2024, following the primary trenching campaign in the beginning of 2024.

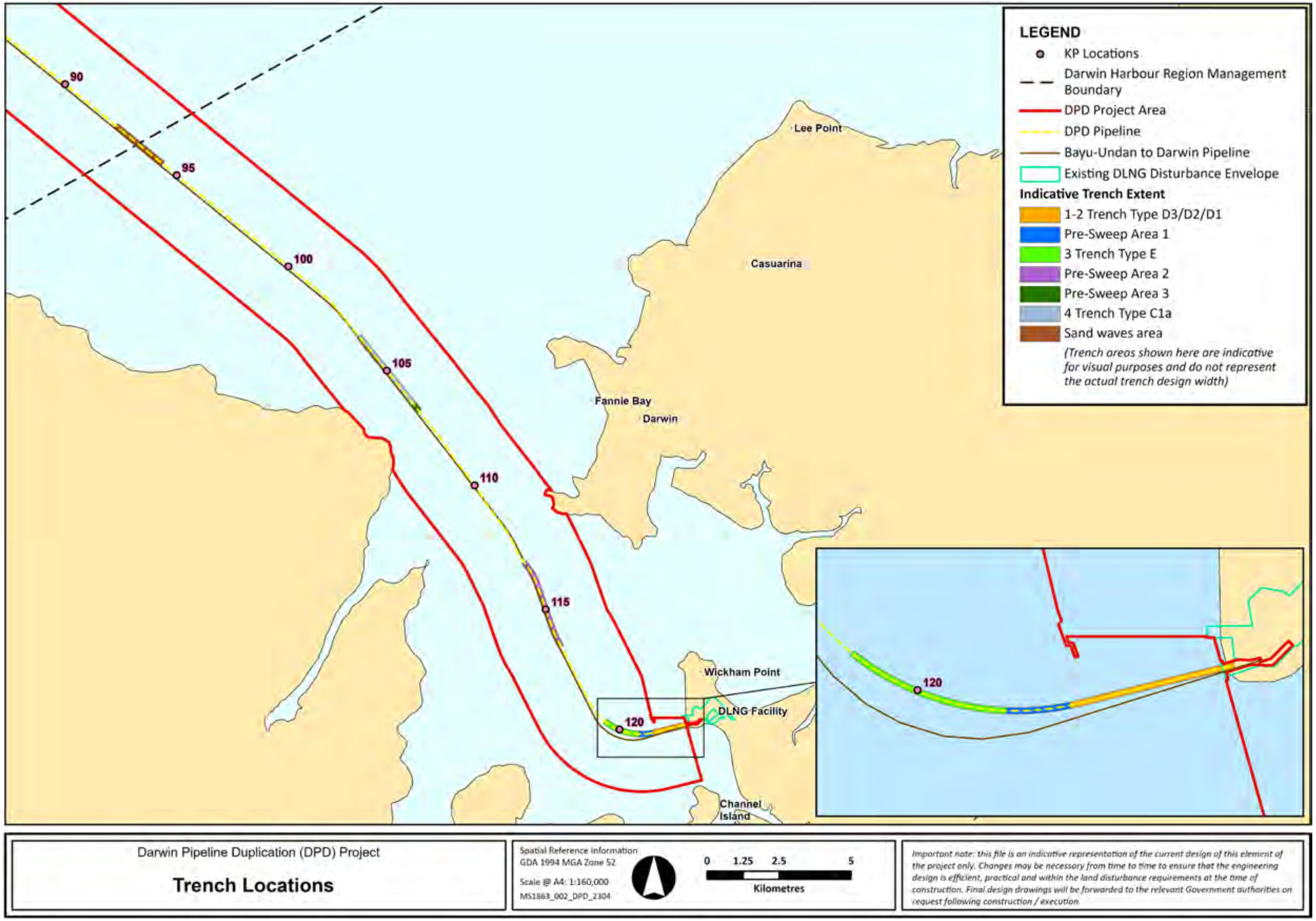


Figure 2-8: Proposed trenching locations

Table 2-1: Trench sections, locations, equipment proposed, and estimated volume of dredged material

Trenching section number	Trenching section	Pipeline location start KP	Pipeline location end KP	Trench length	Equipment	Task description	Base Case (Trench Zones and Sand Waves) Trench Volume m^3	[1]Potential (Pre-Sweep Areas) Trench Volume m^3	Disposal location
NA	Onshore: Trench Zone shore pull onshore termination point to beach valve[2]	~122.7	~122.5	~0.2 km	Excavator	Excavation of material	~5,000		Onshore
1 – 2	Intertidal: Trench to shore pull onshore termination point D1	~122.5	~122.4	~0.1 km	Excavator	Excavation of material	~5,000		Spoil disposal ground As close to LAT as practicable
1 – 2	Intertidal/Nearshore: Trench D2 (Nearshore)	~122.4	~121.9	~0.5 km	BHD / Hydraulic tools & SHB Land based excavator (onshore and intertidal zone)	Excavation of material by BHD, with rock breaking by hydraulic tools when necessary Excavation of material	~17,000		Spoil disposal ground As close to LAT as practicable
1 – 2	Nearshore: Trench D3	~121.9	~121.2	~0.7 km	BHD / Hydraulic tools & SHB	Excavation of material by BHD, with rock breaking by hydraulic tools when necessary	~6,000		Spoil disposal ground
-	Potential Pre-Sweep Area 1	~121.2	~120.6	~0.4 km	TSHD	Excavation of unconsolidated material by TSHD		~4,000	Spoil disposal ground
3	Trench E	~120.7	~119.3	~1.4 km	TSHD pre sweep & CSD	Excavation of unconsolidated material by TSHD Break hard consolidated rock by CSD Second excavation of unconsolidated material by TSHD	~48,000		Spoil disposal ground
-	Potential Pre-Sweep Area 2	~116.4	~113.2	~3.2 km	TSHD	Excavation of unconsolidated material by TSHD		~35,000	Spoil disposal ground
-	Potential Pre-sweep area 3	~106.5	~106.8	~0.3 km	TSHD	Excavation of unconsolidated material by TSHD		~3,000	Spoil disposal ground
4	Trench C1a	~106.6	~103.6	~3 km	TSHD pre sweep & CSD	Excavation of unconsolidated material by TSHD Break hard consolidated rock by CSD Second excavation of unconsolidated material by TSHD	~117,000		Spoil disposal ground

[1] Pre-sweep areas are only potential trench areas and will only be trenched in targeted areas if pre-lay span rectification if required.

[2] This zone is not part of the scope of this TSDMMP.

	Sand Waves Area	~94.4	~92.2	~2.2 km	TSHD	Excavation of unconsolidated material by TSHD	~15,000		Spoil disposal ground
		Expected volume to be disposed at offshore spoil disposal ground					~213,000	~42,000	~255,000
		Maximum volume to be disposed at offshore spoil disposal ground					~750,000		

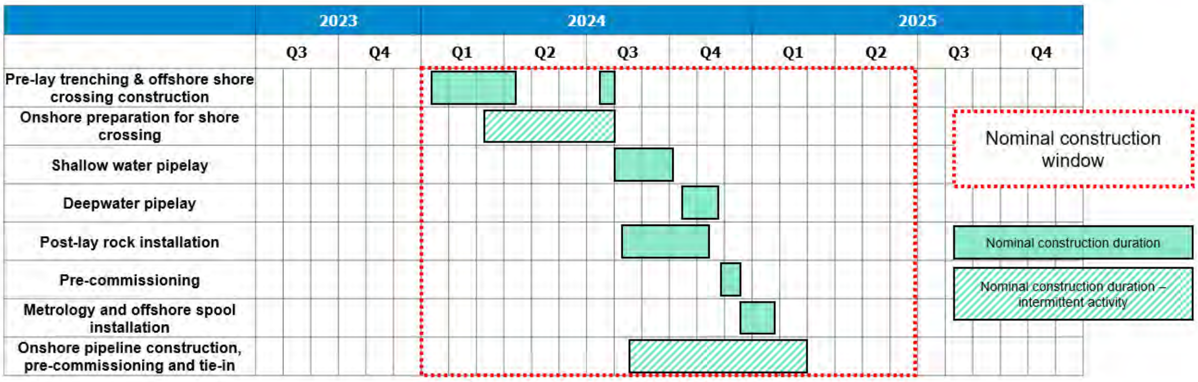
2.5.2 Spoil disposal method

Spoil collected by the TSHD will be discharged via bottom doors. This method of discharging has been identified as the optimal method of spoil disposal in high energy unconfined ocean environments (PIANC 100 workshop). SHBs will also be used to transport and discharge material trenched by BHD in the intertidal and nearshore area. The expected and maximum volumes to be disposed are presented in Table 2-1.

2.6 Indicative dredging and disposal schedule

Santos is anticipating that all DPD regulatory approvals will be in place by Q4 2023 to ensure construction activities do not delay Barossa first gas in the first half of 2025. A nominal DPD construction sequence and schedule is shown in **Table 2-2** representing a start of construction activities at the beginning of nominal construction window. The construction activities will span a nominal cumulative period of 15-months in the field. The actual construction sequence and schedule will be subject to the timely receipt of all regulatory approvals and drivers such as vessel availability, operational issues, and weather. Santos' regulatory approvals and stakeholder consultation consider construction activities at any time between Q1 2024 to mid-2025.

Table 2-2: Preliminary pre-lay, construction, installation, and pre-commissioning schedule for DPD



3 Legal and other obligations

The following sections describe the legislative framework governing the environmental assessment and approval of trenching and spoil disposal activities during the construction of the DPD Pipeline (NT).

3.1.1 Commonwealth environmental approval

The DPD Project including the DPD pipeline section in Commonwealth waters was referred to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) under the EPBC Act on 7 October 2022 (EPBC 2022-9372). On 6 December 2022 the DPD Project was determined to be a Controlled Action requiring further assessment based on Preliminary Documentation. Further information was requested under section 95A(2) of the EPBC Act on 23 December 2022.

It was determined that the Project may have a significant impact on the following controlling provisions under the EPBC Act:

+ Listed threatened species and communities (sections 18 & 18A)
+ Listed migratory species (sections 20 & 20A)
+ Commonwealth marine areas (sections 23 & 24A)

The Preliminary Documentation is currently being prepared for submission to DCCEEW.

This TSDMMP will be updated to reflect any relevant regulatory conditions associated with this approval.

3.1.2 Northern Territory environmental approvals

The DPD Project was referred to the NT EPA on 14 January 2022 under Section 55 of the EP Act. The NT EPA determined the Santos Barossa DPD Project proposal required assessment by supplementary environmental report (SER) (Tier 2) in accordance with the Environment Protection Regulations 2020 (EP Regulations). The SER is required to address public and government submissions and include information additional to the referral document in relation to specific aspects of potential significance. This TSDMMP will be updated to reflect any relevant regulatory conditions associated with this approval.

This TSDMMP has been prepared for submission to the NT EPA with approval documents including the SER (BAS-210 0020). This TSDMMP will additionally be submitted to DITT for approval under the *Energy Pipelines Act 1981.*

The following additional approvals related to trenching and spoil disposal are also required under NT legislation:

+ Development Consent (dredging) and Occupational Licence (spoil disposal) from NT Department of Infrastructure, Planning and Logistics (*Planning Act 1999*).
+ DITT – Energy Division "Consent to construct and Consent to test" (*Energy Pipeline Act 1981* and *Petroleum (Submerged Lands) Act 1981)*
+ Pipeline licences (Energy Pipeline Act 1981)
+ Fisheries Permit (*Fisheries Act 1998*)
+ Underwater Heritage Clearance (*Heritage Act 2011*)

Conditions with these permits, where they are relevant to the environmental management of works will be incorporated into future revisions of the TSDMMP.

3.1.3 Aboriginal Areas Protection Authority certificates

Aboriginal Areas Protection Authority (AAPA) certificates aim to protect indigenous sacred sites preventing damage from nearby works and outlines conditions to be followed when carrying out works on land and sea near to sacred sites across NT. The AAPA administer these certificates under the *National Territory Aboriginal Sacred Sites Act 1989*.

Santos has received an AAPA Authority Certificate (C2022-098) on 23 December 2022 and will ensure the requirements of the certificate (including avoidance of restricted work areas) and the *Northern Territory Aboriginal Sacred Sites Act 1989* are met.

3.2 Legislative framework

Environmental legislative requirements governing the DPD project are described in the following sections. All activities will comply with legislative requirements established under relevant Commonwealth and Northern Territory legislation. Key legislation is described below in **Sections 3.2.1.1** and **3.2.1.2**. Other relevant legislation is described in **Table 3-1** and **Table 3-2**.

3.2.1 Key legislation

3.2.1.1 *Environment Protection and Biodiversity Conservation Act 1999* (Cth)

The EPBC Act is administered by the Commonwealth DCCEEW. The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities, and heritage places, which are defined in the EPBC Act as matters of national environmental significance. There are nine matters of national environmental significance to which the EPBC Act applies these are: world heritage properties, national heritage places, wetlands of international importance, nationally threatened species and ecological communities, migratory species, Commonwealth marine areas, the Great Barrier Reef Marine Park, nuclear actions, and water resources (in relation to coal seam gas development and large coal mining development) (DAWE, 2021). When a person proposes to take an action that they consider may need approval under the EPBC Act, they must refer the proposal to the Commonwealth Minister for Environment.

Section 3A of the EPBC Act sets out the principles of ecologically sustainable development (ESD), which are:

+ Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
+ If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
+ The principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
+ The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
+ Improved valuation, pricing and incentive mechanisms should be promoted.

The construction and operation of the DPD Project (including the Commonwealth waters section) has been referred to DCCEEW under the EPBC Act and assessed to be a Controlled Action (referral number EPBC 2022/9372) requiring further assessment based on Preliminary Documentation (in progress). (**Section 3.1.1**).

3.2.1.2 *Environmental Protection Act 2019* (NT)

The EP Act is administered by Department of Environment, Parks and Water Security (DEPWS). The EP Act protects the environment and related purposes of the Northern Territory. The Act also:

- Promotes ecologically sustainable development
- Recognises the role of environmental impact assessment and environmental approval in promoting the protection and management of the environment of the Territory
- Provides for broad community involvement during the process of environmental impact assessment and environmental approval
- Recognises the role that Aboriginal people have as stewards of their country as conferred under their traditions and recognised in law, and the importance of participation by promotion of ecologically sustainable development

This TSDMMP has been developed under the guidance of this act incorporating the identified core aspects above and will be submitted to NT EPA with DPD SER (BAS-210 0020) for approval (refer **Section 3.1.2** for further information).

3.2.1.3 *Waste Management and Pollution Control Act 1998* (NT)

The duties under the *Waste Management and Pollution Control Act* 1998 (NT) require that a proponent must take all measures that are reasonable and practicable to prevent or minimise the pollution or environmental harm and reduce the amount of the waste. The management actions detailed in **Section 8** demonstrate how the Santos will comply with these duties.

Further the duties under the Act require proponents to understand:

a. the nature of the potential environmental harm and the sensitivity of the environment which may be impacted (refer to **Sections 7** and **5**, respectively)

b. technical information relating to the activity and the likelihood that the management actions would minimise environmental impact (refer to **Sections 2, 6 7.3 and 7.4**, respectively)

c. the financial implications of implementing management actions

Finally, Santos will comply with the duty to notify NT EPA of incidents causing or threatening to cause pollution.

3.2.2 Other relevant legislation

3.2.2.1 Commonwealth

Other commonwealth legislative requirements relevant to the DPD trenching and spoil disposal activities are outlined in **Table 3-1**.

Table 3-1: Other commonwealth legislation relevant to DPD trenching activities.

Title	Description
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	The purpose of this act is to preserve and protect places and objects in Australia and in Australian waters from injury or desecration; places or objects in question must be of particular significance to Aboriginal people with Aboriginal tradition.
Biosecurity Act 2015	The Act describes how to manage biosecurity threats to plant, animal and human health in Australia and its external territories, ensuring a very low level of risk. This involves balancing between protecting Australia from pests and disease and maintaining the ability to trade (DAFF, 2021).
Environment Protection (Sea Dumping) Act 1981[1]	The Act regulates the disposal of wastes at sea, and the creation of artificial reefs and applies to all vessels, aircraft, and platforms in Australian waters, and to all Australian Vessels and aircraft in any part of the sea.
Petroleum (Submerged Lands) (Management of Environment) Regulations 1999[2]	The Petroleum (Submerged Lands) (Management of Environment) Regulations 1999, under *Petroleum (Submerged Lands) Act 1981* (linked via the NT Petroleum (Submerged Lands) (Application of Commonwealth Laws) Regulations 2004), allows for the creation of provisions with respect to the exploration for and the exploitation of the petroleum resources, and certain other resources, of certain submerged lands adjacent to the coasts of the Northern Territory and for related purposes. Aiming to ensure that proponents carry out all petroleum activity in a way that is consistent with the principles of ecologically sustainable development, in accordance with an environment plan that has appropriate environmental performance objectives and standards as well as measurement criteria for determining whether the objectives and standards are met.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006	This Act relates to the protection of the sea from the effect of harmful anti-fouling systems. It covers the application or use of harmful anti-fouling systems and the issue and endorsement of the required certificates and anti-fouling declarations.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act relates to the prevention of pollution (in any form) from ships. MARPOL requirements are implemented under this Act.
Underwater Cultural Heritage Act 2018 *Underwater Cultural Heritage (Consequential and Transitional Provisions) Act 2018*	This Act provides for the protection of shipwrecks, sunken aircraft and their associated artefacts that have lain in territorial waters for 75 years or more. It is an offence to interfere with any shipwreck covered by the Act. Some sites also have a protected zone around them. The Act came into effect on 1 July 2019.

Notes:

1. The *Environment Protection (Sea Dumping) Act 1981* does not apply as spoil disposal will be within NT waters and therefore a sea dumping permit is not required.
2. There will be no trenching of the pipeline route or spoil disposal between the territorial baseline and NT coastal waters limit and therefore the activities included in this TSDMMP do not fall under the jurisdiction of the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999.*

3.2.2.2 Northern Territory

Other Northern Territory legislative requirements relevant to the DPD Project offshore construction activities are outlined in **Table 3-2**.

Table 3-2: Other Northern Territory legislation relevant to the Santos Barossa DPD pipeline project

Title	Description
Aboriginal Land Rights (Northern Territory) Act 1976	The Act provides the basis upon which Aboriginal Australian people in the Northern Territory can claim rights to land based on traditional occupation.
Crown Lands Act 1992	This Act provides for the management of crown lands in the Northern Territory. Including the facilitation of land use for economic development.
Dangerous Goods Act 1998	This Act provides for the safe storage, handling, and transport of certain dangerous goods. These being explosives (including fireworks) and fuel gas (including Autogas) (NT WorkSafe, 2020).
Energy Pipelines Act 1981	This Act allows for the creation of provisions for the construction, operation, maintenance and cessation of use or abandonment of pipelines for the conveyance of energy-producing hydrocarbons, and for related purposes. The NT *Energy Pipelines Act 1981* and subsidiary Energy Pipelines Regulations require the proponent to operate licensed pipelines in accordance with an accepted Pipeline Management Plan (PMP).
Environmental Offences and Penalties Act 2011	This Act defines levels and penalties for environmental offences
Fisheries Act 1988	This Act provides for the regulation, conservation and management of fisheries and fishery resources to maintain their sustainable utilisation, to regulate the sale and processing of fish and aquatic life, and for related purposes.
Heritage Act 2011	This Act provides a framework for the identification, assessment, recording, conservation, and protection of the Northern Territory's cultural and natural heritage.
Marine Act 1981	This Act is to regulate shipping within the Northern Territory and to provide for the application to the Northern Territory of the uniform shipping laws code and for related matters.

Title	Description
Marine Pollution Act 1999	This Act protects the marine and coastal environment by minimising intentional and negligent discharges of ship-sourced pollutants into coastal waters, and for related purposes.
Native Title Act 1993	This Act provides for the recognition and protection of native title and provides or permits for the validation of past acts and intermediate period acts, invalidated because of the existence of native title. It additionally establishes ways in which future dealings affecting native title may proceed and sets standards for those dealings and establishes mechanisms for determining claims to native title.
Northern Territory Aboriginal Sacred Sites Act 1989	This Act aims to provide a practical balance between the recognised need to preserve and enhance Aboriginal cultural tradition, in relation to certain land in the Northern Territory and the aspirations of the Aboriginal and all other peoples of the Northern Territory for their economic, cultural, and social advancement; by establishing a procedure for the protection and registration of sacred sites, providing for entry onto sacred sites and the conditions to which such entry is subject, establishing a procedure for the avoidance of sacred sites in the development and use of land and establishing an Authority for the purposes of the Act and a procedure for the review of decisions of the Authority by the Minister.
Northern Territory Environment Protection Authority Act 2012	This act aims to: a) promote ecology sustainable development; b) to protect the environment, having regard to the need to enable ecologically sustainable development; (c) to promote effective waste management and waste minimisation strategies; and (d) to enhance community and business confidence in the environmental protection regime of the Territory.
Petroleum (Submerged Lands) Act 1981[1]	The *Petroleum (Submerged Lands) Act 1981* allows for the creation of provisions with respect to the exploration for and the exploitation of the petroleum resources, and certain other resources, of certain submerged lands adjacent to the coasts of the Northern Territory and for other purposes.
Planning Act 1999 Planning Regulation 2000	This Act provides a framework of controls for the orderly use and development of land in the Northern Territory. The Development Assessment Services is responsible for the development assessment and control processes within the provisions of the Act. Approval for the DPD Project will be obtained under the Planning Act 1999 (NT), Santos is consulting with the NT Department of Infrastructure, Planning and Logistics regarding the pathway for this approval.
Ports Management Act 2015	This Act provides for the safe, efficient, and effective control, management, and operation of Northern Territory ports.

Title	Description
Territory Parks and Wildlife Conservation Act (TPWC Act) 1976	This Act provides for the establishment of Territory Parks and other parks and reserves and for the study, protection, and conservation of wildlife in Northern Territory. This includes provisions on changes and revocation of parks, reserves and sanctuaries, the preparation and implementation of plans of management, the creation and management of sanctuaries and on the management of wildlife, flora, and fauna.
Waste Management and Pollution Control Act (WMPC Act) 1998	This Act provides for the protection of the environment through encouragement of effective waste management and pollution prevention and control practices and for related purposes. It additionally outlines the general environmental duty that proponents must comply with (**refer to Section 3.2.1.3**).
Water Act 1992	The Act provides for the investigation, allocation, use, control, protection, management, and administration of water resources in the NT. Under the Act a waste discharge licence is the regulatory instrument used to regulate the quality and quantity of waste discharged to water in the NT. As mentioned previously a WDL is not required as the spoil disposal ground is outside the remit of the *Water Act 1992*.

Notes:

1. There will be no trenching of the pipeline route or spoil disposal between the territorial baseline and NT coastal waters limit and therefore the activities included in this TSDMMP do not fall under the jurisdiction of the Petroleum (Submerged Lands) Act 1981.

3.2.3 International conventions and agreements

Australia is signatory to numerous international conventions and agreements that obligate the Commonwealth government to prevent pollution and protect specified habitats for flora and fauna. Those which are relevant to the activity re outlined in **Table 3-3**.

Table 3-3: International agreements and conventions relevant to the activity

International agreements and conventions	
Title	**Description**
International Convention for the Prevention of Pollution from Ships (MARPOL)	This convention is to eliminate international marine environment pollution through hydrocarbons and other toxic substances and to reduce the accidental discharge of such substances.
Japan-Australia Migratory Bird Agreement (JAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan. Implemented in the EPBC Act.
China-Australia Migratory Bird Agreement (CAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China. Implemented in the EPBC Act.
Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Korea. Implemented in the EPBC Act.

International agreements and conventions	
Title	**Description**
United Nations Convention on Biological Diversity – 1992	An international treaty to sustain life on earth.
United Nations Framework Convention on Climate Change (1992)	The objective of the convention is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. Australia ratified the convention in December 1992, and it came into force on 21 December 1993.

3.2.4 Standards, codes and guidelines

There are several Australian Standards, Codes of Practise and Guidelines relevant to this TSDMMP, which have been identified below.

+ AS/NZS 4801 Occupational Health and Safety Management
+ AS/NZS ISO 14001:2004, Environmental management system – Requirements with guidance for use
+ AS/NZS ISO 31000:2009, Risk management – Principles and guidelines
+ HB 203:2006 Environmental Risk Management – Principles and Process
+ Australian Ballast Water Management Requirements. Version 8 (ABWM Requirements; Commonwealth of Australia, 2020a).
+ National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia, 2009a)
+ National Biofouling Management Guidance for Non-trading Vessels (NSPMMPI; Commonwealth of Australia, 2009b)
+ National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000)
+ Australian and New Zealand Guidelines (ANZG) for Fresh and Marine Water Quality (ANZG, 2018)
+ Declaration of Beneficial Uses and Objectives, Darwin Harbour Region, Northern Territory Government Gazette No. G27, 7 July 2010
+ Darwin Port Environmental Management Plan (Darwin Port 2020)
+ Darwin Harbour Water Quality Protection Plan (Department of Land Resource Management, 2014)
+ Darwin Harbour Strategy 2020 – 2025 (DHAC 2020)
+ Guidelines for Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA 2013)
+ Draft Guidelines for the Preparation of an Environmental Management Plan (NT EPA, 2015)
+ Guideline for Reporting on Environmental Monitoring (NT EPA, 2016).

4 Environmental management framework

4.1 Santos Management System (SMS)

Santos's Management System (known as the SMS) exists to support its moral, professional, and legal obligations to undertake work in a manner that does not cause harm to people or the environment. The framework of policies, standards, processes, procedures, tools, and control measures that, when used together by a properly resourced and competent organisation, result in:

+ A common HSE approach is followed across the organisation.
+ HSE is proactively managed and maintained.
+ The mandatory requirements of HSE management are implemented and are auditable.
+ HSE management performance is measured, and corrective actions are taken.
+ Opportunities for improvement are recognised and implemented.
+ Workforce commitments are understood and demonstrated.

The Implementation Strategy and Stakeholder Consultation sections within this TSDMMP (**Section 10** and **Section 11**) aligns with the SMS structure and are designed to require that:

+ Environmental impacts and risks continue to be identified for the duration of the activity and reduced to as low as reasonable possible (ALARP);
+ Controls are effective in reducing environmental impacts and risks to ALARP and acceptable levels;
+ Environmental performance outcomes and standards set out in this TSDMMP are met; and
+ Consultation with relevant and interested persons is maintained throughout the activity as appropriate.

4.2 Santos' Environment, Health, and Safety Policy

Santos' Environment, Health and Safety Policy (**Appendix 1**) clearly sets out its strategic environmental objectives and the commitment of the management team to continuous environmental performance improvement. This TSDMMP has been prepared in accordance with the fundamentals of this policy. By accepting employment with Santos, each employee and contractor is made aware during the recruitment process that he or she is responsible for the application of this policy.

4.3 DPD Project Environmental Management Plans

This TSDMMP falls under the overarching Offshore CEMP (BAS-210 0024). The Offshore CEMP covers all DPD Project construction activities from the Commonwealth/NT waters boundary to the shore pull onshore termination point. This TSDMMP sit under the Offshore CEMP and addresses all trenching and spoil disposal activities associated with the construction of the pipeline up to the onshore termination point. These activities are described in **Section 2**.

4.4 Supporting management processes and procedures

4.4.1 Contractor health, safety and environment requirements

The Santos HSE Contractor Management Operating Standard (SMS-HSS-OS08) and the Contracting and Procurement Operating Standard (SMS-PRC-OS01) supports the minimum requirements and expectations for HSE management of Contractors and subcontractors. It includes the following minimum requirements:

+ Contractors to comply with all applicable HSE laws and regulations and any additional guidelines, operating standards and policies provided to the Contractor.
+ A review of the Contractor HSE Management System is completed before being contracted.
+ Provisions for Santos to conduct audits/inspections of the Contractor's operations, equipment and emergency procedures at any time.

In addition, the DPD Project has a contractual HSE Exhibit for scopes of work. The HSE Exhibit has a detailed environmental requirements section including:

+ Contractor to develop environmental implementation plan to demonstrate how applicable environmental legislation and environmental approval requirements under this TSDMMP will be met
+ Contractor to use an Environmental Management System for managing environmental impacts and risks throughout the activity. Requirements for demonstrating leadership and accountability, organisational capability, and training/induction processes and performance against environmental requirements
+ Key activities to support continuous environmental improvement
+ Definition of the operational area of the work
+ Chemical selection, approvals and chemical register requirements
+ Prohibition of materials and chemicals
+ Vessel environmental requirements, including trenching and spoil disposal requirements, marine discharge requirements, waste management requirements, unplanned discharge requirements, marine fauna interaction requirements, lighting requirements and invasive marine species requirements.

4.4.2 Santos marine vessel vetting process

Santos manages marine vessel vetting and assurance using a hierarchy of procedures, outlined below. These requirements for vessel acceptance criteria include technical, personnel (e.g. crew competencies) and operational requirements for marine vessels engaged by Santos.

4.4.2.1 Marine Assurance

The Marine Offshore Assurance Criteria (1530-045-STN-0001) is a standard that requires all vessels (including MODUs) used by Santos to be vetted. The vetting process is based on industry standards and best practices along with considerations of guidelines and recommendations from recognised industry organisations such as Oil Companies International Marine Forum (OCIMF) and International Maritime Contractors Association (IMCA), and international regulatory agencies like the IMO and vessel Classification Societies. Marine Offshore Assurance Criteria (1530-045-STN-0001) requires a valid Offshore Vessel Inspection Database (OVID) report or Common Marine Inspection Document (CMID) report as required for vessel operation types. For vessels where the OVID and/or CMID are not valid or available, a Santos Approved Inspection Report is required.

4.4.2.2 Marine Standards and Compliance

The standards and guidelines that Santos expects the chartered vessels to operate to are:

- Flag State Legislation
- Coastal State Legislation for Marine Operations including Biosecurity Compliance
- MCA Code of Safe Working Practices for Merchant Seamen (2015)
- IMCA – M117
- IMCA – M182
- OCIMF – OVID and OVMSA
- A.714(17) Code of Safe Practice for Stowage and Securing (CSS Code) 2011 (IMO)
- Guide for Offshore Marine Operations (GOMO) (Previously NWES Guidelines)
- International Convention for the Safety of Life at Sea (SOLAS) 1974, as amended (IMO).
- International Maritime Dangerous Goods (IMDG) Code (IMO)
- Guidelines for the Preparation of cargo Securing Manual (MSC.1/Circ.1353 – IMO)
- IACS - International Association of Classification Societies Rules

Santos performs a risk assessment or HSE Qualification Evaluation process for each vessel to identify any HSE issues or specific management requirements prior to commencing activities.

4.4.3 Santos waste management process

As per the Santos Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02), Santos requires that for all waste generated at its facilities and by contractors under its influence, the hierarchy of waste management applies whereby wastes are (in order of preference) avoided, reduced, re-used, recycled, treated and/or correctly disposed. A waste inventory must be documented and onshore waste disposal records standardised (Waste Monitoring and Reporting Procedure – SMS-EXA-OS01-PD02-PD01) to allow accurate and consistent waste tracking. Contractors under this TSDMMP will demonstrate waste management processes aligned with regulatory and Santos' requirements through a Waste Management Plan.

4.4.4 Ballast water management

4.4.4.1 Summary of requirements

The Australian ballast water requirements set out the obligation on vessel operators with regards to the management of ballast water and ballast tank sediment when operating within Australian seas. All internationally operating vessels entering Australia will require:

- An approved Ballast Water Management Plan
- Maintenance of a complete and accurate record of all ballast water movements including those conducted in Australian waters
- An international Ballast Water Management Certificate.

Ballast water exchange should be conducted in areas at least 12 nm from the nearest land and in water at least 50 m deep. Volumetric exchange must be at least 95% of the relevant tank. Records on ballast water exchange shall include the start and finish times and geographic coordinates of the operation.

All ballast water management equipment such as pumps will be maintained as per the vessel preventive maintenance system and regularly tested to ascertain accurate calculations for ballast water exchange operations.

4.4.4.2 Australian pre-arrival report

All international vessels must submit a Ballast Water Report and a Pre-Arrival Report (PAR), 96 to 12 hours prior to arriving in an Australian port through the Maritime Arrival Reporting System (MARS), for the Australian Department of Agriculture to review and process.

MARS is the online portal for commercial Vessel Masters and Shipping Agents to submit reports required of all international vessels seeking Australian biosecurity clearance; and request services such as coastal strip, waste removal, ship sanitation certification and crew change.

Department of Agriculture will request evidence from vessels with a ballast water management system of:

+ Valid ballast water management plan specific to the vessel (consistent with the Convention)
+ Valid ballast water management certificate, or certificate of compliance, that is approved by a port state administration, or a recognised survey authority (consistent with the Convention)
+ Ballast water management records that clearly demonstrate the ballast water management has been operated consistent with the ballast water management plan.

A Department of Agriculture biosecurity officer will board the vessel to verify the Pre-Arrival Report and Vessel Master must ensure the vessel and personnel are available and able to demonstrate proficiency in the operation and maintenance of the ballast water management system.

4.4.5 Biofouling management

IMS may be present as biofouling on the vessel hull, or within piping, sea chests, etc. The biofouling which may be found on and in a vessel reflects the vessel's design, construction, maintenance, and operations. Each of these aspects introduces biofouling vulnerabilities but also offers opportunities to limit the extent and development of biofouling, with commensurate reduction in biosecurity risks.

4.4.5.1 Vessel risk assessment

Vessels mobilised to Darwin Harbour/DPD Project Area from international or domestic waters will comply with the Australian National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (DAFF; Commonwealth of Australia, 2009). This includes:

+ Completion of a biofouling risk assessment
+ Implementation of mitigation measures commensurate with the level of risk.

Figure 4-1 presents the risk assessment process. Factors that will inform risk are:

+ Timing of marine pest risk assessment relative to vessels selection and movement to the title area to ensure there is sufficient time to implement control measures in cases where management is warranted
+ History of the vessels including time spent in ports of call since last dry dock and clean to inform whether the facility or vessel may have been exposed to high-risk ports/locations
+ Level of biofouling and the presence of species of concern (in particular the presence of marine pests) within biofouling communities on the vessels associated with the activity (often informed by biofouling record books and/or maintenance/cleaning or inspection programs)
+ Operational profile relevant to biosecurity risk such as operating speed, time alongside a facility and the need for ballast exchanges within the title area

- Receiving environment including the presence of shallow water sensitivities within proximity to the activity and the presence and area of non-biocidal surfaces on facilities that could harbour marine pests
- Presence and effectiveness of external and internal marine growth prevention systems including effectiveness and integrity of antifouling coatings and functionality of internal treatment systems
- Qualifications and competency of personnel conducting and reviewing the risk assessment and making management decisions.

4.4.5.2 Vessel risk status

There are three outcomes from the risk assessment which categorise the vessels risk status as outlined below. Vessels are required to have a 'low' risk status to demonstrate to the government that Santos has taken all reasonable measures to minimise the risk of IMS.

- Low – low risk of introducing IMS; no additional management measures required
- Uncertain – risk of introducing IMS is not apparent; precautionary approach adopted, additional management measures required to achieve low status
- High – high risk of introducing IMS; additional management measures will be required.

4.4.5.3 Potential management measures to achieve low risk status

The outcome of the risk assessment will determine management measures required. If the vessel is deemed as 'low' risk status, no other measures are required (providing the vessel does not exceed the seven-day threshold at stationary or slow speed, in waters outside Australia (similar region).

For vessels that present an 'uncertain' or 'high' risk, Contractors will engage a qualified IMS inspector to conduct inspections and/or provide advice on obtaining low status. lists mitigation measures that can be applied to achieve 'low' risk status.

Table 4-1: Biofouling mitigation measures

No.	Mitigation Measure	Overview
1	IMS inspection	Visual inspection of submerged surfaces and niche areas by a qualified biosecurity inspector to better understand the actual biosecurity risk. IMS Inspectors will have the qualifications and align inspections and reports with DPIRD guidance in: + Criteria for Suitably Qualified Invasive Marine Pest Experts (DPIRD, 2017a) + Best Practice Guidelines for Invasive Marine Species Inspections (DPIRD, 2017b) + Invasive Marine Species Inspection Report Requirements (DPIRD, 2017b).

No.	Mitigation Measure	Overview
2	In-water cleaning	The appropriateness of in-water cleaning operations must be a decision made closely with IMS inspector on a case-by-case basis. Many factors will be considered, including: + Degree and type of biofouling; + Location of biofouling on the vessel. Prior to undertaking in-water cleaning within Australia, approval from the relevant state/territory authority must be granted and conditions may be imposed. Application for administering authority (Harbour Master, local government or state environmental protection agency) at least five working days prior to the proposed commencement of the work.
3	Dry docking cleaning	Dry docking and the removal/cleaning of biofouling will include hull surfaces, niche areas such as sea chests, all retractable equipment such as thrusters, intakes and outlets, anodes and voids.
4	Temporal or spatial controls	Temporal or spatial controls to limit vessel exposure to sources of risk.
5	Application of anti-fouling coating	Depending on the age the vessel may require application of new anti-fouling coating. The anti-fouling coating type will be based on technical advice and carried out by professional operators. All vessels greater than 400 gross tonnes will retain Antifouling System Certificate.
6	Treatment of internal seawater systems	In the absence of a marine growth prevention system, cleaning of internal seawater systems may be required, which may include: + Dehydration + Heat + Physical removal + Chemical treatment. Treatment of Internal Seawater systems will ideally be undertaken prior to mobilisation to Australia. Where chemical treatments are to be undertaken within Australian waters, advice will be sought from the Australian Pesticides and Veterinary Medical Authority (www.apvma.gov.au) in relation to permit and reporting requirements as it is prohibited to clean internal systems without a permit.

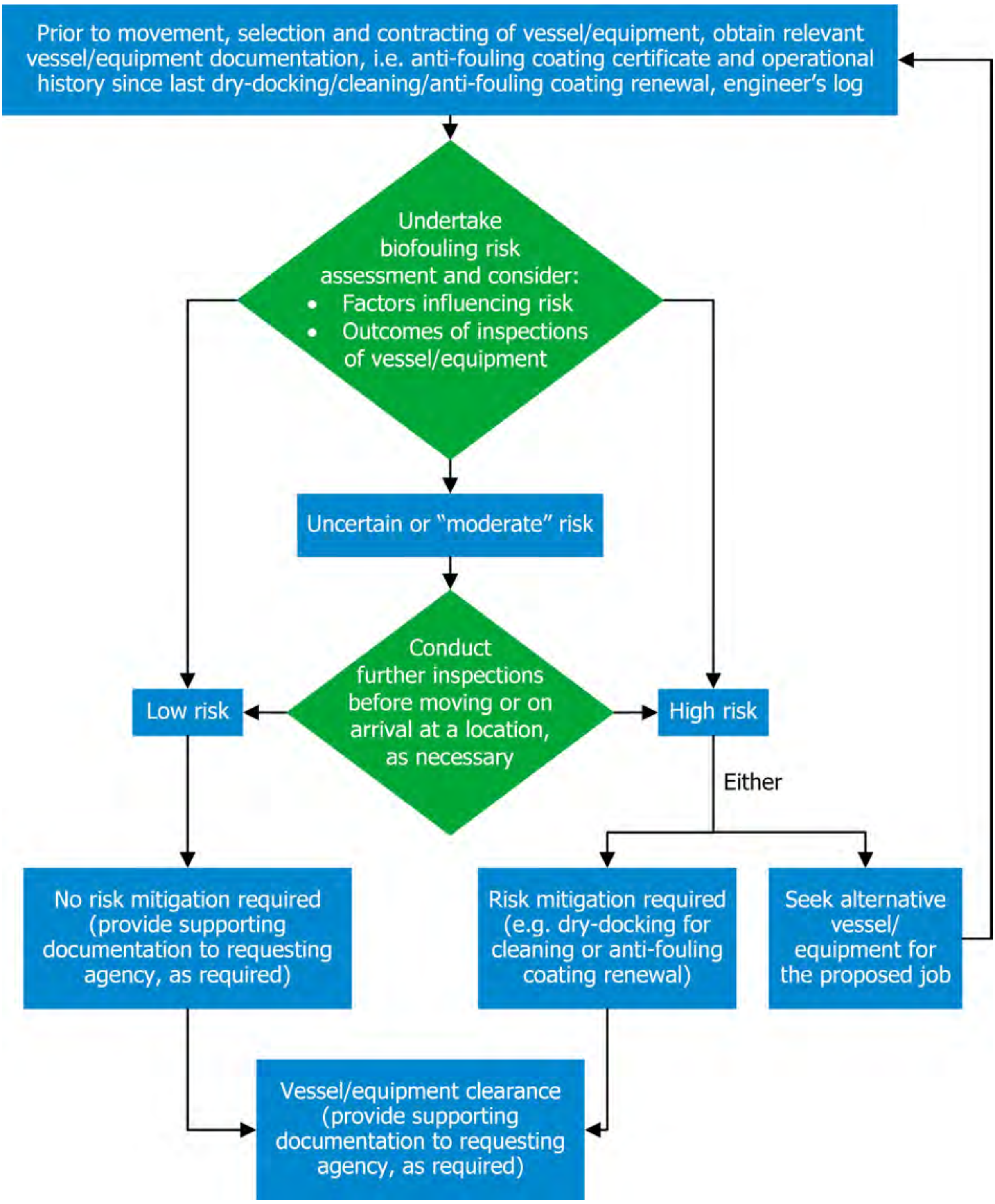


Figure 4-1: Generic biofouling risk assessment process (from Department of Agriculture, Fisheries and Forestry, 2009)

5 Existing Environment

This section describes the key physical, biological, socio-economic, and cultural characteristics of the Project Area. Based on the existing environment description in the Darwin Pipeline Duplication (DPD) Project - NT EPA referral (BAA-201 0003; Santos, 2021a) supporting document, Santos Barossa DPD – Pipeline Benthic Survey Report (RPS, 2022) and the following documents:

+ Darwin Pipeline Duplication (DPD) Project – EPBC Referral Supporting Information (BAA-201 0004; Santos, 2022)
+ Darwin Pipeline Duplication (DPD) Project – NT EPA referral (BAA-201 0003; Santos, 2021)
+ Santos Barossa DPD – Pipeline Benthic Survey Report (BAS-210 0014; RPS, 2022)
+ Ichthys Gas Field Development Project – Draft Environmental Impact Statement (EIS) (INPEX, 2010)
+ INPEX Ichthys GEP Dredging and Spoil Disposal Management Plan (INPEX, 2014)
+ Darwin Harbour – A Summary of the Ichthys LNG Project Nearshore Environmental Monitoring Program (Cardno, 2014)

5.1 Physical environment

The Darwin region is host to unique physical environmental conditions described below. Further details of the physical environment can be found in DPD Project NT EPA Referral (BAA-201 0003, Santos, 2021).

5.1.1 Meteorological conditions

5.1.1.1 Climate

The project area resides within the monsoonal (wet-dry) tropics of Northern Australia, which is subject to two distinct seasons a hot wet season from November to March and a warm dry season from May to September, with both April and October acting as transitional months between wet and dry seasons, respectively.

Temperatures are hot all year round with mean maximum temperature >30°C, November is the hottest month of the year ranging from 25°C mean minimum temperature to 33°C mean maximum temperature. While June and July are the coolest months in the year ranging from 19 – 20°C mean minimum temperature to 30°C mean maximum temperature (BOM, 2022).

5.1.1.2 Rainfall

The annual mean rainfall for Darwin is 1723.8 mm with the majority of this (87%) rainfall coming in wet season months between November and March. Mean monthly evaporation ranges from 160 mm in February to 245 mm in October, with annual daily evaporation of 6.7 mm. Mean 9am and 3pm relative humidity is also higher in the wet season following similar trends to rainfall (BOM, 2021). Monthly and annual mean, max and min rainfall averages from 1941 to 2021 for Darwin International Airport are provided in **Table 5-1**.

Table 5-1: Average monthly and annual mean, max and min rainfall from 1941 to 2021 for Darwin International Airport (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	431.3	369.0	310.7	101.6	20.7	1.8	1.1	4.7	16.6	70.2	141.8	252.0	1723.8
Max	940.4	1110.2	1013.6	396.2	295.9	50.6	26.6	83.8	129.8	338.7	370.8	664.5	2776.6
Min	136.1	103.3	88.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	17.2	18.8	1024.7

5.1.1.3 Wind direction and speed

During the wet season winds are predominately consists of light westerly and west-north-west winds, whilst in the dry season winds are varying from the south-east through to the north. Mean wind speeds are generally stronger in the afternoon than in the morning throughout the year. Mean morning wind speeds are typically stronger in the dry season, whilst mean afternoon wind speeds increase during the late dry season and build into the wet season where stronger winds are associated with afternoon storm cells.

5.1.1.3.1 Cyclone activity

The monsoonal tropics are also subject to intermittent cyclone activity usually resulting in the strongest winds and heaviest amount of rainfall in the occur during the cyclone season (November to April). Cyclones in the Anson-Beagle region are known to occur with low to moderate frequency. Most of the damage caused by cyclones occurs near to the coast, within 50 km from the coastline. Storm surges often result in flooding, raised tidal levels, and increased wave heights resulting in damage, causing concern for vessels and coastal developments in the area. Storm surges are hard to predict and dependent on the characteristics of the associated cyclone such as speed, intensity, and the angle it crosses the coast. Bathymetry also contributes to the risk level of storm surges (BOM, 2022).

5.1.2 Coastal morphology

5.1.2.1 Offshore Northern Territory waters

The bathymetry of the project area in offshore NT waters has been thoroughly investigated and is well understood. Recent surveys have shown that the seabed along the project pipeline route in offshore NT waters and within the spoil disposal ground is generally flat and featureless, with a typical depth of <30m.

5.1.2.2 Darwin Harbour

Darwin Harbour is a large, drowned river system approximately 500 km^2 in extent. It is comprised of three arms (East Arm, West Arm, and Middle Arm) which along with the smaller Woods Inlet, converge into a single channel before opening to the ocean and into Beagle Gulf in the north.

Freshwater inflow from the Elizabeth River into the East Arm and the Blackmore and Darwin rivers into the Middle Arm generally occurs between January and April creating more estuarine conditions (Hanley, 1988).

Port Darwin's main channel is approximately 1525 m wide and 15 – 25 m deep, with a maximum recorded depth of 36 m. The channel is generally deeper on the eastern side of the Harbour, while the western side is broader and shallower with more extensive intertidal flats and shoal areas. The channel extends into the East Arm with depths of more than 10 m below LAT, the bathymetry of this area has been modified by dredging associated with the development of East Arm Wharf. There is a slightly deeper channel in the Middle Arm extending up to the western side of Channel Island.

5.1.3 Oceanography

5.1.3.1 Offshore Northern Territory waters

The North Marine Region has no major ocean currents. However, there are tidal currents that play a role in the movement of water, biota, and benthic sediments. There are three recognised large-scale ecological systems in the North Marine Region which are the:

+ Gulf of Carpentaria
+ Arafura
+ Joseph Bonaparte Gulf.

The offshore NT waters project area traverses two meso-scale bioregions, the Bonaparte Gulf and Anson-Beagle bioregions. The Bonaparte Gulf bioregion is predominately within offshore Commonwealth waters, but overlaps with NT coastal waters, south of Bathurst Island.

The extent of the continental shelf in Beagle Gulf in the Anson-Beagle bioregion means ocean currents only have a minor influence on this region. Beagle Gulf has limited oceanic interaction and is strongly influenced by strong internal circulation. During the dry season (May to September) there is a south westerly drift due to south easterly winds, the Indonesian flowthrough, and South Equatorial Current. Whilst during the wet season (November to March) there is a north easterly drift due to the north westerly monsoonal winds. The gulfs tides range from 6 to 8 m (IMCRA Technical Group, 1998).

Wave action in Beagle Gulf is seasonal; monsoonal north westerly winds during the wet season increase wave energy within Beagle Gulf and at the entrance to Darwin Harbour, due to the uninterrupted fetch over the Timor Sea. Whilst in the dry season south easterly trade winds generate low wave energy due to limited fetch.

Further offshore oceanic currents within the Bonaparte Gulf are influenced by the Indonesian flowthrough and South Equatorial Current. During the dry season (May to September) nearshore currents are generally westerly, whilst in the wet season (November to March) nearshore currents are easterly. Tides are semi-diurnal (two highs and two lows each day) and vary throughout the bioregion from offshore microtidal range (2 to 3 m variation) to inshore mesotidal range (3 to 4 m variation).

5.1.3.2 Darwin Harbour

Darwin Harbour has a macrotidal (more than 4 m) regime with tide range reaching 8 m. Tides are generally semidiurnal (two highs and two lows each day) with some inequality between successive tides in a single day. Neap tides result in a two-day period where tidal conditions are nearly diurnal (one high and on low each day). There is a great degree of variation in daily tidal range with the presence of spring-neap tide cycle approximately every 15 days. The spring phase of the cycle has an average tidal range of 6 m, while the neap phase average tidal range is 3 m (Cardno, 2014). Large tidal movements and to a lesser extent wind, drives rapid and regular exchange of large volumes of water between Darwin Harbour and Beagle Gulf.

Darwin Harbour is sheltered, with tsunamis and swell waves unlikely to occur due to the harbour's orientation, shallow bathymetry and protection afforded by the Tiwi Islands. Most waves are generated within Darwin Harbour or Beagle Gulf and are well below 1 m with periods of 2 – 5 seconds, under non-cyclone conditions. Tropical cyclones can cause extreme wave conditions producing significant wave height of 4.5 m and approximate periods of 7.5 seconds at the entrance to Darwin Harbour. Inside the harbour waves heights are reduced by the bathymetry to approximately 0.7 m (GHDM, 1997).

5.1.4 Water quality

5.1.4.1 Offshore Northern Territory waters

Ichthys NEMP monitoring found that waters in Beagle Gulf were highly turbid in the wet season compared to the dry season likely due to stronger winds, larger waves, greater rainfall, and increased freshwater input (Cardno, 2014).

Environmental surveys to support the Barossa GEP Installation EP investigated water quality within the Barossa field (seasonal through 2015) and along the Barossa Gas Export Pipeline (GEP) (July to August 2017). This included areas close to the Project Area in Offshore NT waters, in which results showed metal concentrations below Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) dissolved metal trigger values (Santos, 2021).

In 2021, water sampling and analysis along the DPD pipeline route and at the spoil disposal ground in the offshore NT waters of the Project Area was completed (RPS, 2022 BAS-210-0014). Concentrations of three metals in water samples were detected above ANZG (2018) default guideline values (DGVs) (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) Copper concentrations ins samples from three sites at western end of the offshore pipeline route were above the DGV; one of these exceedances was much higher than the DVG with the other two only slightly greater than the DVG, therefore it is likely an outlier and indicative of a potential contaminant. Lead concentrations were found to be much higher in the offshore Darwin Harbour samples than in samples taken at the spoil ground, with one sample above the DGV. Zinc concentrations were found at or above the DGV in 5 samples collected from the western end of the offshore pipeline route and across the proposed spoil disposal ground, with no clear trend in exceedances between surface and bottom waters. Arsenic was recorded below the ANZG (2018) DGV (RPS, 2022).

All nutrient concentrations were below the associated ANZG (2018) DGV (RPS, 2022). Dissolved hydrocarbons were below the limits of reporting (LoR) for all samples. Naturally Occurring Radioactive Material (NORMs) were detected in near-seabed samples at two sites along the offshore pipeline route in low concentrations.

Total Suspended Solids (TSS) concentration were all above the LoR and ranged from 1.7 to 8.6 mg/L at offshore sites and 1.4 to 6.2 mg/L at spoil disposal grounds. There was no correlation between depth and TSS at either location.

Water column profiles at sites along the offshore pipeline and at the spoil ground showed no indications of stratification of the water column.

5.1.4.2 Darwin Harbour

Typically, water quality is high in the harbour, although naturally turbid as well. Water quality is highly variable within Darwin Harbour dependent upon tide, location, and season (**Table 5-2**). Darwin Harbour water quality is affected by high levels of surface runoff in the wet season (November to March), which can extend until April or May depending on rainfall received. Tides also influence water quality in the harbour, neap tides promote water clarity while spring tides reduce it by resuspending fine sediment from the harbour floor and fringing mangroves (DHAC, 2008).

The Darwin Harbour Water Quality Report Card (NT Government, 2021) found the Harbour's water quality was largely graded very good in 2021 with an overall grade of 'A', except for Buffalo Creek estuary which was impacted by wastewater discharge from the Leanyer-Sanderson sewage treatment plan. However, Buffalo Creek is outside the Project Area.

Table 5-2: Summary of processes affecting water quality in Darwin Harbour

Parameter	Influencing factors	
	Open Harbour	Tidal creeks
Temperature	Season	Season
Salinity	Season, location	Season, tide
Dissolved Oxygen	Tide (minor)	Tide
pH	(none)	Season, tide
Turbidity and light attenuation	Season, tide	Tide
Nutrients	(none)	Location

Water temperatures within Darwin Harbour are predominately high with some seasonal variation, averaging 30.6°C in the wet season and 24.5°C in the dry season. The lowest water temperatures occur in June and July (23°C) while the highest occur in October and November (33°C) (Padovan, 1997).

Salinity within Darwin Harbour is also subject to some seasonal variation, with mean salinity levels in the harbour being lower during the wet season, due to freshwater influence being greater. Sea water salinity has a global average of 35 ppt, however salinities throughout the harbour are approximately 37 ppt during the dry season. Salinity is higher in the dry season due to increased evaporation and less freshwater inflow. Areas in the middle of the harbour such as Weed Reef can experience salinity as low as 27 ppt due to monsoonal inflow during February and March (Parry & Munksgaard, 1995). Salinities in the arms are heavily influenced by freshwater inflow in the wet season and can drop to 17 ppt. The water column during this time is heavily stratified with Parry and Munksgaard (1995) reported salinities on the bottom of the harbour to be up to 12 ppt higher than the surface.

Darwin Harbour waters remain well oxygenated throughout the year with Padovan (1997) finding no seasonal effects. Dissolved oxygen levels range from 74% to 96%, averaging approximately 84%. Dissolved oxygen levels are slightly higher at the harbours mouth compared to further into the estuary. Additionally, during spring tide cycles oxygen levels increased by 7% at high tide compared low tide (Padovan, 1997).

Darwin Harbour waters have a narrow pH range of 8.3 – 8.6. Padovan (1997) found no seasonal, spatial, or tidal effect on the pH of the harbour.

Turbidity in the Darwin Harbour is higher in the wet season compared to the dry season, mainly due to influx of terrigenous sediment and somewhat due to surface water sheet flow. Light levels at the bottom of the harbour can be as low as 1% of surface light levels during the wet season (Padovan, 1997). However, the most important factors affecting turbidity are tidal cycle and location (Padovan, 1997). Spring tides are associated with higher current velocities, and therefore higher capacity of water to move sediment, which results is greater turbidity (DHAC, 2005).

5.1.5 Sediment quality

5.1.5.1 Offshore Northern Territory Waters

The Bonaparte Gulf has been reported to have relatively uniform sediments mainly consisting of sand. Within offshore NT waters, sediments are a mixture of gravelly, sandy sediments (Rochester *et al.*, 2007).

In 2021 sediment sampling and analysis along the DPD pipeline route and the at the spoil disposal ground in the offshore NT waters of the project area was completed (RPS, 2022). The offshore pipeline route was found to predominately consist of sand (RPS, 2022). Particle size was seen to transition from gravelly silty sand at sites further offshore, to less gravelly more silty sand with higher proportions of clay at sites closer to Darwin Harbour (RPS, 2022). The particle size distribution was consistent across the spoil ground, with sediments comprising of sand with some gravel and silt. Total recoverable hydrocarbons (TRH) and benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN) results were both below LoR for samples collected along the DPD Project pipeline and in the spoil disposal ground (RPS, 2022). All metal and metalloids with National Assessment Guidelines for Dredging (NAGD) screening levels (CoA, 2009a) had concentrations below the associated screening level, except for Arsenic concentrations that are naturally high but below NAGD SQG-High value (RPS, 2022). Nutrient and Total Organic Carbon (TOC) concentrations were all low and exhibited low variability (RPS, 2022). NORM concentrations were well below the NAGD screening level (effects range-low) (CoA 2009a).

5.1.5.2 Darwin Harbour

Darwin Harbour sediments can be split into four types (Michie, 1988):

+ Terrigenous gravels mainly found in the main channel
+ Calcareous sands with >50% biogenic carbonate, largely derived from mollusc shell fragments, found among or close to small coral communities at East Point, Lee Point and Channel Island.
+ Terrigenous sands predominately consisting of quarts and clay, with 10 – 50% carbonate largely derived from molluscs.
+ Mud and fine sand found on broad gently inclined intertidal mudflats that occur in areas with low current and tidal velocities.

Soft surfaces with varying amounts of sand and gravel occur in the main channel and near the mouth of the harbour. Although, spatial extent is hard to define due to the gradual transition between muddy, sandy, and coarser sediments and sediment movement caused by large tidal influences (Fortune, 2006). Coarser sediments are in the central channels of tributaries and the main body of the harbour rather than landward margins.

Sediment quality assessments completed for the Ichthys Gas Field Development Project identified a range of potential contaminants. Metal concentrations recorded in surface sediments were typically consistent between the East Arm, Middle Arm, and main body of Darwin Harbour. Arsenic concentrations are naturally high in Darwin harbour sediments, although bioavailability testing indicated only a very small proportion would become bioavailable (INPEX, 2010). Chromium and Mercury mean concentration levels were below guideline screening levels. Hydrocarbon and tributyltin were generally all below laboratory detection limits (INPEX, 2010). Total organic carbon levels were within the range to support biomass growth, averaging 0.3% w/w in East Arm and the main body of the harbour, and 0.5% w/w in Middle arm (INPEX, 2010). Soluble nitrogen (nitrite and nitrate) levels were low throughout the harbour and therefore considered an insignificant portion of the total nitrogen pool (INPEX, 2010). Mean total phosphorus (TP) levels were recorded within the range of previous study by Parry et al. (2002). Potential acid sulfate soil (ASS) risk was identified at sites throughout the East Arm and along the Ichthys project pipeline.

Further sediment sampling and analysis along the DPD Project pipeline route within Darwin Harbour in 2021 (RPS, 2022) indicated:

- Particle size distribution varied from north to south along the pipeline route in Darwin Harbour. The northmost site was found to have high proportions of silt and clay, while the sand wave area in the outer section of the harbour had very high proportions of sand and the southern end of the pipeline route consisted of gravelly silty sand.
- TPH, TRH and BTEXN were detected at Darwin Harbour sites, at low levels. Normalised TPH and TRH concentrations met the relevant guidelines across all sites. PAH concentrations at all sites were below the LoR.
- Concentrations of naturally occurring radioactive materials, pesticides and tributyltin were all below limits of detection in harbour sediments.
- There is low potential for acid sulfate soils as, although inorganic sulphur is present in the sediments, there is significant acid neutralising capacity kinetically available to neutralise the oxidation products from the inorganic sulphur.
- All metal and metalloids were above the LoR, with the exception of mercury. Of these metals and metalloids with NAGD screening levels (CoA, 2009a) only arsenic had concentrations above the screening level; however, arsenic levels were below the NAGD SQG-High value (RPS, 2022).
- No contaminants of concern were found in the sediments along the pipeline route or at the potential spoil disposal ground. The elevated levels of arsenic found are considered to be naturally occurring. Therefore, the sediments along the pipeline route are suitable for unconfined ocean disposal, as per the NAGD (CoA, 2009a) and the NT EPA: Draft Guidelines for the environmental Assessment of Marine Dredging in the Northern Territory (NT EPA, 2013).

5.1.5.3 Acid sulfate soils

ASS are formed naturally and often occur in low lying coastal areas (BAA-201 0003; Santos, 2021). Coastal estuarine and mangrove environments develop ASS due to its typical waterlogged nature, saltwater influences and anaerobic soils.

ASS mapping over the Darwin region indicates that the Project Area shore crossing has a high potential for ASS to occur (BAA-201 0003; Santos, 2021). Considering the historical earthworks undertaken as part of the development of the DLNG facility, the natural material has been removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m below ground level (Santos, 2022c).

5.1.6 Underwater noise

Underwater noise, excluding naturally occurring noise, within Darwin Harbour is influenced by the existing shipping traffic, biological sources, and weather. Vessel traffic in Darwin Harbour is a year-round source of noise with the Port of Darwin recording 1,510 trade vessels in the 2021 – 2022 financial year (Darwin Port Operations, 2022). Further information regarding ambient noise levels in Darwin Harbour including measures is detailed in the MMNMP (BAS-210 0022).

5.2 Benthic habitats

The Darwin region supports several benthic habitats including mangroves, coral, seagrass, macroalgae, filter feeders and soft-bottom benthos described below. Further details of benthic habitats can be found in DPD Project NT EPA Referral (BAA-201 0003; Santos, 2021) and DPD Project Supplementary Environmental Report (BAA-201 0020, Santos, 2021a).

5.2.1 Offshore Northern Territory waters

Baseline investigations for the DPD Project were completed in October 2021 and June 2022 using drop/towed video at 30 sites and ROV video transects at 42 sites, respectively (BAS 210 0014; RPS, 2022). These surveys were used to describe the seabed of the offshore Project pipeline route. The results are included in full in the Santos Barossa DPD – Pipeline Survey Report (BAS 210 0014; RPS, 2022) and are summarised below.

The benthic habitats along the offshore Project pipeline route verified the predictions of the AIMS (2021) habitat modelling and comprised silty shelly sand with burrows and polychaete worm tubes. Biota commonly associated with this habitat included sparsely distributed hydroids, soft corals (gorgonians*, Junceella* and Alcyoniidae), sea stars and sponges. Within three of these silty shelly sand sites, there were sections of sand waves, roughly one metre high, with silty sand in the troughs and coarse shelly sand at the peaks. This substrate was associated with very sparse epibiota. The proposed sand waves trenching area (**Figure 2-8**) was found to contain rippled coarse sand with very little epibiota (<1% abundance), consisting of soft corals and crinoids.

The spoil disposal ground sites all consisted of the same soft substrate habitat. This habitat is defined by silty/clay sediment with medium density biota. Biota commonly seen at this habitat were soft corals (gorgonians*, Junceella,* and Alcyoniidae), branching and encrusting sponges, Bryozoa (lace coral), invertebrate burrows, polychaete tubes, brown algae and occasional motile crinoids.

5.2.2 Darwin Harbour

Benthic habitat surveys were completed in Darwin Harbour in October 2021 and in June 2022 (BAS 210 0014; RPS, 2022). The October 2021 survey was completed systematically to describe habitats along the proposed pipeline route. The June 2022 survey targeted sites which were predicted by the AIMS 2021 benthic habitat map (AIMS, 2021) to have unique habitat or showed features from geophysical surveys, that were considered to potentially represent maritime heritage features. The comparison between the AIMS and survey datasets revealed differences between predicted and observed habitat types, particularly with the level of information provided (approximate densities of biota, substrate types are not available in AIMS data).

Overall, the benthic habitat and communities survey indicated the Barossa DPD pipeline route is a transitional environment, with soft sediment habitats along the offshore pipeline route and spoil ground, and with areas of both soft and hard substrate habitat within Darwin Harbour. The soft sediment habitats support very sparse to sparse epibiota, and the rocky substrates support low to medium density filter-feeder communities.

Sections 5.2.2.1 and 5.2.2.2 summarise the findings of the October 2021 and June 2022 surveys respectively.

5.2.2.1 October 2021 survey

Darwin Harbour benthic habitats comprised soft sediment and two hard substrate habitats. Hard substrates were recorded along the section of the pipeline route offshore from Fannie Bay and low-profile reef was recorded offshore of Woods Inlet with medium to high density epibiota. The soft substrate habitat adjacent to hard substrate habitats in Darwin Harbour were generally silty, shelly sand with very sparse soft corals to no conspicuous epibiota. As this habitat was recorded both adjacent to and between hard substrate habitats, this soft substrate habitat is potentially a veneer overlying submerged geology. Other recorded soft sediment benthic habitats in Darwin Harbour included:

+ Sand waves <1 m with coarse shelly sand and very sparse epibiota
+ Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids) (at the southern end of the pipeline, near the shore crossing)
+ Silty, shelly sand with sparse epibiota (soft corals) and scattered bombora (at the southern end of the pipeline, near the shore crossing).

5.2.2.2 June 2022 Survey

Key objectives of the June 2022 survey were to ground truth AIMS (2021) habitat mapping at selected sites within Darwin Harbour and to increase the number of benthic survey sites along the pipeline route. Ground-truthing within Darwin Harbour focused on sites predicted to be suitable for rarer high-value biota types (e.g., macroalgae, hard corals and seagrass) that were closest to the proposed pipeline route (and therefore had the greatest potential to be influenced by DPD Project construction activities, including trenching). This included an area west of the pipeline route where the route comes closest to the shoreline of Cox Peninsula (including sites HAB 1-4), an area west of the pipeline route where the route comes closest to Weed Reef (including sites HAB 6-8) and sites close to the shore crossing (HAB 9 and 10) (refer to **Figure 5-1**).

Results from these surveys showed that the selected sites which were predicted as suitable for macroalgae, seagrass and/or hard coral by AIMS (2021) mapping typically did not show presence of these biota types (BAS 210 0014; RPS 2022, **Figure 5-1 - Figure 5-3**). Additional to these benthic habitat ground-truthing sites, a number of benthic habitat monitoring sites used by INPEX during the Ichthys project were ground-truthed including hard coral sites (INPHCMAN, INPHCWED, INPHCCHI, INPHCSSI and INPHCNEW) and seagrass sites (INPSGWOD and INPSGCPW) (refer **Figure 5-1 - Figure 5-3**). Surveys from these sites generally confirmed the presence of seagrass or hard coral as expected, although seagrass was observed at very low densities. The additional sites surveyed along the pipeline route within Darwin Harbour in June 2022 provided results consistent with surveys in October 2021 in that sites comprise a mix of hard substrate and sediments supporting varying densities of filter-feeding biota such as soft corals, hydroids, crinoids and sponges but with an absence of photosynthetic biota such as hard corals, seagrass and algae (BAS 210 0014; RPS, 2022; **Figure 5-1 – Figure 5-3**).

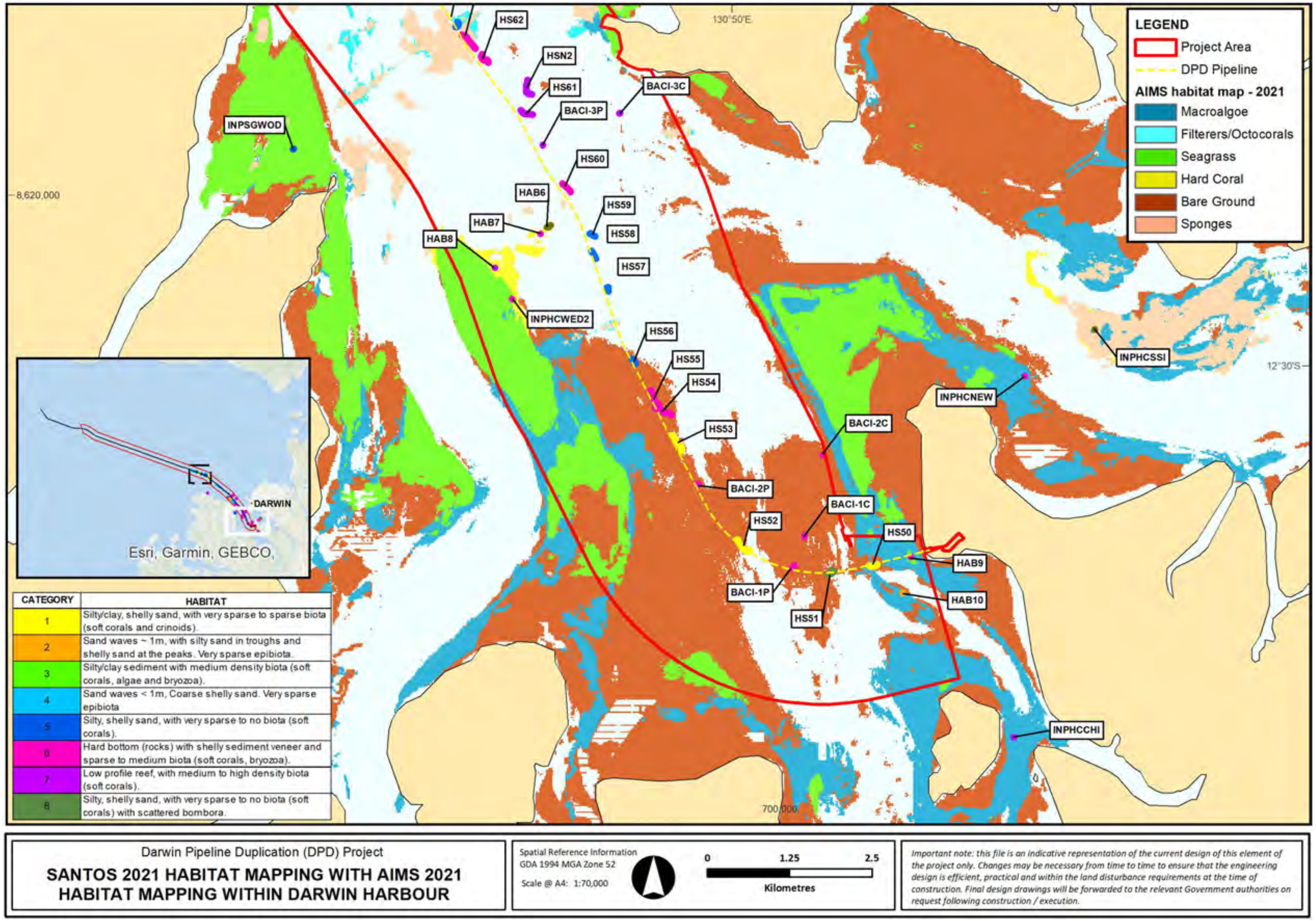


Figure 5-1: RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021)

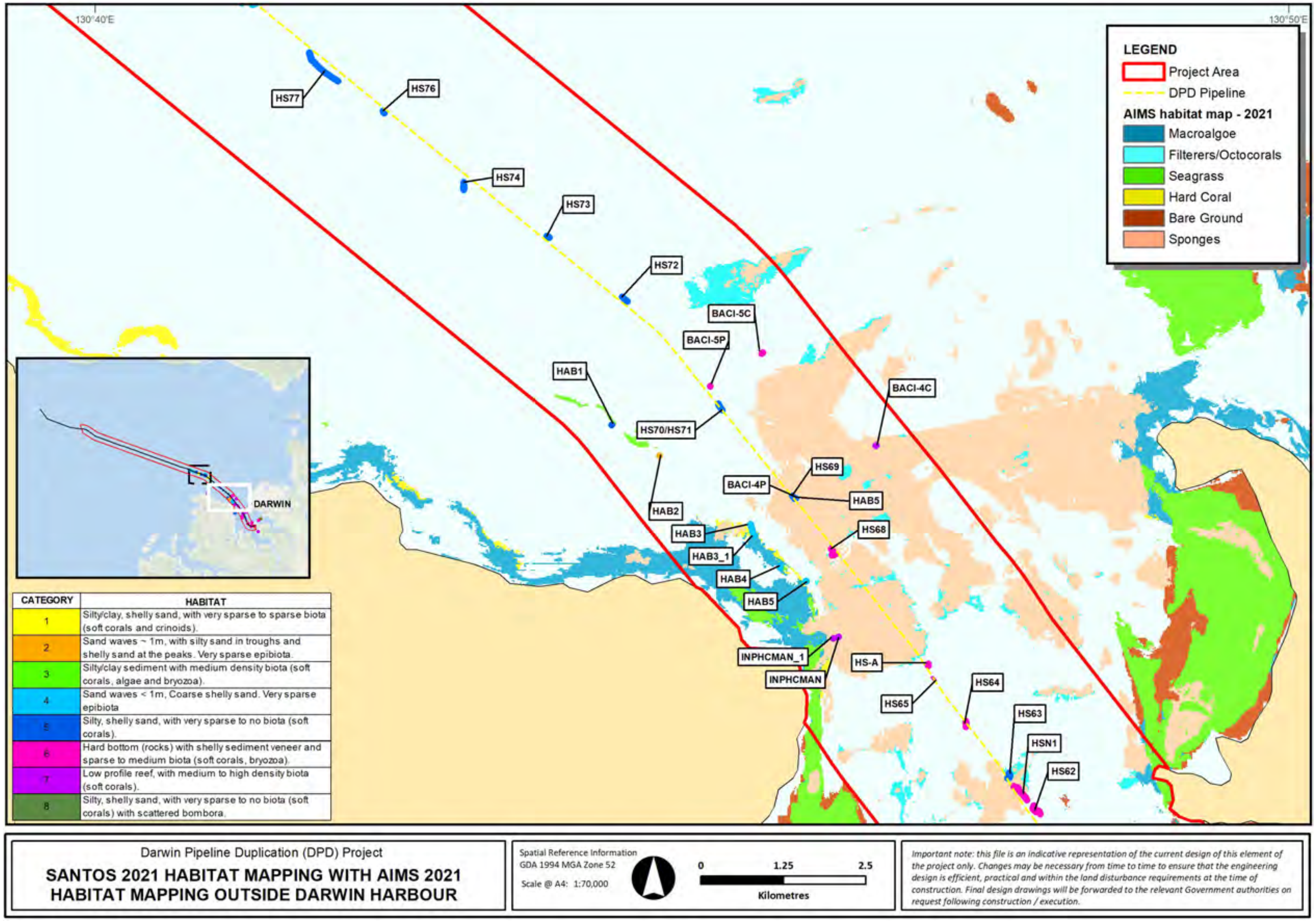


Figure 5-2: RPS surveys habitat mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021)

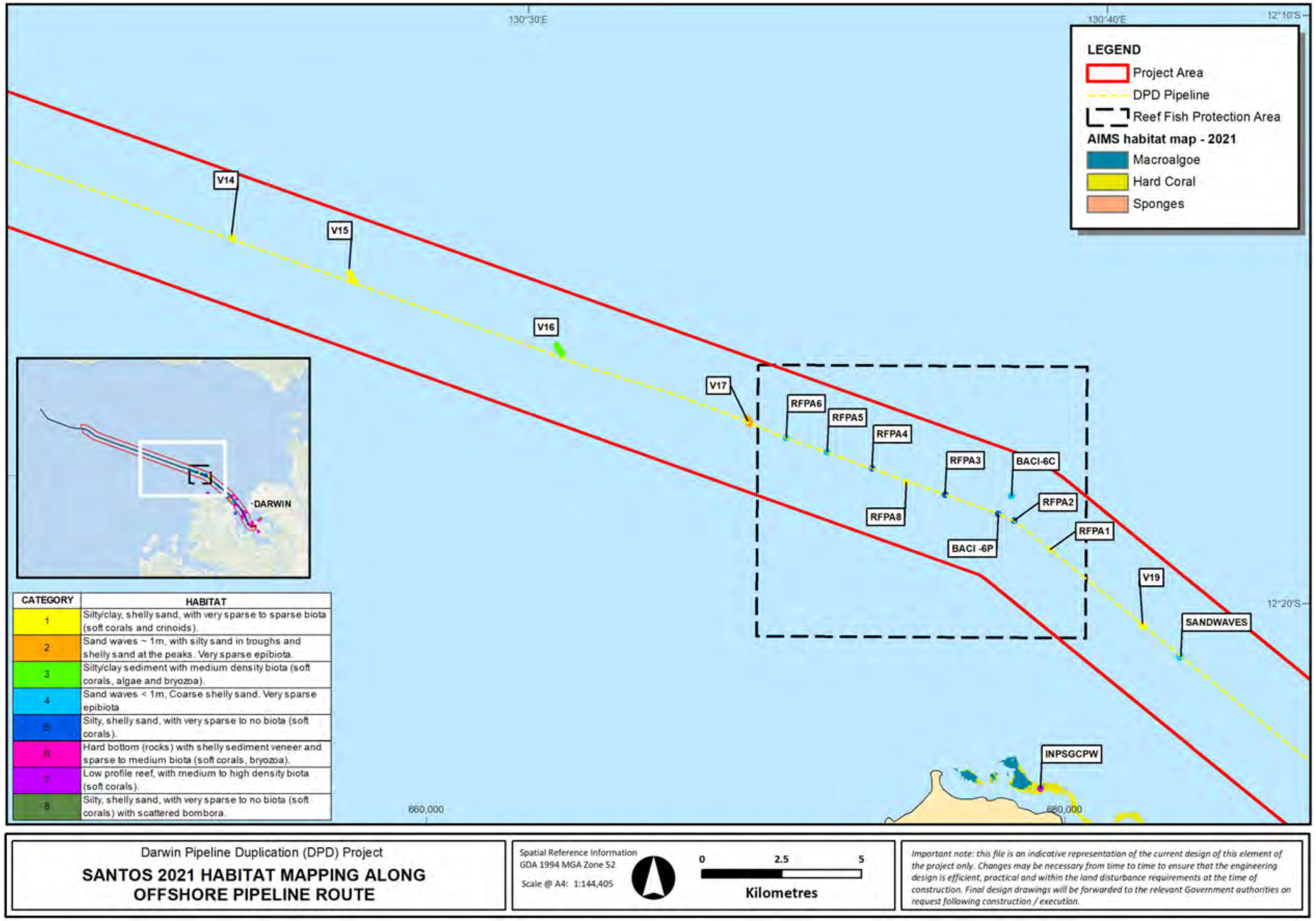


Figure 5-3: RPS surveys habitat mapping along offshore pipeline route

5.2.3 Hard Coral

Hard coral communities in Darwin Harbour mainly consist of low-relief encrusting, small massive, sub-massive and low-profile foliose types found in the lower intertidal and upper subtidal areas, down to depths of 5 – 10 m below LAT (Cardno, 2014). Coral communities are sparse and consist of patches of individual colonies occupying approximately 20% of the seabed. A total of a 123 species have been reported to inhabit the Darwin region with Ichthys NEMP identifying 48 species within the Darwin Harbour (Wolstenholme *et al*., 1997; Cardno, 2014). Coral species inhabiting the harbour tolerate variable salinity, high turbidity, low light availability and high sedimentation. Additionally, corals can be impacted by high water temperatures and exposure due to spring low tides, making them vulnerable to desiccation and possibly freshwater impacts if tides coincide with heavy rainfall events (Cardno, 2015). In addition to specific environmental pressures coral communities are also subject to natural biological pressures such as predation, disease, and competition (Cardno, 2014).

Hard coral communities were found within the Project Area during the June 2022 RPS survey at Weed Reef (INPHWED2), Mandorah (INPHCMAN & INPHCMAN_1) and at sites in the central portion of the harbour and outside the Project Area at Channel Island (INPHCCHI), Northeast Wickham Point (INPHCNEW), and South Shell Island (INPHCSSI) (BAS 210 0014; RPS, 2022; **Figure 5-1** and **Figure 5-2**). All these sites were predicted to be suitable to support hard corals by AIMS 2021 habitat mapping. Charles Point Wide (INPSGCPW) was additionally predicted to support hard corals although the June 2022 survey found no hard corals present (**Figure 5-3**). Channel Island coral communities are protected under the *Heritage Act 2011* (NT) due to their high diversity despite being well inside a large, drowned river valley characterised by multiple stressors (DCCEEW, 2022).

5.2.4 Filter Feeders

The DPD Project October 2021 and June 2022 habitat surveys found varying densities of soft corals occurring at sites both within and outside the harbour, including along the pipeline route and at the spoil ground. Soft coral types consisted of gorgonians*, Junceella sp* and Alcyoniidae with *Neptheidae* only found at offshore sites (BAS 210 0014; RPS, 2022). Other filter feeding biota observed from benthic habitat surveys along the pipeline route included hydroids, bryzoa, crinoids, anemones, and sponges (BAS 210 0014; RPS, 2022).

5.2.5 Seagrass

Seagrass meadows have been identified to occur along the Cox Peninsula near Charles Point and Woods Inlet as well as along the eastern shore from Fannie Bay to Lee Point (Cardno, 2014). This seagrass habitat is dominated by early colonising seagrass species *Halodule uninervis* and *Halophila decipiens*. These species are fast growing and known to survive well in unstable and depositional environments (Green & Short, 2003).

Other than these areas, Darwin Harbour is not known to host significant seagrass meadows. Very sparse *Halophila sp* and sparse *Halodule uninervis* and *Halophila decipiens* coverage has been recorded during other environmental surveys at Weed Reef and Wickham Point respectively (INPEX, 2010).

The AIMS 2021 benthic habitat mapping predicted seagrass habitat north of Mandorah within the Project Area and Woods Inlet outside the Project Area. However, the habitat surveys completed in June 2022 only found low density seagrass meadows at Woods Inlet (BAS 210 0014; RPS, 2022).

5.2.6 Macroalgae

Within Darwin Harbour macroalgae communities are typically located between the intertidal and subtidal zones, a few metres either side of the low-water mark and generally are associated with coral or sponge dominated communities. Macroalgae community composition is dependent on seasonality, INPEX (2010) suggests that this is regulated by the amount of time exposed during spring low tides. Turf algae is more dominate during the build-up season (October to December), due to large tidal range and extreme spring low tides occurring during the middle of the day, causing larger macroalgae dieback. Larger macroalgae species are more dominant during the dry season when the tidal range is less extreme.

The AIMS 2021 benthic habitat mapping predicted macroalgae habitat sites at the opening of Darwin Harbour north of Mandorah, and sites close to Wickham Point including Channel Island and northeast Wickham Point. However, macroalgae communities were only found to occur at sites at the opening of Darwin Harbour north of Mandorah with very low coverage and in the central portion of the harbour in moderate densities (BAS 210 0014; RPS, 2022).

5.2.7 Soft-bottom benthos

It is estimated that approximately 80% of available substrate in the Darwin Harbour consists of soft substrates (McKinnon *et al.*, 2006). This was confirmed by DPD Project benthic habitat surveys which found that soft sediment benthic habitats were well represented along the pipeline route (BAS 210 0014; RPS, 2022). The Barossa DPD surveys recorded filter feeders at sparse densities across almost all soft substrate types. The outer offshore pipeline route was observed to be dominated by fine sand/silt with sparse epibiota, consisting of occasional sponges and soft corals, and bioturbation with some sand waves. The habitat just outside the mouth of Darwin Harbour consisted mainly of course rippled sand, with low overall epibiota. Spoil ground sites consisted of the same silty/clay soft substrate habitat with medium density of biota (BAS 210 0014; RPS, 2022). This biota mostly consisted of soft corals (gorgonians, *Junceella*, Alcyoniidae), branching and encrusting sponges, Bryzoa (lace coral), invertebrates, polychaetes, brown algae, and occasional motile crinoids (BAS 210 0014; RPS, 2022).

5.3 Terrestrial ecosystems

5.3.1 Flora

A search of the DEPWS Natural Resource (NR) Maps database for threatened flora and significant flora within 5 km of the onshore Project Area identified one significant flora species, Byblis (*Byblis aquatica*) (DEPWS, 2022). This species is listed as near threatened under the *Territory Parks and Wildlife Conservation Act 1976* (TPWC Act) and was recorded approximately 5 km to the south-east of the onshore Project Area. It grows in semi-aquatic conditions and is insectivorous to acquire nutrients in nutrient-poor environments (Atlas of Living Australia, 2022). This species is commonly found in areas specifically between Darwin and Berry Springs.

Previous flora surveys of the DLNG Facility disturbance envelope did not identify the presence of any threatened or conservation significant flora species (BAA-201 0003; Santos, 2021). The Byblis is unlikely to occur within the onshore Project Area as it has been previously disturbed and there are no permanent freshwater habitats present (BAA-201 0003; Santos, 2021).

5.3.2 Mangroves

Darwin Harbour is known for its mangrove diversity with 36 of the 50 known mangrove species found in the fringing coastal area (Lee, 2003). The most common species in Darwin Harbour are *Rhizophora stylosa*, *Ceriops tagal*, *Sonneratia alba*, *Bruguiera exaristata*, *Avicennia marina* and *Camptostemon schultzii* (NTG, 2002). Mangroves cover approximately 27,350 ha of intertidal mudflats in the greater Darwin Harbour area and are an integral part of the ecosystem acting as nursery and spawning grounds for fish and crustacean species, as well as having recreational value (McKinnon *et al.*, 2006; Semeniuk, 1985; NTG, 2011).

5.4 Fauna

The Darwin region supports several marine fauna including marine reptiles, marine mammals, and fish/sharks with key species described below. Further details of key species can be found in DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021) and SER (BAS-210 0020)

5.4.1 Marine mammals

Darwin Harbour is classified as a Biologically Important Area (BIA) for three species of coastal dolphin (Australian Snubfin dolphin, Indo-Pacific Spotted bottlenose dolphin and Indo-Pacific humpback dolphin).

Dolphin species are the most recorded marine mammal in Darwin Harbour and within Darwin Harbour, with the Australian snubfin (*Orcaella heinsohni*), Indo-Pacific humpback (*Sousa chinensis*) and Indo-Pacific spotted bottlenose (*Tursiops aduncus*) having known resident populations in Darwin Harbour. There are approximately 150 individuals across all species thought to inhabit the Darwin region (Brooks & Pollock, 2015). Other than the dolphins, occasional pods of false killer whales (*Pseudorca crassidens*) are known to inhabit Darwin Harbour.

Dugongs (*Dugong* dugon) are also known to occur in the Darwin region. Ichthys NEMP dugong monitoring estimates approximately 180 to 300 individuals inhabit the Darwin Region (Cardno, 2014). Within the Darwin Harbour Region Marine Management Area, dugongs have been observed to be associated with seagrass habitat at Casuarina Beach and Lee Point with greater abundance in these areas, as recorded by visual surveys (Cardno, 2014).

5.4.2 Marine reptiles

Six species of marine turtle (all listed as threatened under the EPBC Act) are known to occur in NT waters, of these only green, hawksbill and flatback turtle are known to inhabit Darwin Harbour regularly (**Table 5-3**). While olive ridley and loggerhead turtles are known to occasionally inhabit Darwin Harbour, leatherback turtles are unlikely to occur in Darwin Harbour as they are an oceanic species (Whiting, 2001; Whiting, 2003). Within Darwin Harbour, the closest nesting sites are at Casuarina Beach and Cox Peninsula, although these sites are not considered a significant nesting area (Chatto & Baker, 2008; Pendoley, 2022). Important turtle nesting sites in the region include Bare Sand Island and Quail Island located approximately 50 km from Darwin near the mouth of Bynoe Harbour.

Saltwater crocodiles (*Crocodylus porosus*) are known to commonly inhabit Darwin Harbour (**Table 5-3**). Saltwater crocodiles breed during the wet season between October and May. Nesting within Darwin Harbour is known to be limited.

Table 5-3: Marine reptile conservation status

Scientific name	Common name	Conservation status	
		Commonwealth	Northern Territory
Chelonia mydas	Green turtle[1]	Endangered/Migratory	Vulnerable
Eretmochelys imbricata	Hawksbill turtle[1]	Vulnerable/Migratory	Near threatened
Natator depressus	Flatback turtle[1]	Endangered/Migratory	Critically endangered
Caretta	Loggerhead turtle[2]	Vulnerable/Migratory	Vulnerable
Lepidochelys olivacea	Olive ridley turtle[2]	Endangered/Migratory	Vulnerable
Dermochelys coriacea	Leatherback turtle	Vulnerable/Migratory	Data deficient
Crocodylus porosus	Saltwater crocodile[1]	Migratory	Least concern

Notes:

1. Regularly frequent Darwin Harbour
2. Occasionally frequent Darwin Harbour

5.4.3 Fish and sharks

Darwin Harbour supports an abundance of fish species across an array of habitats. There is a diverse range of species within the harbour, from small site-specific species such as gobies, cardinals, and pipefish to larger species of recreational and commercially importance such as mackerel, trevallies, and barramundi. Barramundi is the most targeted recreational species in the NT accounting for 26% of total recreational catch, however, barramundi only accounts for 5% of total catch in Darwin Harbour. Jewfish are the most targeted species in Darwin Harbour followed by Golden snapper (Cardno 2015f) Juvenile recreationally and commercially important species such as mackerel, trevallies and barramundi utilise mangroves within Darwin Harbour for habitat.

There are three EPBC Act listed sawfish species, the dwarf sawfish (*Pristis clavate*), freshwater sawfish (*Pristis prisitis* or *Prisitis microdon*) and green sawfish (*Pristis zijsron*), which have been occasionally recorded in the Darwin area however, they are considered unlikely to occur with the Project Area.

Whale sharks are known to migrate to Australian waters seasonally, aggregating at Ningaloo Reef and in the Coral Sea following surges in food productivity. The migratory paths of whale sharks are not known to include Darwin Harbour and records from NT coastline are anecdotal (Woinarski *et al.*, 2007).

5.4.4 Seabirds and shorebirds

Of the 37 species of migratory shorebirds that regularly visit Australia (Commonwealth of Australia, 2017b; Lilleyman *et al*., 2018), 25 of them occur along the coastlines of Darwin Harbour, which has a variety of coastal habitats that migratory shorebirds use during the non-breeding season (Lilleyman *et al*., 2018). This includes natural sites such as beaches, rocky reefs, intertidal sand and mud flats, but also an artificial site – the dredge spoil disposal ponds at Darwin Port's East Arm Wharf.

Lilleyman *et al*. (2018) undertook aerial surveys of Darwin Harbour and recorded 724 individuals of 19 species of bird during the low tidal phase of the survey and at high tide recorded 789 individual shorebirds belonging to 13 species. The study was focused on the Far Eastern curlew (*Numenius madagascarensis*), two flocks of which were identified in numbers that meet the threshold for protection of threatened shorebirds under the EPBC Act. One flock was recorded at East Arm Wharf, where large congregations assemble frequently. The other flock was at a saltpan, south-east of East Arm Wharf, adjacent to the Darwin LNG Plant (although it was noted that this roosting site may not be available at the highest tides) (Lilleyman *et al*., 2018).

5.4.5 Phytoplankton

Inner Darwin Harbour is known to have low concentrations of bio-available nutrients, low light levels and high turbidity which limits the growth of phytoplankton, additional the large tidal range also ensures that the Harbour is well flushed (Cardno, 2014). Ichthys NEMP monitoring found low biomass of phytoplankton indicated by low Chlorophyll-a fluorescence, although there was a slight increase in phytoplankton biomass during the wet season compared to the dry season (Cardno, 2014). This could be due to the additional nutrient input from increased rainfall and subsequent runoff (Cardno, 2014). Variations in phytoplankton biomass within Darwin Harbour follows complex patterns indicating that multiple factors may influence the productivity of phytoplankton in the Harbour (Cardno, 2014).

5.5 Parks, reserves and reef protection areas

The conservation, control and management of parks and reserves within NT is the responsibility of the DEPWS. Parks and reserves located within the Darwin Harbour management area, and a summary of their values are stated in **Table 5-4**. None of these parks and reserves overlap with the DPD Project area.

Additionally, East point (~365 ha) and Doctors Gully (~14 ha) Aquatic Life Reserves (**Figure 5-4**) have been established under the *Fisheries Act* (NT), to provide protection of marine life and habitats. East Point Aquatic Life Reserve allows for restricted recreational fishing while Doctors Gully Aquatic Life Reserve prohibits all fishing (NTG, 2016). Both of these Aquatic Life Reserves are within Darwin Harbour but outside of the DPD Project area.

Table 5-4: Parks and reserves in the Darwin area

Name	Description
Charles Darwin National Park	The national park is located a short distance from Darwin City centre in Frances Bay and is approximately 4 km from the DPD Project Area at its closest point. The park encompasses approximately 1,040 ha protecting natural, cultural, recreational, and historical values (PWC NT, undated). Natural values protected within the park consists of mangrove communities and sections of relatively undisturbed woodland/grassland communities, which host diverse flora and fauna communities and intertidal mudflats rich in birdlife (PWC NT, undated). In addition to these natural values the park has Aboriginal cultural values. The Larrakia people have strong links to the land, including Aboriginal shell middens. There is also historical significance as the area was used by the defence force during World War Two (PWC NT, undated).

Name	Description
Casuarina Coastal Reserve	The Reserve covers approximately 1,361 ha and is located 15 km from Darwin City centre and is approximately 10 km from the DPD Project Area at its closest point. It encompasses woodlands, monsoonal vine forest and a pristine coastline, making it a popular area for locals and visitors to frequent (PWC NT, 2016). Although the reserve is primarily used for recreation it also possesses natural and cultural values of significance locally. Key natural values protected in the reserve include feeding and roosting sites for migratory shorebirds, significant seagrass meadows and nesting sites for three marine turtle species (PWC NT, 2016). The reserve falls within land traditionally owned by the Larrakia people and is still very important and regularly used by the traditional custodians, with the being several sacred sites throughout the reserve (PWC NT, 2016). There is additionally historical significance, as it was developed as part of the coastal defence strategy after World War Two. Ten of the original eleven 'Singapore-style' observation posts remain in the reserve and are open to visitors (PWC NT, 2016).
Shoal Bay Coastal Reserve	The Coastal Reserve is 40 km east of Darwin and protects a vast coastal area from Howard River to Gunn Point's eastern boundary (Top End Tourism, 2022). It is approximately 30 km from the DPD Project Area. Extensive mud and sandflats are the most predominant habitat throughout Shoal Bay, although the site does include several swamps and remnants of monsoonal vine forest (Harrison *et al*., 2009). The vast tidal flats throughout Shoal Bay provide essential roosting and feeding habitat for the migratory shorebirds in the non-breeding season (Harrison *et al*., 2009). Shoal Bay also protects large areas of cultural significance to the Larrakia people, with 1,000-year-old shell middens being present within the higher ground near the swamps (NTG, 2022).
Tree Point Conservation Area	The Conservation Area protects a section of the Shoal Bay coast on Tree Point Peninsula, an extensive mangroves habitat and a tidal creek, which runs toward the Shoal Bay Coastal Reserve (PWC NT, undated). It is approximately 30 km from the DPD Project Area. The area is fringed with coastal vine thickets and a swampy floodplain and hosts several bird species throughout the year (PWC NT, undated). The area is only open to the public during the day and is primarily used for walking, bird watching and fishing (PWC NT, undated).

The DPD Project pipeline intersects the Charles Point Wide Reef Fish Protection Area (RFPA) (NT) and is approximately 9 km to the east of the Lorna Shoal RPA (**Figure 5-4**). The objectives of the reef protection areas are specific to impacts from the fishing industry. No fishing activities are permitted within RPAs as the protection of these areas is to prevent over-fishing and/or barotrauma related injury of Golden snapper, Black jewfish and other vulnerable reef species. NT Fisheries also identified a known jewfish aggregation area within the RFPA. This is approximately 2.5 km to the south-west of the pipeline route. The Charles Point Wide RFPA is outside of Darwin Harbour and no DPD Project trenching and spoil disposal activities will occur within this area.

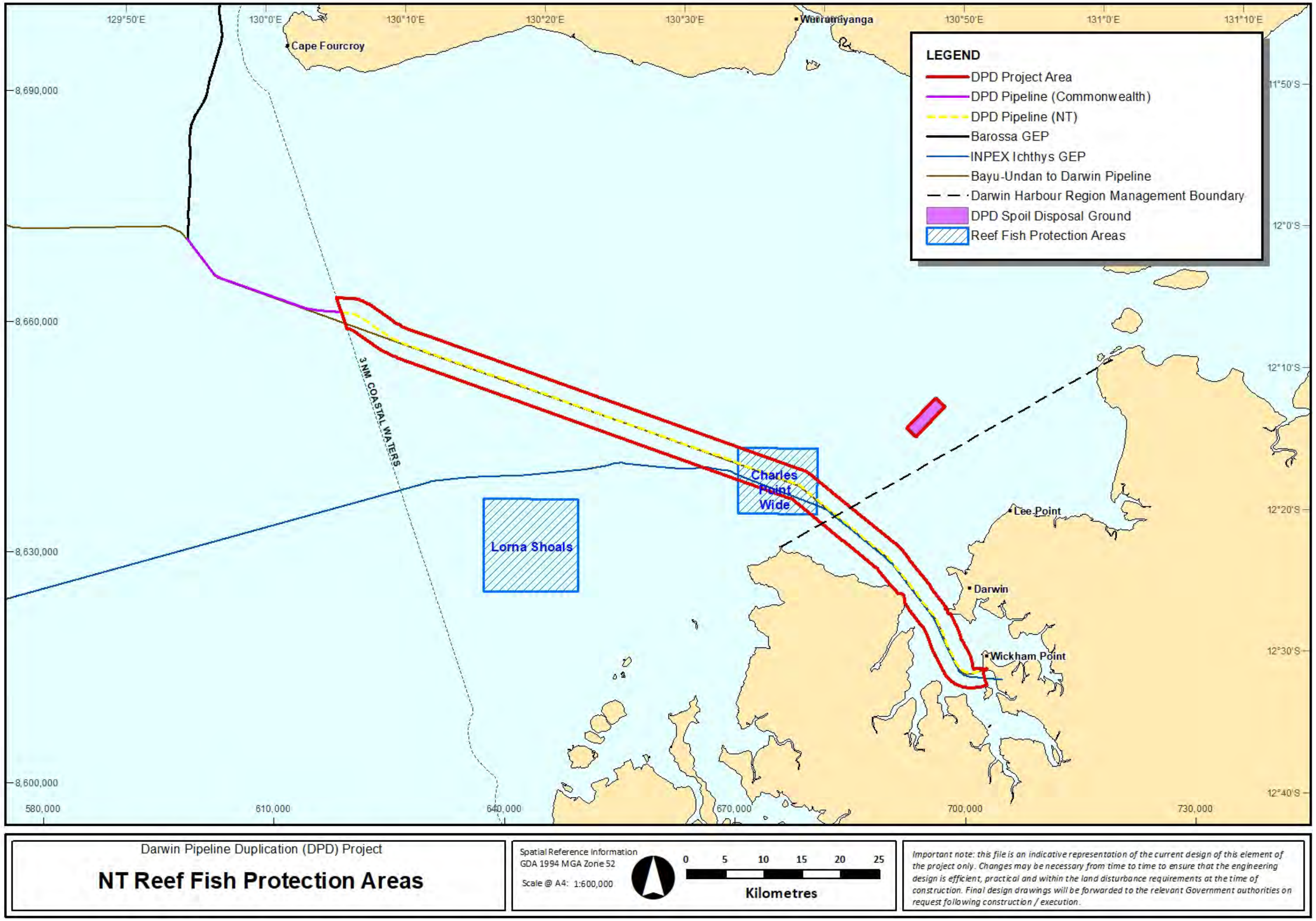


Figure 5-4: Charles Point Wide and Lorna Shoals reef fish protection areas

5.6 Socio-economic environment

Socio-economic activities that may occur within the Project Area and surrounds including commercial fishing, oil and gas exploration and production, and to a lesser extent, recreational and traditional fishing, defence activities, heritage places and tourism, as summarised in **Table 5-5.**

More detailed descriptions of socio-economic considerations are provided in DPD Project Offshore CEMP (BAS-210 0024) and DPD Project Supplementary Environmental Report (SER) (BAS-210 0020).

Table 5-5: Summary of socio-economic activities that may overlap with the Project Area

Value/ sensitivity	Description
Commercial fishing – Commonwealth	The Northern Prawn Fishery is the only active Commonwealth fishery that overlaps the Project Area. There are three other inactive or low operating (less than five vessels active in the fishery each year since 2005) Commonwealth managed fisheries overlapping the Project Area: Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and the Western Skipjack Tuna Fishery (DoAWR, 2016).
Commercial fishing and aquaculture – state (NT)	There are five NT State fisheries which intersect the Project Area: Coastal line, Demersal, Offshore net and line, Spanish mackerel, and Aquarium Fishery.
Recreational fishing	Recreational fishing does occur within the Project Area. The Darwin Harbour/Surrounds fishing zone supporting 63% of total fishing effort within the Greater Darwin Area (Matthews *et al.*, 2019).
Traditional fishing	Traditional Australian Indigenous fishing in NT waters predominately occurs within inshore tidal waters. Approximately 55% of NT's coastline is owned by Traditional Aboriginal Owner groups in the Northern Land Council region (NLC, 2022).
Tourism	Within Darwin Harbour common tourism/recreational activities include fishing, boating, scuba-diving, sailing, water-skiing, and beach use (INPEX Browse, 2010).
Shipping	The closest major commercial port to the Project Area is Darwin. The Darwin Port Corporation serves multiple shipping and cargo markets, including cruise and naval vessels, livestock exports, dry bulk ore, offshore oil and gas rig services, and container and general cargo.
Defence	The Project Area intersects a Central Defence Practice Area of the Darwin Air Weapons Range (AWR), a maritime military zone administered by the Department of Defence. The Project Area is also nearby to the Australian Exercise Area (NAXA) Defence Training Area approximately 3km to the South. Additionally, the Project Area borders the HMAS Coonawarra Naval Base in Darwin Harbour.

Value/ sensitivity	Description
Petroleum industry	Several offshore petroleum projects are in operation and there is considerable exploration activity within the region; however, only the existing INPEX Ichthys and Santos Bayu-Undan to Darwin gas export pipelines overlap with the Project Area.
Cultural heritage – Aboriginal sacred sites	The AAPA certificate (C2022/098) issued to Santos for the DPD Project has identified a restricted works area where no works or damage is to occur.
Cultural heritage – Non-Indigenous heritage sites.	Five Historic shipwrecks listed under the *Commonwealth Cultural Heritage Act 2018* are overlapped by the Project Area: I-124 Japanese Submarine (1942) 800 m radial protection zone, Yu Han 22 unlisted protection zone, Song Saigon (1982) unlisted protection zone, Mauna Loa USAT (1942) 100 m radial protection zone and Meigs USAT (1942) unlisted protection zone (DAWE, 2022). Additional potential maritime heritage objects have been identified within the Project Area through surveys and third-party maritime heritage assessment, the majority of which will be avoided by Project activities (Cosmos, 2022). Two identified heritage objects have been identified along the DPD Pipeline route that cannot be avoided, further assessment and intervention works will be undertaken prior to construction in accordance with NT Heritage Branch requirements to minimise disturbance to these objects.

5.6.1 Commercial fishing and aquaculture

5.6.1.1.1 Commonwealth fisheries

The Northern Prawn Fishery is the only active Commonwealth managed fishery that overlaps the Project Area (Santos, 2021). The Commonwealth managed Southern Bluefin Tun Fishery, the Western Tuna and Billfish Fishery and the Western Skipjack Tuna Fishery overlap with the project area but have been excluded from assessment as these fisheries are either inactive or operate at extremely low levels (< 5 vessels active each year since 2005) within or nearby the project area (DoAWR, 2016; Santos, 2021).

5.6.1.1.2 Northern Territory fisheries

Northern Territory fisheries include the NT Aquarium Fishery, the Offshore Net and Line Fishery, the Spanish Mackerel Fishery, the Coastal Line Fishery, the NT Demersal Fishery (Santos, 2021). The NT Aquarium Fishery includes freshwater, estuarine, and marine habitats to the outer boundary of the Australian Fishing Zone (AFZ), which is 200 nm offshore (Santos, 2021). Offshore Net and Line Fishery and Spanish Mackerel Fishery extend from the high-water mark of NT waters to the outer boundaries of the AFZ (Santos, 2021). The NT Demersal Fishery extends 15 nm from the NT low water mark to the outer limit of the AFZ, excluding the area of the Timor Reef Fishery (Santos, 2021). The Coastal Line Fishery extends seaward from the high-water mark to 15 nm from the low water mark, covering the entire NT coastline (Santos, 2021).

Most fisheries are not permitted to operate within Darwin Harbour, except for the Coastal Line Fishery and NT Aquarium Fishery (Department of Primary Industry and Resources , 2015). There are 51 licences for the Costal Line Fishery with only 7 – 8 being active in 2019 (Department of Primary Industry and Resources, 2018). Therefore there is little to no commercial fishing taking place within Darwin Harbour (INPEX, 2018).

The Darwin Aquaculture Centre is located on Channel Island in the Middle Arm Peninsula. It is a research facility undertaking a range of research and development projects on several species including pearl oysters, sea cucumbers, giant clams, prawns, barramundi, mud crabs, reef fish (NT Government, 2018). As well as undertaking several disease investigations (NT Government, 2018).

5.6.2 Shipping

Darwin Harbour is Australia's nearest port to Asia and is the 'northern gateway' for Australasian trade. Operations mainly consists of marine traffic from non-commercial vessels and trading vessels, which includes commercial vessels carrying cargo and passengers, rig tenders, tankers and bulk-cargo vessels that utilise East Arm Wharf and the cruise ship terminal at Fort Hill Wharf (Darwin Port, 2020).

In 2021/22 the port of Darwin was visited by 1,510 trade vessels and 36 cruise ship vessels, cruise ship numbers in 2020/21 and 2021/22 have been significantly lower than previous years likely due to COVID-19 restrictions (Darwin Port Operations, 2022).

5.6.3 Recreational activities and tourism

During 2021 there were 1,283,000 visitors to the Northern Territory, which contributed an estimated $1.84 billion to the local community. This was substantially lower than 2019, with 2,001,000 visitors contributing an estimated $2.6 billion, likely due to the reduction in international visitation resulting from border closures (Northern Territory Government, 2022).

The Darwin Harbour supports a range of commercial and recreational uses, including fisheries, tourism and recreational shipping and boating activities. Fishing tours often frequent Fenton Patches located approximately 30 km north-west of Darwin Harbour. Recreational fishers also visit Casuarina Bay and Lee Point (INPEX, 2010).

The INPEX Nearshore Environmental Monitoring Plan identified the presence of distinct seasonal behaviour of recreational anglers, with barramundi commonly targeted in the wet season and golden snapper, black jewfish, mackerel and tuna commonly targeted in the dry season (Cardno, 2014).

The water surrounding Middle Arm Peninsula is used for recreational fishing, sailing, and boating. However, tour boats tend to avoid this section of the harbour due to navigational hazards associated with the shallow nearshore waters (URS, 2002).

5.6.4 Traditional fishing

Approximately 55% of NT's coastline is owned by Traditional Aboriginal Owner groups in the Northern Land Council region (NLC, 2022). Several areas within this coastal region have been declared Aboriginal sacred sites, which are restricted from other recreational and commercial fishing. Within Darwin Harbour, fishing and foraging for food and other resources occurs within the intertidal regions, mainly around Nightcliff, Coconut Grove, Kululuk, Sadgroves Creek, and Lee Point (INPEX, 2010). As such, Indigenous fishing is likely to occur within the coastal areas of the Project Area but is likely to be restricted mainly to NT coastal waters.

5.7 Cultural environment

Darwin Harbour is host to a wide range of historical, spiritual and heritage values that are significant to the people of the Northern Territory and Australia. These values have been broadly categorised as either Aboriginal and non-Aboriginal values and are described in more detail in the following sections.

5.7.1 Aboriginal sacred sites

Sacred sites are places within the landscape that have a special meaning or significance under Aboriginal tradition, this can include hills, rocks, waterholes, trees, plains, lakes, billabongs (AAPA, 2022). There are many sacred sites within Darwin Harbour and the surrounding waters, all sacred sites within the NT are protected under the *Northern Territory Aboriginal Sacred Sites Act 1989* (Sacred Sites Act). In coastal and sea areas, sacred sites may include features which lie both above and below the water (AAPA, 2022).

Sacred sites within Darwin Harbour, including three rocky areas or shoals on the western side of the Darwin Harbour, and an underwater sand and rock bar outside the mouth of the harbour, north of the Cox Peninsula (INPEX, 2010).

Santos has received an AAPA Authority Certificate (C2022-098) and will ensure the requirements of the certificate (including avoidance of restricted work areas) and the *Northern Territory Aboriginal Sacred Sites Act 1989* are met.

5.7.2 Non-Indigenous heritage sites

Darwin Harbour is host to several shipwrecks and sunken aircraft, some of which are protected under the *Heritage Act 2011* (NT) and/or the *Underwater Cultural Heritage Act 2018* (Commonwealth). Most wrecks are associated with either, the bombing of Darwin in 1942 or Cyclone Tracy in 1974 (INPEX, 2018). The Project Area is within ~2 km east of the oldest known wreck in Darwin Harbour the SS *Ellengowan*, a nineteenth-century Norwegian-built iron steamer, which is of high significance to maritime archaeology (NTG, 1999).

The *Underwater Cultural Heritage Act 2018* may declare a protected zone around wrecks which require a permit to enter, there are currently three protected zones having closed water orders in NT. These are the Japanese submarine I-124 (1942), Florence D (1942) and Sanyo Maru (1937). The regional harbourmaster has also ordered the Booya and Catalina 6 wrecks to have closed water controls over them and permission from the Heritage Branch is needed to enter the zones.

The Australian National Shipwrecks Database has identified five historic wrecks that overlap the Project Area, all of which are listed under the Underwater Cultural Heritage Act (DCCEEW, 2022). These wrecks are the Japanese submarine I-124 (1942) 800 m radial protection zone, Yu Han 22 unlisted protection zone, Song Saigon (1982) unlisted protection zone, Mauna Loa USAT (1942) 100 m radial protection zone and Meigs USAT (1942) unlisted protection zone (DCCEEW, 2022)

No European heritage is currently listed at Wickham Point, with the remnants of artefacts documented and removed prior to the construction of the DLNG facility. There are no World, National or Commonwealth heritage places within or near the Project Area.

The DPD pipeline route has been selected so that potential maritime heritage objects identified within the Project Area, will be avoided by Project activities (Cosmos, 2022). Two identified heritage objects have been identified along the DPD Pipeline route that cannot be avoided, further assessment and intervention works will be undertaken prior to construction in accordance with NT Heritage Branch requirements to minimise disturbance to these objects.

5.8 Windows of sensitivity

Timing of peak activity/sensitivity for marine fauna and flora and socio-economic activities is outlined in **Table 5-6**.

Table 5-6: Windows of sensitivity for environmental receptors in the vicinity of the Project Area

Key	
	Peak activity, presence reliable and predictable
	Lower level of abundance/activity/ presence
	Very low activity/presence
	Activity can occur throughout year

Footnotes

[1] The 'run-off' is towards the end of the wet season and is the peak Barramundi fishing season for recreational fishers (https://northernterritory.com/things-to-do/outdoor-activities/fishing/fishing-seasons/the-run-off)

[2] Chatto & Baker (2008)

Receptors (critical lifecycle stages)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Seagrass												
Coral (spawning periods)												
Larger Macroalgae												
Turf Algae										Build-up season		
Mangroves (increased productivity)												
Other benthic and terrestrial habitats												
Fish/sharks and fisheries species												
Barramundi			'The Run-Off'[1]									
Goldband snapper	Spawning							Spawning				
Black jewfish								Spawning				
Grey mackerel									Spawning			
Narrow-barred Spanish mackerel										Spawning		
Marine mammals												
Dugong (breeding)	Breeding								Breeding			
Australian snubfin Dolphin	Breeding											
Indo-Pacific Humpback Dolphin	Breeding											
Spotted Bottlenose Dolphin								Breeding				
Marine reptiles												
Hawksbill turtle (resident adult and juveniles[2])	Widespread throughout North Australian waters, highest density of adults and juveniles over hard bottom habitat (coral reef, rocky reef, pipelines, etc.)											
Flatback turtle (resident adult and juveniles[2])	Widespread throughout North Australian, increased density over soft bottom habitat 10 to 60 m deep, post-hatchling age classes and juveniles spread across shelf waters											
Flatback turtle (nesting[2])												
Green turtle (resident adult and juveniles[2])	Widespread throughout North Australian, highest density associated with seagrass beds and macro algae communities, high-density juveniles in shallow waters off beaches, among mangroves and in creeks											
Loggerhead turtle (resident adult and juveniles[2])	Widespread throughout the North Australian, increased density associated with soft bottom habitat supporting their bivalve food source, juveniles associated with nearshore reef habitat											
Socio-economic												
Northern Prawn Fishery												
Oil and gas												
Shipping												
Tourism/recreational												

6 Sediment Dispersion Modelling and Water Quality/Benthic Habitat Impact Predictions

6.1 Introduction

Sediment dispersion modelling was completed for the DPD Project (BAS 210 0036; RPS, 2022b) to investigate the potential impact on water quality and benthic habitats from the following sources during construction:

+ Suspended material generated during trenching along the pipeline route
+ Suspended material during spoil disposal at the spoil disposal ground.

This sediment dispersion model included two parts:

1. A Hydrodynamic and Wave model
    a. Existing D-FLOW hydrodynamic and D-WAVE wave model frameworks in Darwin Harbour were reconfigured to increase resolution within the harbour and update the model with the latest bathymetric data. This was followed by re-validation of the model predictions against available measurements of water levels, currents and waves.
    b. Two years (2019 – 2020) of hydrodynamic and wave simulation data were produced for use as input to the sediment dispersion model.
2. A Sediment Dispersion model:
    a. Inputs for the trenching program were prepared for the DREDGEMAP model, accounting for all potential concurrent sources of sediment characterised by location, intensity, particle size distribution, vertical distribution in the water column, and levels of cohesivity.
    b. Two trenching and disposal scenarios were simulated (Section 6.4)
    c. Simulation outputs from each separate trenching and disposal activity were post-processed, combined and analysed to determine outcomes including zones of impact and influence for each scenario based on specified threshold criteria (**Section 6.3** and **Section 6.5.2**).

Key model outcomes were provided as spatial datasets in GIS shapefile format. Further details of sediment dispersion modelling methodology can be found in the Santos Barossa DPD Sediment Dispersion Modelling (BAS 210 0036; RPS, 2022).

6.2 Dredge plume sources

To accurately represent the pipeline trenching and spoil disposal operations in DREDGEMAP, a range of information was defined for the proposed operations, including trenching and disposal methodology, production rates, and sediment/rock types and quantities. Six different sources of suspended sediment plumes during trenching and disposal operations, can be broadly defined as:

1. Direct suspension of material from the BHD bucket, from grabbing and lifting sediments and rock through the water column, including sedimentation from dewatering of SHBs accounting for periods of no-dewatering.
2. Disposal of sediment and rock excavated by the BHD from the SHBs to the spoil ground.

3. Direct suspension of material by the TSHD during trenching of sediments, and CSD-crushed material, accounting for no-overflow and overflow periods.
4. Disposal of sediment and CSD-crushed material removed by the TSHD to the spoil ground.
5. Direct suspension of material by the CSD during trenching of rock and casting material behind the dredge at low velocity, just above the seabed.
6. Indirect suspension of material due to the propeller-wash of the SHB and TSHD while trenching.

Each of these sources of suspended sediment plumes will vary in strength and persistence depending on the nature of the operations. In the DREDGEMAP model, each source is defined by specifying the time-varying flux rate, PSD and vertical profile in the water column.

For each source of suspended sediment during trenching and disposal operations the associated loss rates and approximate volumes of suspended sediment expected were determined. The volumes assigned to the respective non-overflow and overflow periods for TSHD trenching, and non-dewatering period for BHD trenching, are based on the modelled cycle times as detailed in the Santos Barossa DPD Sediment Dispersion Modelling report (BAS 210 0036; RPS, 2022).

It is important to note that finalisation of the DPD pipeline route and associated trenching requirements occurred after sediment dispersion modelling was completed. The expected trenched spoil volume of ~255,000 m^3 (refer **Table 2-1**) is lower than that modelled (~306,000 m^3) due to a reduction in trenching requirements. Trenching within zones labelled as trench zones 4, 5 and 7 within in this section and in **Figure 6-1** to **Figure 6-5** and **Figure 6-16** to **Figure 6-19**, are no longer required. Given the removal of some trenching zones and the lower expected spoil volume required to be disposed at the offshore spoil disposal ground, the modelling results and subsequent interpretation are considered to provide a conservative representation of effects and impacts from trenching and spoil disposal.

6.3 Tolerance limits for habitats

Predictions of Suspended Sediment Concentration (SSC) and sedimentation for each scenario were assessed against a series of water quality and sedimentation thresholds to categorise the modelled outcomes into management zones of influence and impact, defined with regard to environmental sensitivities in the study region. The thresholds and the approach applied to the DPD Project are based on the extensive environmental monitoring and threshold work that INPEX completed for the Ichthys project environmental impact statements, and capital and maintenance dredge management plans in Darwin Harbour (INPEX, 2010, 2011, 2013, 2018 and 2022).

To calculate areas of potential impact from trenching-induced excess SSC and sedimentation, INPEX established seasonal tolerance limits/thresholds for sensitive receptors including mangrove, seagrass and hard coral habitats (**Table 6-1**). The INPEX tolerance limits for SSC were derived from comprehensive site-specific water quality monitoring data (covering multiple years and locations), and the tolerance limits for sedimentation were derived from habitat-specific dose-response experiments and field observations reported in the scientific literature (INPEX, 2018). The defined tolerance limits also varied across four trenching impact reporting zones, which were defined based on available water quality monitoring data (INPEX, 2018). The trenching impact reporting zones are named as follows:

+ East Arm
+ Middle Arm
+ Middle Harbour

+ Offshore.

Table 6-1: Tolerance limits for excess SSC and sedimentation (INPEX, 2018)

Habitat	Trenching Impact Reporting Zone	Season	SSC (mg/L)	Sedimentation (mm)
Mangrove	Anywhere	All	N/A	50
Coral	East Arm	Dry	11.9	15
		Wet	23.8	
	Middle Arm	Dry	12.4	15
		Wet	27.0	
	Mid Harbour	Dry	10.7	15
		Wet	28.4	
	Offshore	Dry	17.9	15
		Wet	64.2	
Seagrass	Anywhere	Dry	13.3	40
		Wet	60.6	

6.4 Modelled scenarios

Analysis of wind data in the region from 2012 – 2021 indicated that the period of 2019 – 2020 is likely representative of typical conditions. The modelling simulations therefore used hydrodynamic and wave data from this period, with nominal start dates for model simulations of 1 April 2019 (winter/dry) and 1 October 2019 (summer/wet).

A summary of the scenarios that were modelled is as follows:

+ Scenario 1: trenching works to commence on 1 April 2019 (winter/dry start):
  - TSHD trenching and disposal operations were programmed to occur between 1 April 2019 and 10 May 2019.
  - CSD trenching and disposal operations were programmed to occur between 8 April 2019 and 5 May 2019.
  - BHD trenching and disposal operations were programmed to occur between 1 April 2019 and 30 April 2019.
  - A simulation run-on period was assumed to occur between 10 May 2019 and 10 July 2019. Sediments suspended in the water column during previous operations were subject to settlement and progressively reducing levels of resuspension during this time.
+ Scenario 2: trenching works to commence on 1 October 2019 (summer/wet start):
  - TSHD trenching and disposal operations were programmed to occur between 1 October 2019 and 9 November 2019.
  - CSD trenching and disposal operations were programmed to occur between 8 October 2019 and 4 November 2019.

- BHD trenching and disposal operations were programmed to occur between 1 October 2019 and 30 October 2019.
- A simulation run-on period was assumed to occur between 9 November 2019 and 9th January 2020. Sediments suspended in the water column during previous operations were subject to settlement and progressively reducing levels of resuspension during this time.

6.5 Results

6.5.1 Sediment fate modelling results

6.5.1.1 General plume movement

Simulations indicated there may be significant spatial patchiness in the distribution of SSC and sedimentation at any point in time during the trenching and disposal operations due to variability in the number of sediment suspension sources, variability in the flux from each of these sources, and the varying dynamics of the transport, settlement and resuspension processes affecting the sediments.

The SSC results presented in the following sections are depth averaged. There is significant variability in the vertical distributions of SSC in the water column, with a distinct increase in concentration towards the seabed. Most material will initially be suspended low in the water column, and material suspended higher in the water column will sink as it moves away from the source. Frequent resuspension of material will also mostly affect the deeper levels. Thus, the spatial area affected above a given concentration is typically greater in the near-seabed layer than in the near-surface layer.

The localised movement and dispersion of the suspended sediment is governed over short time scales by the very strong tidal flows in the trenching areas and at the offshore disposal ground. Additionally, Darwin Harbour is relatively sheltered from the variations in large-scale circulation observed offshore. Beyond the harbour entrance, wind-driven current movements are superimposed on the tidal motion, which drives some seasonal differences in the overall drift patterns of the suspended sediments. However, the tidal currents dominate even in the area offshore of the harbour and seasonal differences are small. The sediment plume extends slightly more southwards during the winter/dry season scenario and slightly more northwards during summer/wet season scenario.

The dominance of the tidal flows means typical sediment plume movements are predicted to reflect the oscillations of the ebbing and flooding tide; towards the Harbour entrance (south-eastwards parallel to the coast) during the ebbing tide and into the Harbour, typically staying close to the western side (Woods Inlet and West Arm) or extending south into Middle Arm, during the flooding tide. At the proposed offshore disposal site sediment plumes from disposal operations move south-west towards Darwin Harbour on the ebbing tide and north-east towards Clarence Strait on the flooding tide. As is expected, the predicted plume drift trajectories during the spring tide periods are much longer than during neap tide periods, with the suspended material being more widely dispersed and SSC becoming patchy.

6.5.1.2 Spatial distribution of suspended sediment concentration

The results observed on any given day will not always be representative of the typical transport patterns, and plume concentrations and distributions are forecast to vary markedly. To explore this variability, statistical distributions for each scenario are examined. Percentile distributions summarise the outcomes over the duration of the trenching and disposal operations (not including the run-on period) and do not represent an instantaneous plume footprint at any point in time.

Forecasts of median depth-averaged SSC values (values exceeded 50% of the time) do not exceed 1 mg/L in both seasonal scenarios, while at the 80th percentile values 1 mg/L or greater are forecast to be found in small, isolated patches just offshore of West Point (in line with Trench Zone 6, designated 4 Trench Type C1a in **Figure 2-1**) and at Wickham Point near the shore crossing area.

At the 90th percentile, the winter/dry season scenario forecasts show depth-averaged SSC values 1 mg/L or greater are found in a continuous band stretching north-westwards parallel with the coast to just offshore Charles Point, and southwards into Darwin Harbour extending a short way into Woods Inlet and to the eastern side of Talc Head. Smaller patches above 1 mg/L are predicted at other locations: around Wickham Point, in the middle Harbour area, in the vicinity of the proposed offshore disposal site, and in the shallows at South West Vernon Island (**Figure 6-1**). The corresponding summer/wet season scenario forecast shows a similar spatial area affected by SSC levels above 1 mg/L with some slight seasonal differences evident (**Figure 6-3**). In the summer/wet season scenario, the predicted 90th percentile SSC forecast shows the largest band above 1 mg/L has a shorter extent to the south and does not extend into Woods Inlet, a slightly larger area in the middle Harbour, and an extension of 1 mg/L concentrations to the north-east at the offshore disposal site.

At the 95th percentile, the winter/dry season scenario forecasts show depth-averaged SSC values 1 mg/L or greater are found in a continuous band stretching north-westwards parallel with the coast past Charles Point, and southwards into Darwin Harbour extending a short way into Woods Inlet and West Arm, with smaller patches above 1 mg/L extending from Wickham Point into the middle Harbour and a short way into Middle Arm. Depth-averaged SSC values 1 mg/L or greater are also found in the vicinity of the proposed offshore disposal site extending outwards to the east and west, with a larger extent to the east (**Figure 6-2**). Some very small patches above 1 mg/L are predicted in the shallows at South West Vernon Island. As found in the 90th percentile SSC distributions, the corresponding summer/wet season forecast shows a similar spatial area above 1 mg/L with some slight seasonal differences (**Figure 6-4**). Again, during the summer/wet season the largest band above 1 mg/L has a shorter extent to the south and there is an extension of 1 mg/L concentrations to the north-east at the offshore disposal site.

In both scenarios the 95th percentile depth-averaged SSC values are predicted to exceed 2.5 mg/L (but remain below 5 mg/L) in isolated patches in the vicinity of Trench Zone 6 (designated 4 Trench Type C1a in **Figure 2-1**), extending ~8 km north-west and also south into Woods Inlet in the winter/dry season scenario, and extending ~13 km north-west with only minimal extent to the south in the summer/wet season scenario. Additionally, in both seasons the 95th percentile depth-averaged SSC values are predicted to exceed 2.5 mg/L in a relatively small patch extending north from Wickham Point and a very small patch in the shallows at South West Vernon Island.

Santos

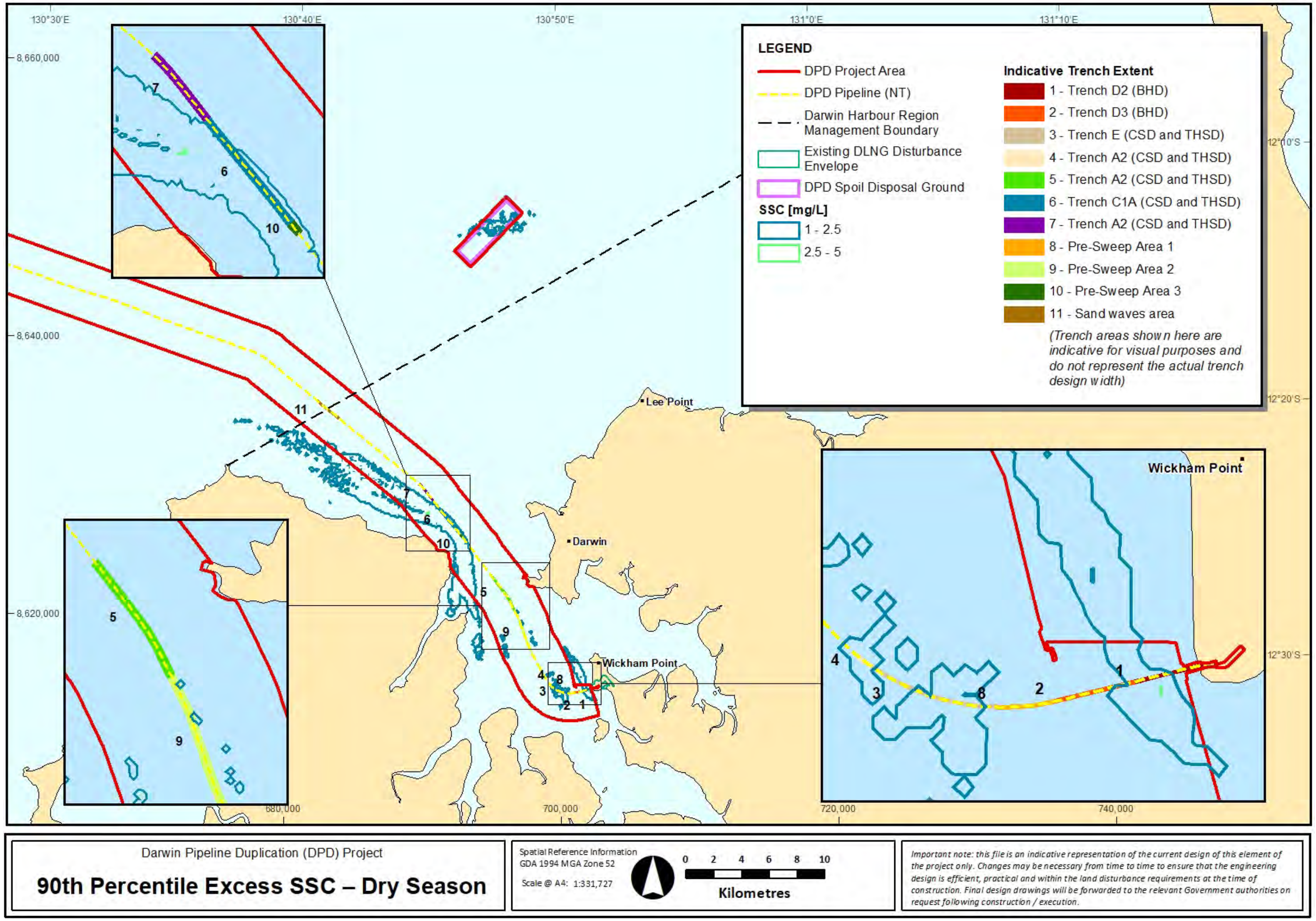


Figure 6-1: Predicted 90th percentile trenching-excess SSC throughout the entire trenching program for the winter/dry season scenario (1st April to 10th May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in ***Figure 2-1***

Santos

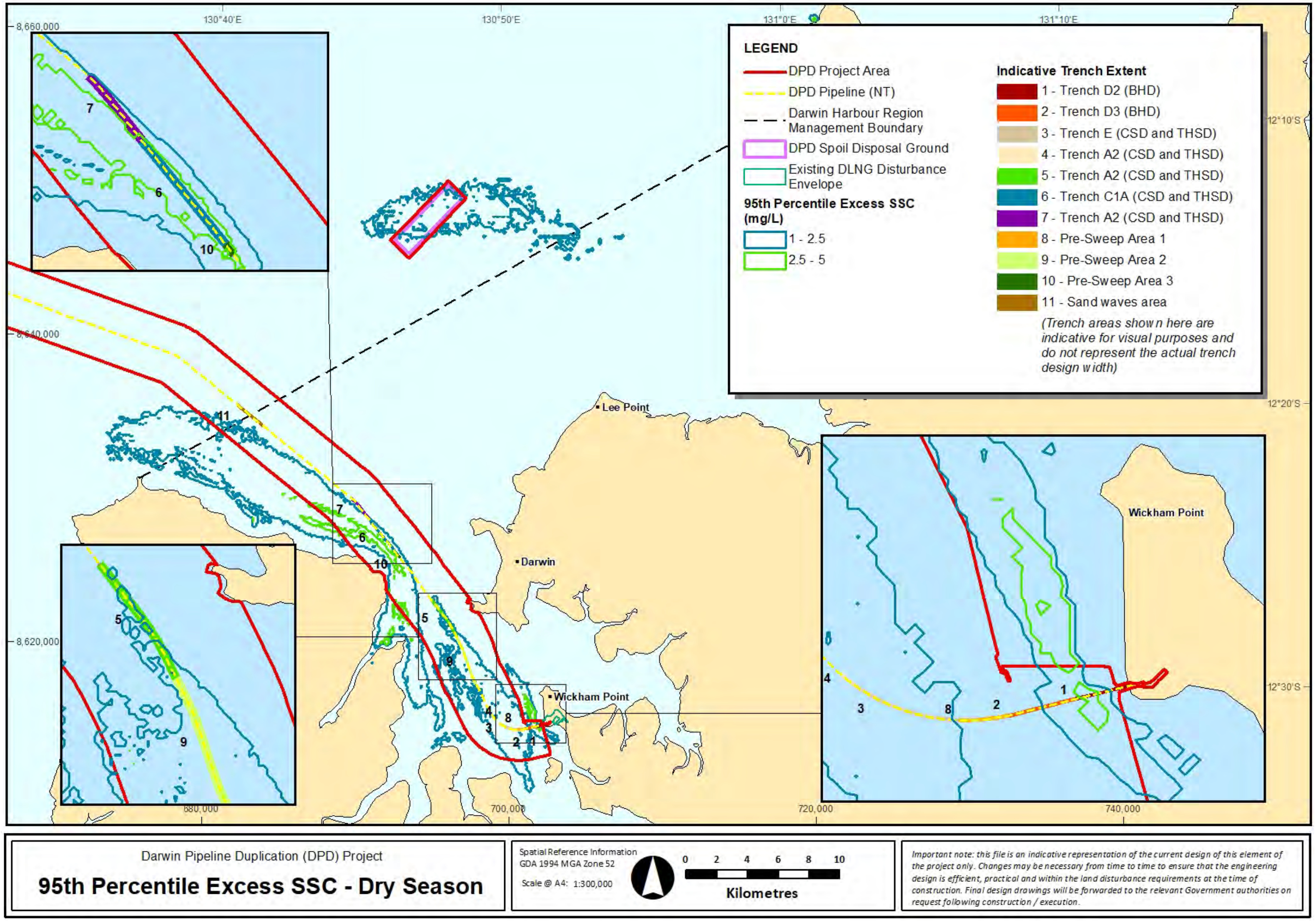


Figure 6-2: Predicted 95th percentile trenching-excess SSC throughout the entire trenching program for the winter/dry season scenario (1st April to 10th May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in ***Figure 2-1***

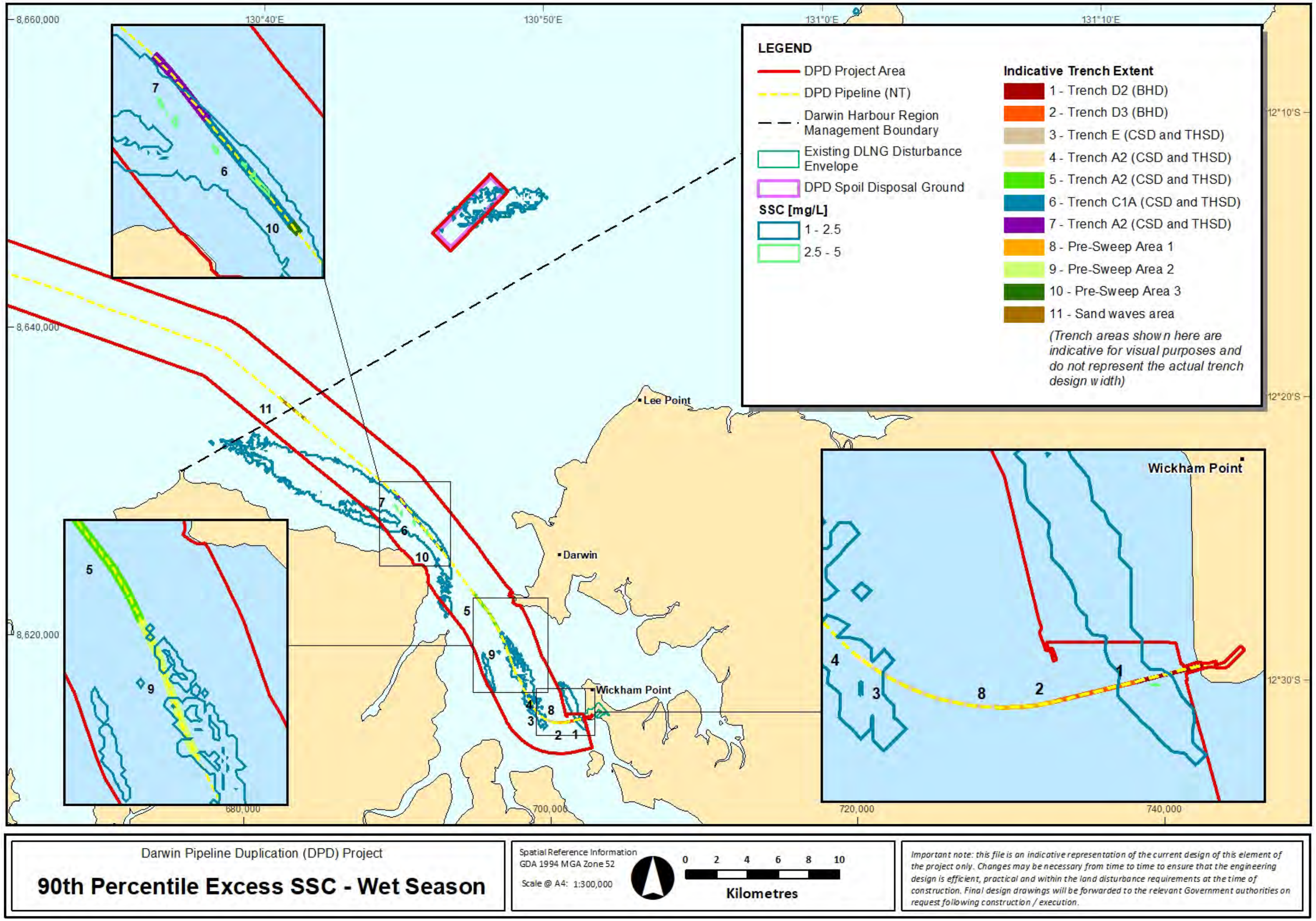


Figure 6-3: Predicted 90th percentile trenching-excess SSC throughout the entire trenching program for the summer/wet season scenario (1st October to 9th November). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in ***Figure 2-1***

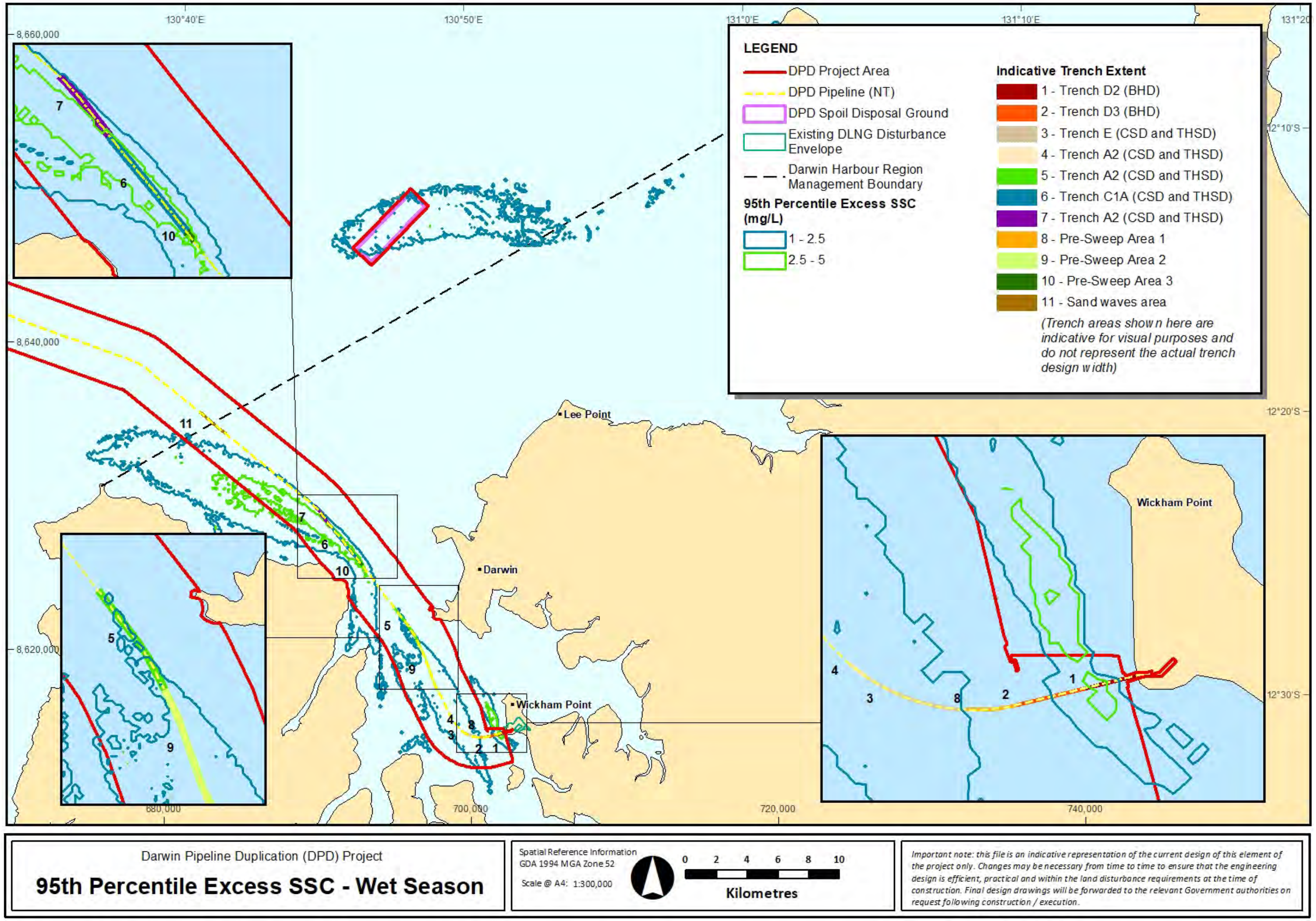


Figure 6-4: Predicted 95th percentile trenching-excess SSC throughout the entire trenching program for the summer/wet season scenario (1st October to 9th November). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in ***Figure 2-1***

6.5.1.3 Temporal variability of suspended sediment concentration

The simulations indicated that there will be significant temporal variability in the distribution of SSC during the trenching and disposal operations. The temporal variation in trenching-excess SSC at analysis sites within Darwin Harbour, outside the harbour and at the offshore disposal area reflect the spatial patchiness of the plumes and the oscillations of the dominant tidal flows in the area, with rapidly changing (over hourly scales) sharp peaks and troughs.

To explore the temporal exposure of sensitive receptor sites, a time series analysis at a set of specific locations has been conducted to supplement the spatial maps. The analysis locations were selected from existing sensitive receptor monitoring sites within the predicted elevated SSC footprint. In addition to the sensitive receptor monitoring sites, locations were defined at the proposed offshore disposal area, and at the Vernon Islands where elevated SSC levels was predicted by the model. **Figure 6-5** presents the locations of the points selected for the time series analysis. For presentation purposes the points have been split into groups as follows:

+ WI_S, CHI and WED1 are the monitoring sites inside Darwin Harbour.
+ CPW_1, MAN and CHP are the monitoring sites outside Darwin Harbour.
+ VI_S and VI_E are the Vernon Island sites.
+ OD1 to OD5 are the offshore disposal ground long cross-section sites (aligned south-west to north-east).
+ OD6 to OD9 are the offshore disposal ground short cross-section sites (aligned north-west to south-east).

Inside Darwin Harbour (**Figure 6-6** and **Figure 6-7**) the intensity of SSC depends on the proximity to the trenching areas, with the plume rarely reaching Channel Island and only at low concentrations typically less than 4 mg/L. At Woods Inlet south the exposures show a clear tidal signal, with plumes predicted to reach the site during spring tidal periods and with minimal SSC exposure during neap tides. This site also shows seasonal differences, with higher peaks during the winter/dry season, reflecting the more southerly drift pattern during the dry season as found in the spatial plots. Weed Reef sees similar levels of SSC to Woods Inlet south, however because it is in the mid-harbour close to the dredging areas there are minimal seasonal differences.

Outside Darwin Harbour along the coast from West Point to Charles Point (**Figure 6-8** and **Figure 6-9**) show a similar pattern of exposure to the sites inside the harbour, with higher predicted SSC levels during spring tide periods, particularly towards the end of the trenching period when the dredging takes place closer to these areas. At Charles Point west and Mandorah the predicted trenching-excess SSC is relatively low, being less than 1 mg/L 98% of the time (**Table 6-2**). Charles Point is predicted to have higher SSC intensities than the other two sites, particularly during the summer/wet season when drift patterns tend towards the north-west along this section of the coast. However, the duration of the peaks in predicted SSC at Charles Point are short, and this is reflected in the 98th percentile SSC values which are less than 7 mg/L in both seasonal scenarios.

The time series of trenching-excess SSC at the Vernon Islands sites (**Figure 6-10** and **Figure 6-11**) show that SSC intensities are predicted to be relatively low, particularly east of Vernon Islands. Peak SSC concentration is predicted to be typically higher in the summer/wet season scenario, showing the effect of increased drift trajectories towards the Clarence Strait during this season.

At the offshore disposal area, the temporal variability in predicted SSC also reflects the tidal oscillations with periods of spring and neap tides evident. However, superimposed on this signal is additional variability due to the sporadic nature of the disposal sources, which are variable in time and space (**Figure 6-12** to **Figure 6-15**). Locations within the disposal ground (Offshore Disposal 2, 3, 4, 7 and 8) show similar overall patterns with periods of higher and lower SSC; however, the timings and intensities of the individual peaks vary due to the relative proximity of each site to individual disposal events. Elevated SSC levels (in the order of 100 – 200 mg/L) occur immediately after disposal events but are rapidly dispersed and do not persist for long periods of time (scales of hours). The sites along the two cross-sectional alignments lying outside the disposal ground (Offshore Disposal 1, 5, 6 and 9) show that the intensity of the modelled SSC values is predicted to reduce significantly within 1 – 3 km of the disposal ground boundaries. The intensity of the predicted SSC reduces significantly within 1 – 3 km of the disposal ground boundaries.

Table 6-2: Percentiles (95th and 98th) and maximum predicted trenching-excess SSC (mg/L) (depth-averaged and maximum-in-water-column) for each time series analysis location, throughout the entire trenching program and run-on period for the winter/dry and summer/wet season scenarios. Values presented are rounded to the nearest whole number

Location	95th percentile				98th Percentile				Maximum			
	Depth-Averaged SSC (mg/L)		Maximum SSC (mg/L) in Water Column		Depth-Averaged SSC (mg/L)		Maximum SSC (mg/L) in Water Column		Depth-Averaged SSC (mg/L)		Maximum SSC (mg/L) in Water Column	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
WI_S	1	1	1	1	2	1	3	1	15	6	16	6
CHI	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	4	2	6	5
WED1	1	1	2	2	1	1	4	4	4	4	17	15
CPW_1	0[1]	0[1]	0[1]	0[1]	0[1]	1	0[1]	1	3	10	5	17
MAN	1	0[1]	1	1	1	1	1	1	6	3	7	4
CHP	1	1	1	2	3	6	3	7	51	55	65	71
VI_S	0[1]	0[1]	1	1	0[1]	1	1	2	2	3	5	8
VI_E	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	0[1]	2	3
OD1	0[1]	0[1]	1	1	0[1]	0[1]	1	1	1	3	6	19
OD2	1	1	4	4	1	1	8	9	33	9	163	42
OD3	1	1	5	5	1	2	9	10	10	14	52	88
OD4	1	1	4	5	1	1	7	7	6	11	27	50
OD5	0[1]	0[1]	1	1	0[1]	0[1]	2	2	2	2	17	16
OD6	0[1]	0[1]	2	2	1	1	5	5	9	3	47	21
OD7	1	1	5	6	1	2	9	10	18	5	102	36
OD8	1	1	4	5	1	2	8	10	13	12	68	86

Location	95th percentile				98th Percentile				Maximum			
	Depth-Averaged SSC (mg/L)		Maximum SSC (mg/L) in Water Column		Depth-Averaged SSC (mg/L)		Maximum SSC (mg/L) in Water Column		Depth-Averaged SSC (mg/L)		Maximum SSC (mg/L) in Water Column	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
OD9	0[1]	0[1]	2	2	1	1	5	5	6	3	36	19

Note:

1. These values are greater than 0.0 but less than 0.5 mg/L

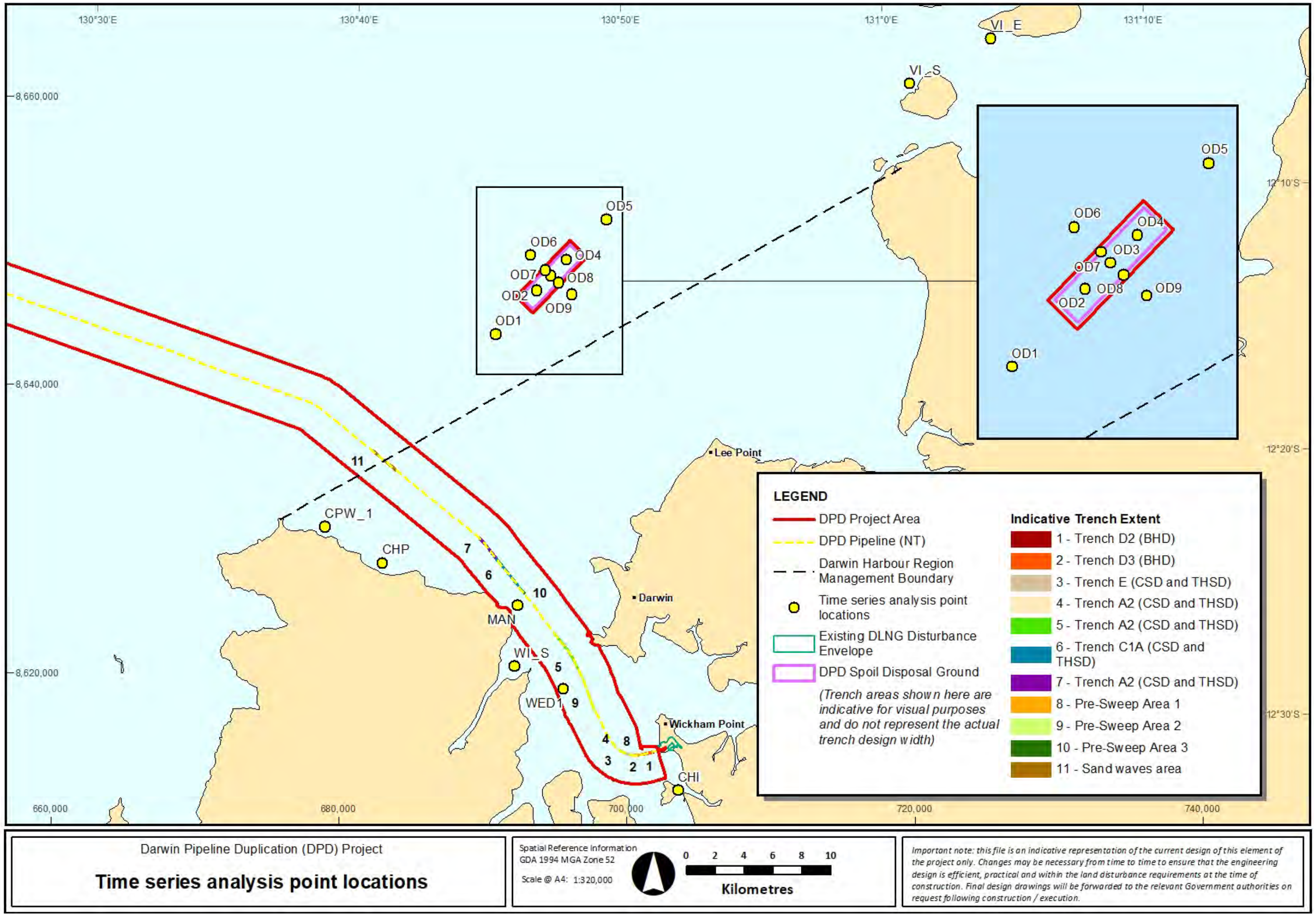


*Figure 6-5: Time series analysis point locations. Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1***

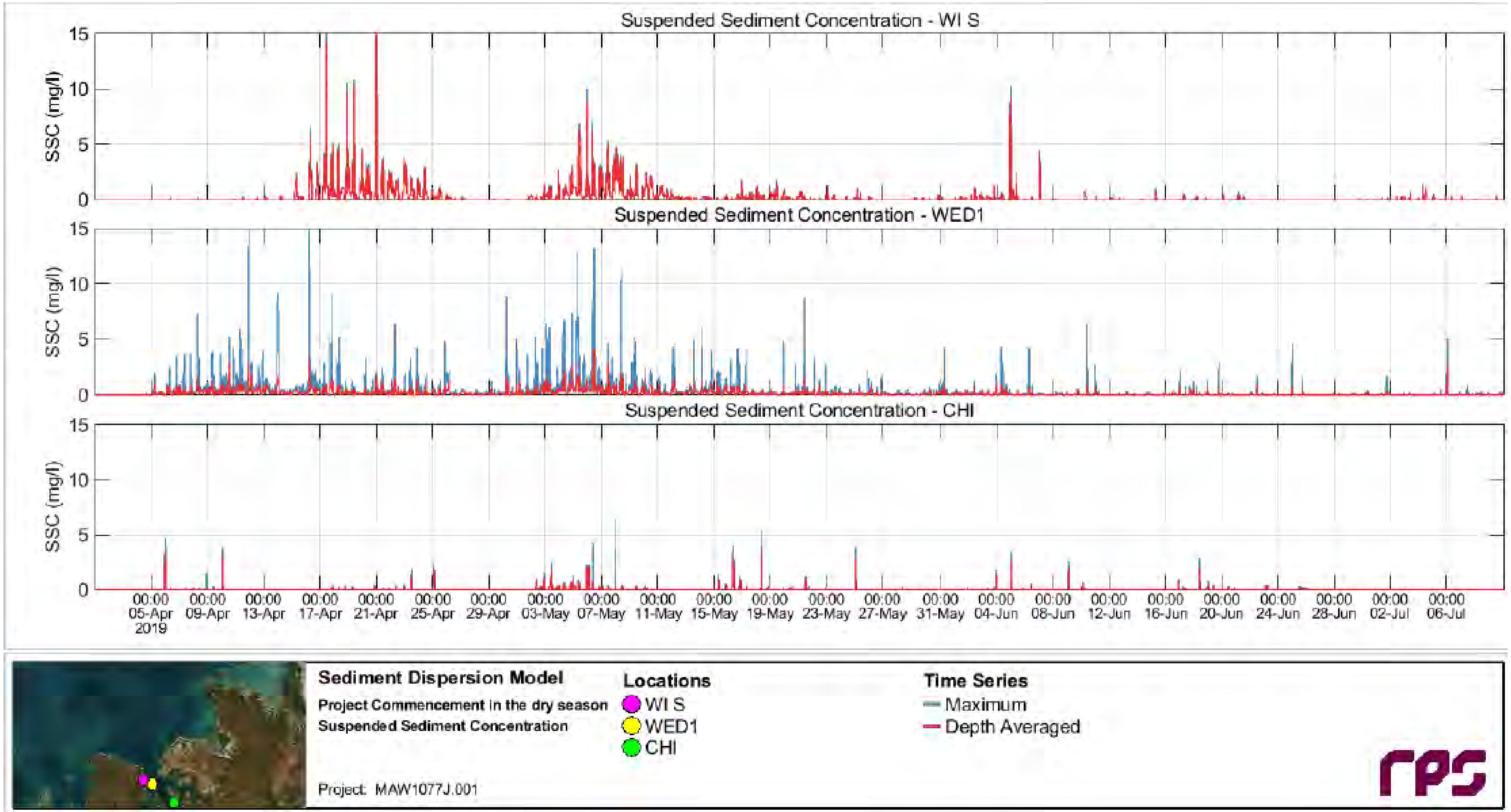


Figure 6-6: Time series of predicted trenching-excess SSC at the Woods Inlet South, Weed Reef 1 and Channel Island sites throughout the entire trenching program and run-on period in the winter/dry season scenario

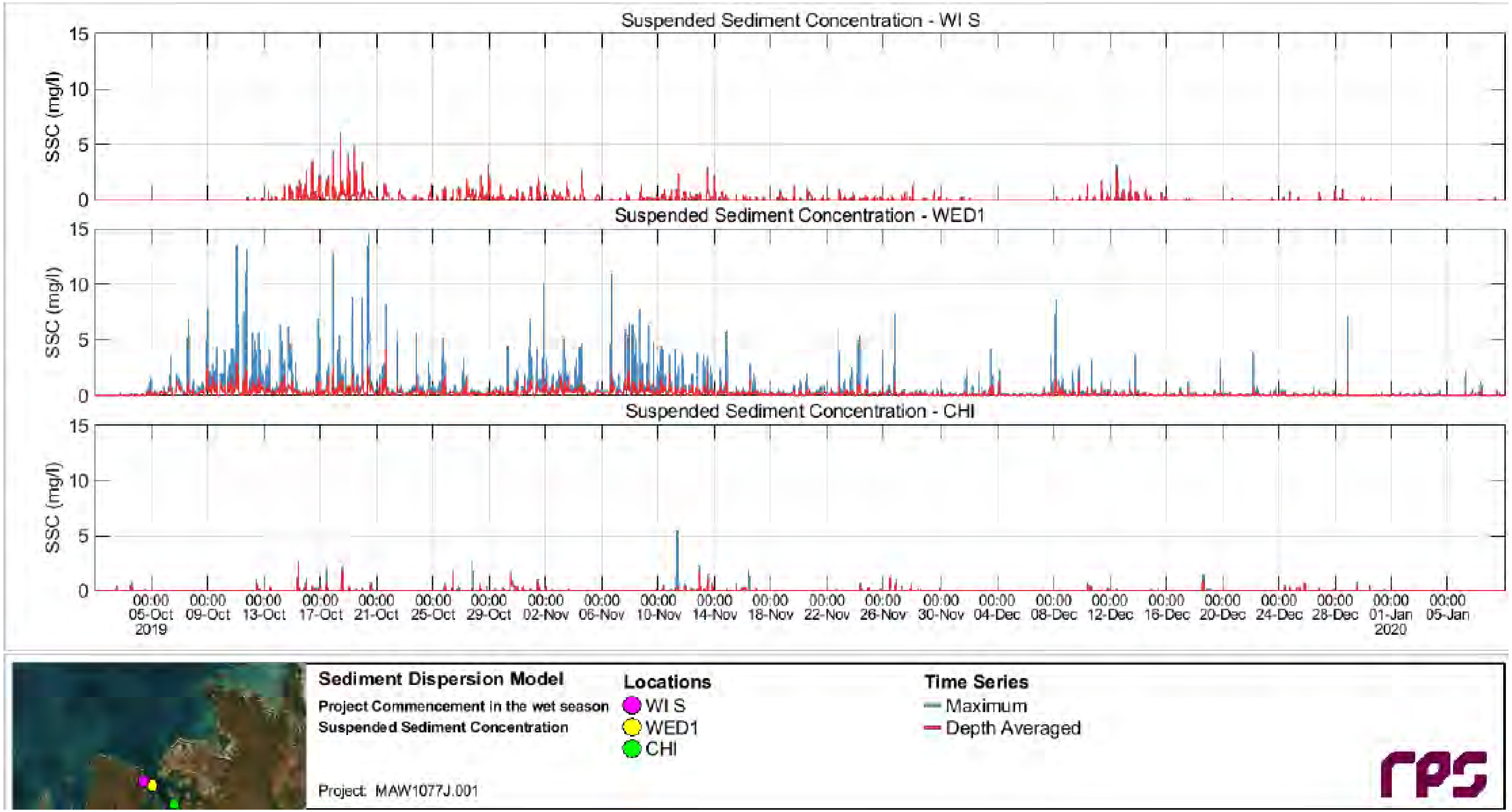


Figure 6-7: Time series of predicted trenching-excess SSC at the Woods Inlet South, Weed Reef 1 and Channel Island sites throughout the entire trenching program and run-on period in the summer/wet season scenario

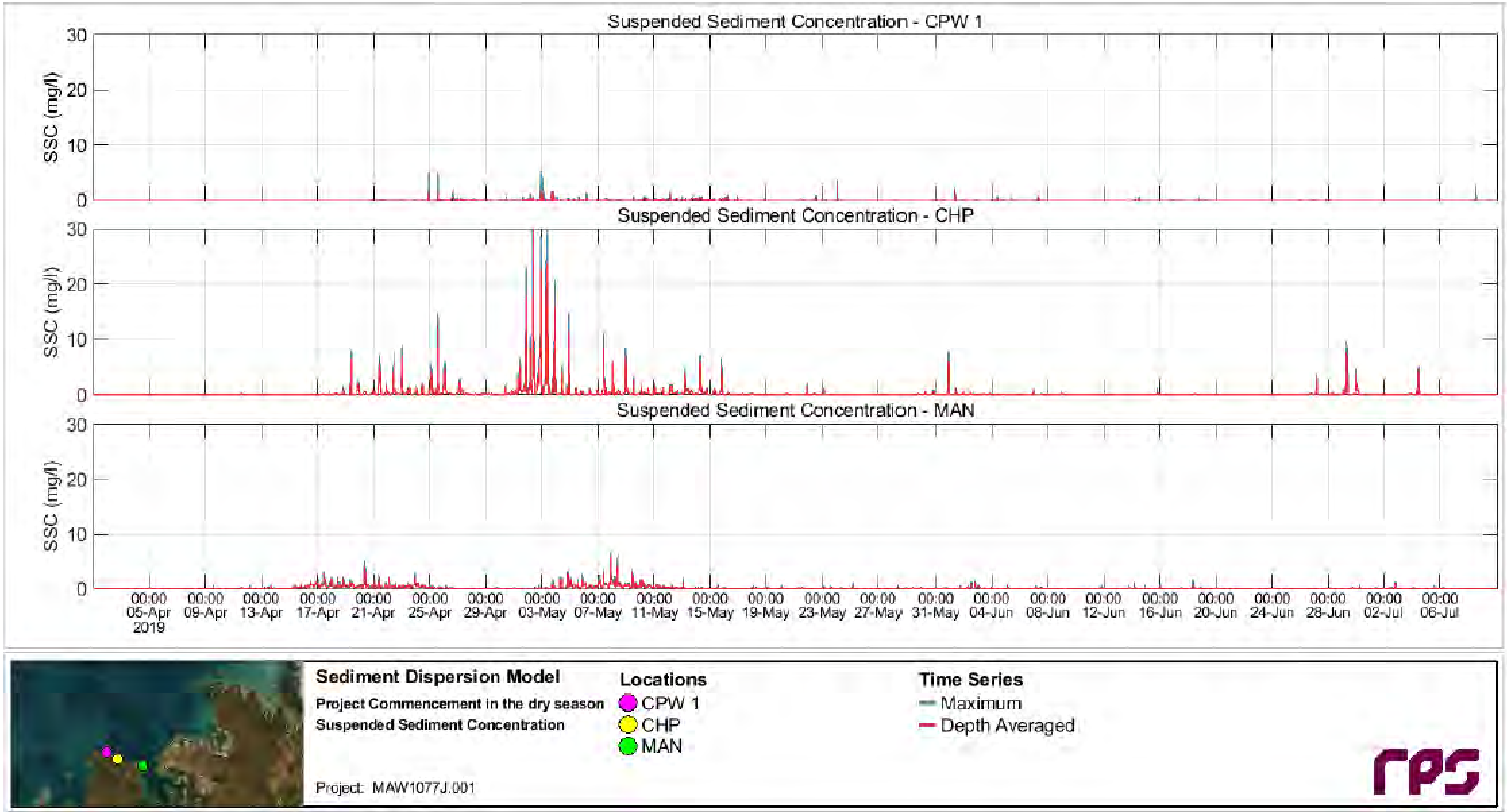


Figure 6-8: Time series of predicted trenching-excess SSC at the Charles Point Wide 1, Mandorah and Charles Point sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

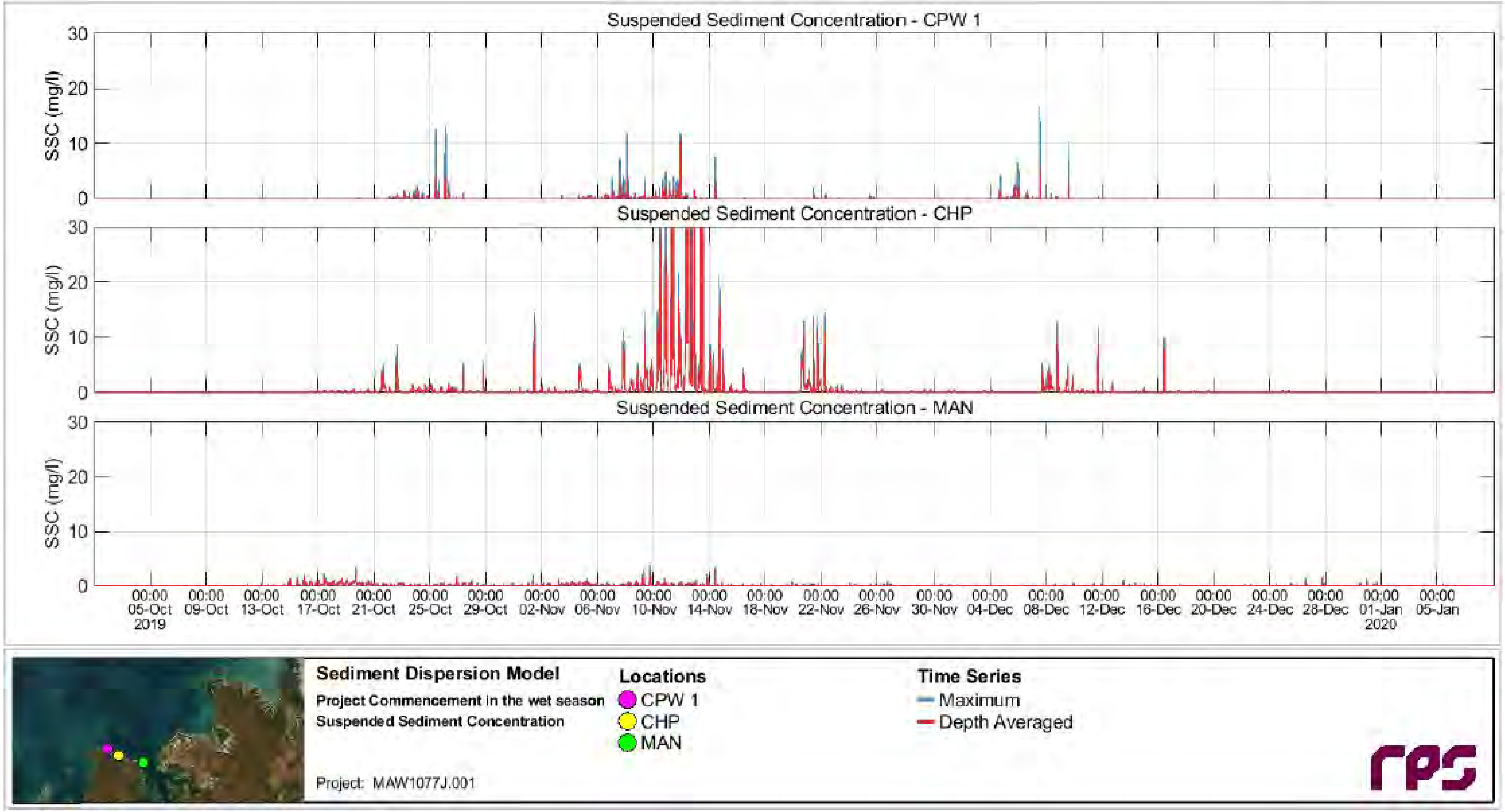


Figure 6-9: Time series of predicted trenching-excess SSC at the Charles Point Wide 1, Mandorah and Charles Point sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

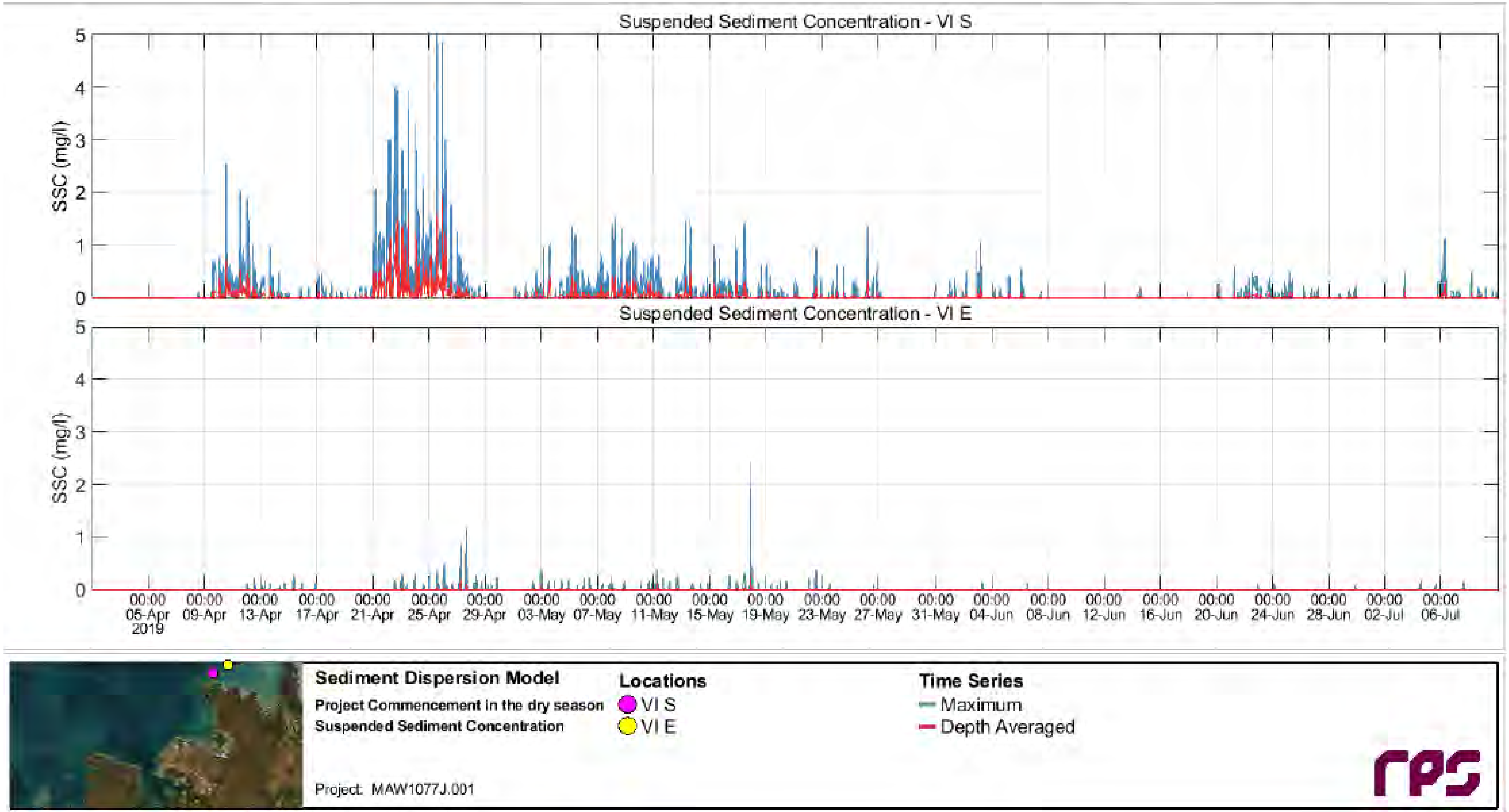


Figure 6-10: Time series of predicted trenching-excess SSC at the Varanus Island S and Varanus Island E sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

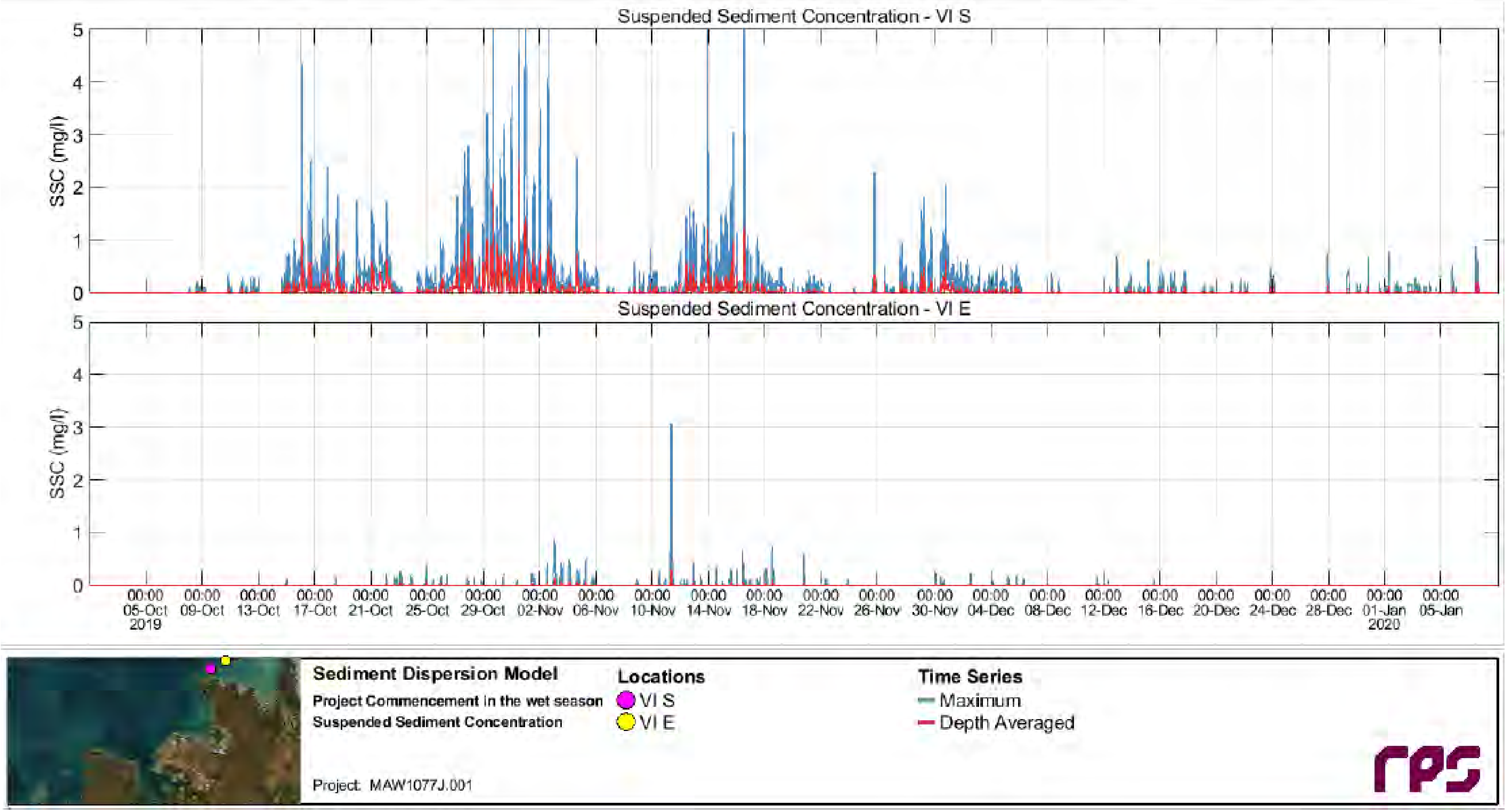


Figure 6-11: Time series of predicted trenching-excess SSC at the Varanus Island S and Varanus Island E sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

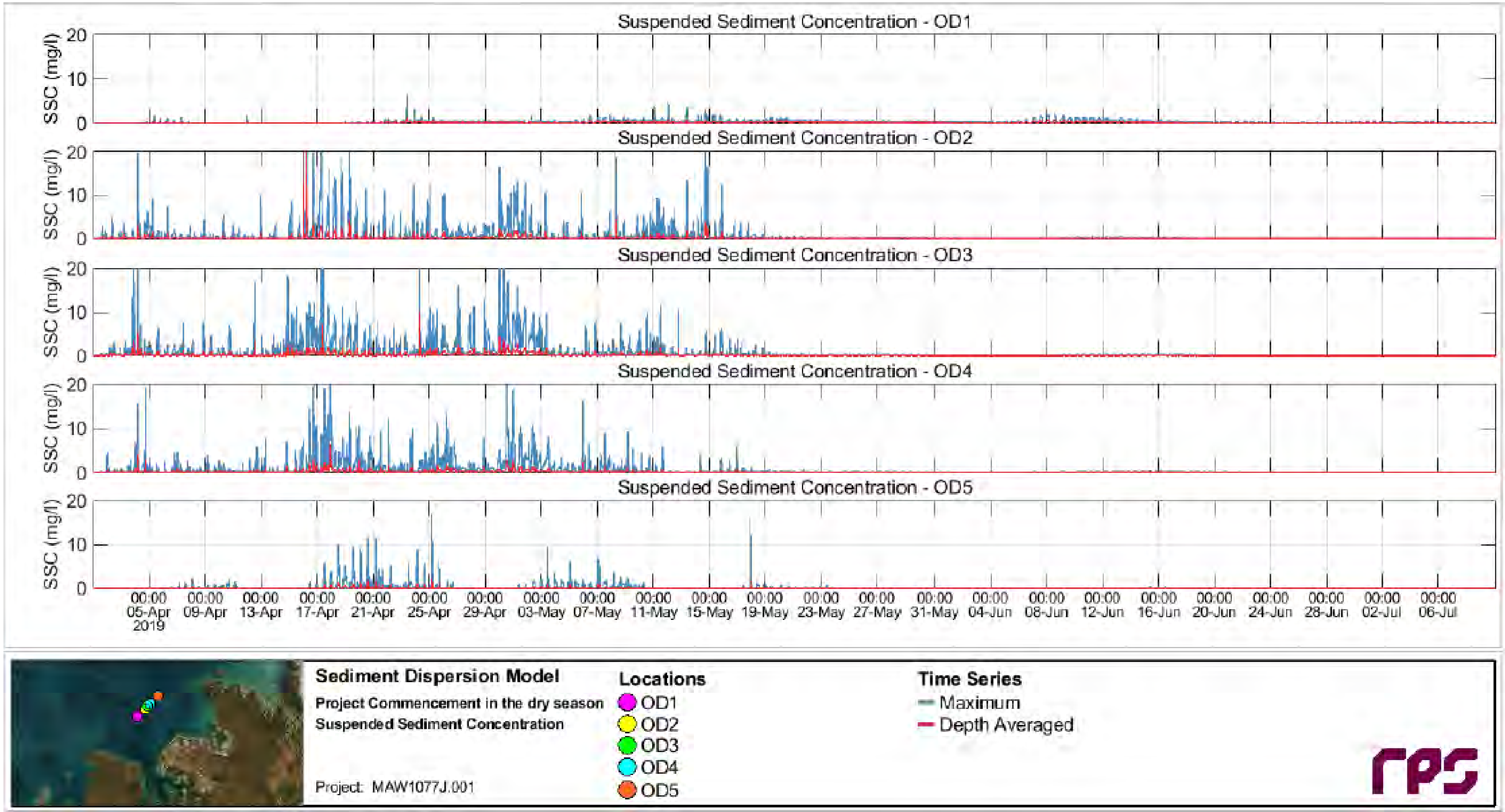


Figure 6-12: Time series of predicted trenching-excess SSC at the Offshore Disposal 1 to Offshore Disposal 5 sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

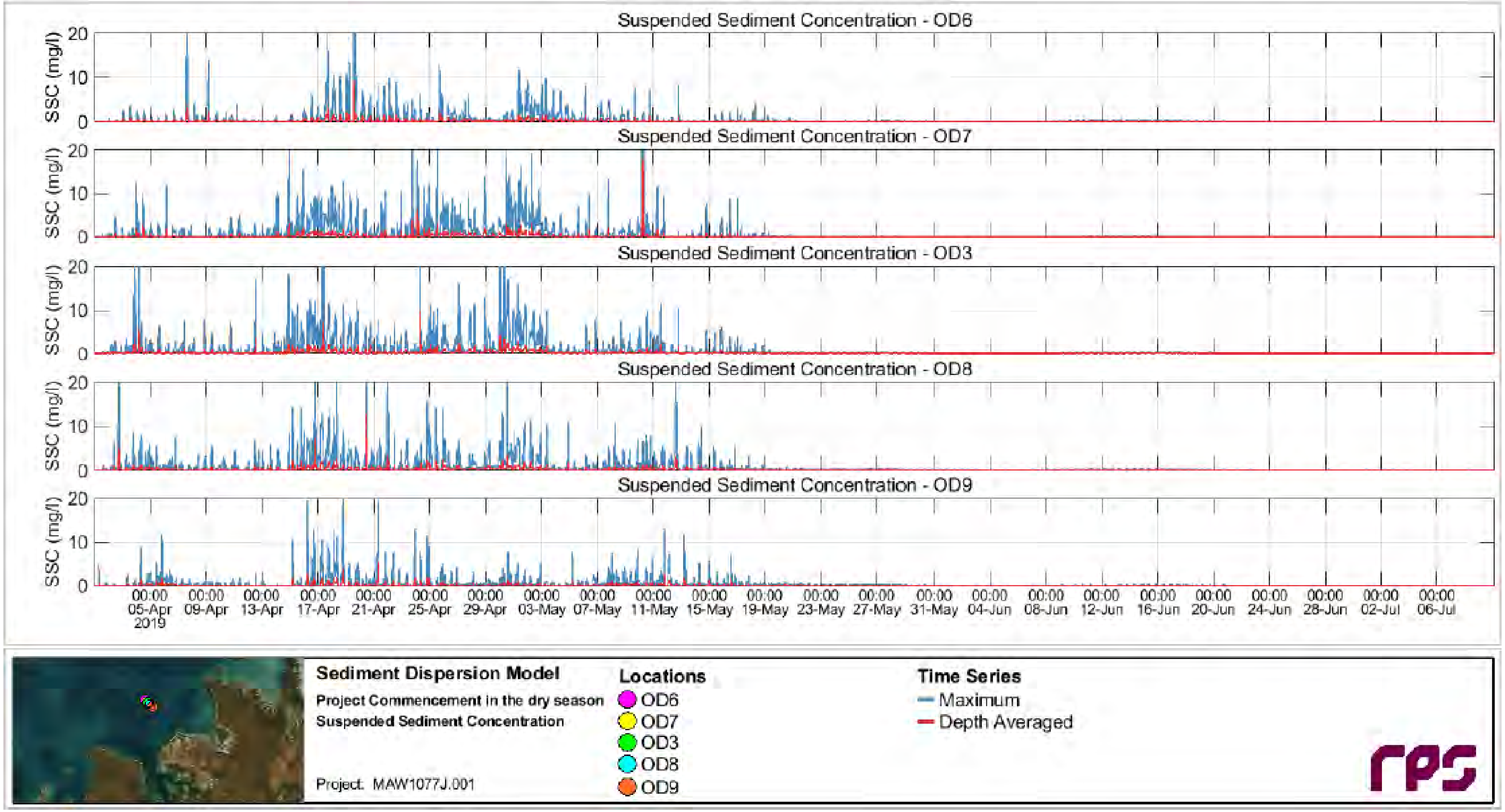


Figure 6-13: Time series of predicted trenching-excess SSC at the Offshore Disposal 6 to Offshore Disposal 9 (via Offshore Disposal 3) sites throughout the entire trenching program and run-on period in the winter/dry season scenario.

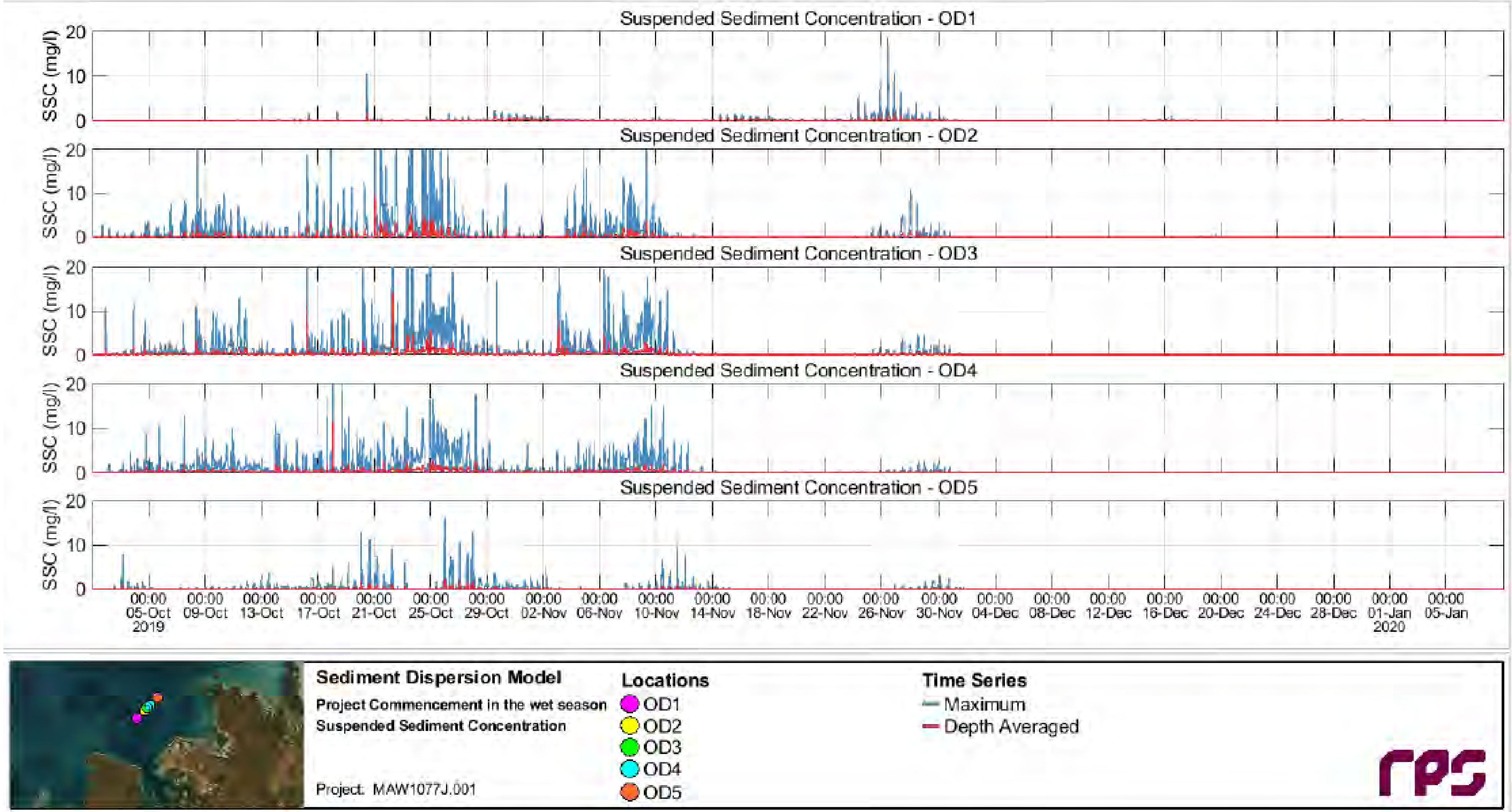


Figure 6-14: Time series of predicted trenching-excess SSC at the Offshore Disposal 1 to Offshore Disposal 5 sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

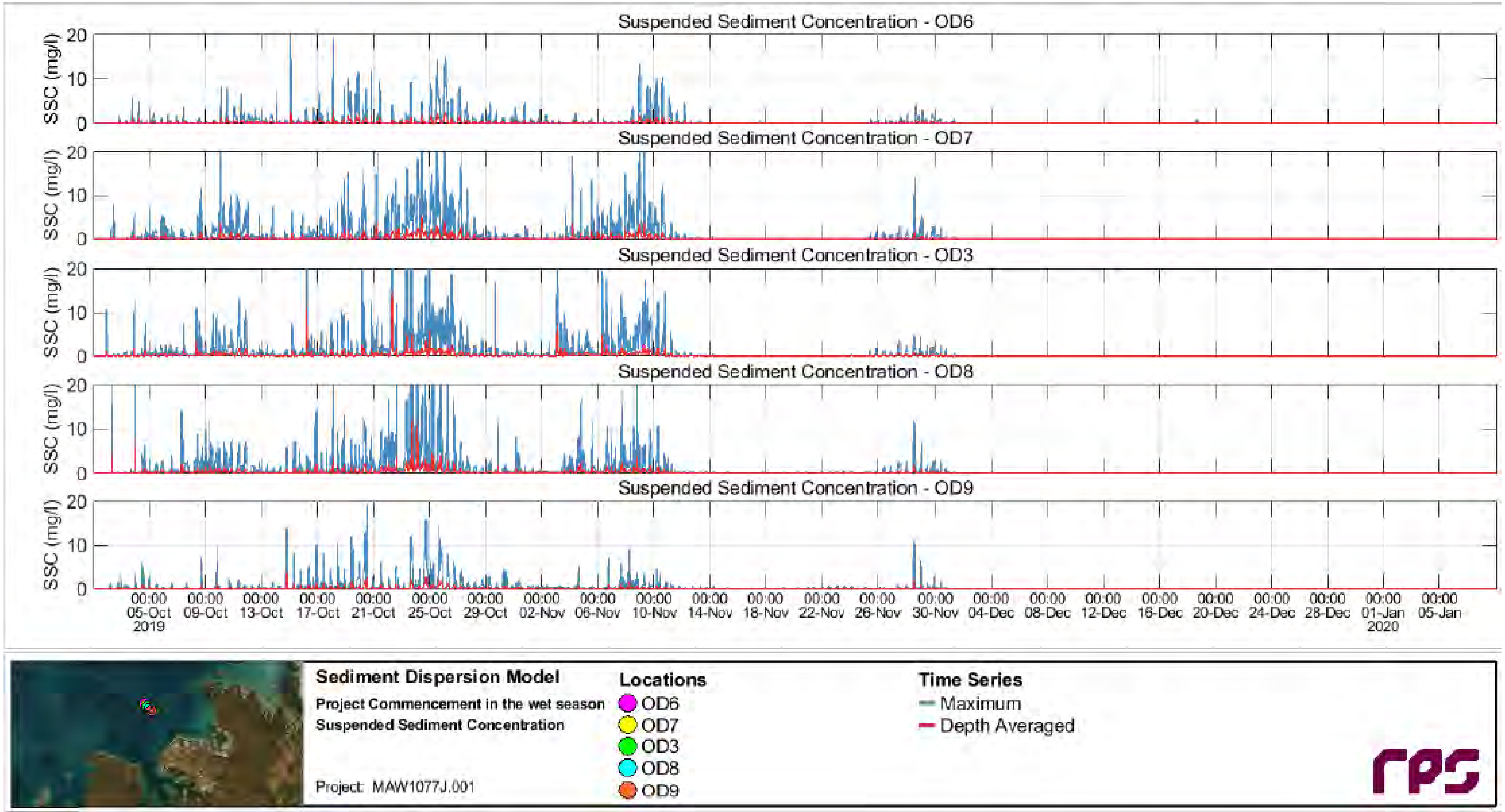


Figure 6-15: Time series of predicted trenching-excess SSC at the Offshore Disposal 6 to Offshore Disposal 9 (via Offshore Disposal 3) sites throughout the entire trenching program and run-on period in the summer/wet season scenario.

6.5.1.4 Spatial distribution of sedimentation

Given the strong tidal flows in the Darwin area, settlement of the finer trenching-generated sediment is minimal with fine material (clay and silts) being continuously resuspended on each tide, particularly during spring tide periods where even fine sand size material is predicted to be resuspended. Coarse material (sand size) is predicted to settle rapidly near the trenching zones and at the proposed offshore disposal area, but the fine material will remain suspended, or will deposit at slack tide only to be resuspended on the following tide. This results in suspended sediment plumes having long drift trajectories, with sediments dispersed widely but at low concentrations, and with sediments deposited in thin layers.

6.5.1.5 Temporal variability of sedimentation

To explore the temporal exposure of sensitive receptor sites to sedimentation generated by the trenching and disposal operations, a time series analysis at analysis sites within Darwin Harbour, outside the harbour and at the offshore disposal area (the same as was used for the time series analysis of SSC).

The deposition rates at distance from the trenching areas and the offshore disposal area are low, forming only very thin layers of material. At all sites other than those around the disposal area, the predicted thicknesses remain less than 0.2 mm and those plots have not been included here. The low rates of deposition are due to the magnitude of the tidal currents in the area: material that is suspended is dispersed rapidly and widely, with material deposited at slack tide being typically resuspended on the next tide – or the following spring tide period.

6.5.2 Spoil stability modelling

Simulation of spoil stability at the proposed spoil ground over the one-year run-on period showed that settlement of the finer spoil material is minimal and there is potential for significant resuspension of the finer proportions. The localised movement and dispersion of the disposal-generated and resuspended sediment is governed by the tide, with very strong tidal flows at the spoil ground.

Coarse material (coarse sand size and above) is predicted to settle rapidly, while available fine material in the spoil is predicted to be continuously resuspended on each tide, particularly during spring tide periods where even fine to medium sand size material is predicted to be resuspended. Deposition is forecast to occur at slack tide, however much of this settled material is resuspended on the following tide. This results in suspended sediment plumes having long drift trajectories, with sediments dispersed widely but at low concentrations, and with sediments deposited in thin layers. Drift trajectories from the spoil ground are predicted to be longest to the north-east towards the Clarence Strait and Van Diemen Gulf.

There is significant variability in the predicted vertical distributions of SSC in the water column at the proposed spoil ground, with a distinct increase in concentration towards the seabed. The higher SSC concentrations near the seabed are due to the resuspended material typically being mixed to the lower reaches (1 – 3 m) of the water column.

6.5.3 Zones of impact and influence

Three management zones were defined based on the approach applied by INPEX (2010, 2013, 2018), determined using the varying levels of impact on sensitive receptor communities:

+ Zone of High Impact (ZoHI)
+ Zone of Moderate Impact (ZoMI)

+ Zone of Influence (ZoI)

These management zones are described in the following sections.

6.5.3.1 Zone of High Impact

The ZoHI is defined as the area where direct impact from trenching and disposal will occur, such as removal of substrate or smothering of substrate (INPEX, 2018). Predicted impacts within this zone are expected to be severe and often irreversible. This zone includes the trench footprint and disposal area with a 20 m buffer extending outwards from these areas. For determining the ZoHI footprint, an indicative 40 m trench width (top of trench), representing a wide trench design, has been used with a 20 m buffer applied either side.

6.5.3.2 Zone of Moderate Impact

The ZoMI is defined as the area where sensitive receptor communities are predicted to be indirectly impacted by elevated SSC and sedimentation due to trenching and disposal activities (INPEX, 2018). Damage/mortality of sensitive receptor communities may occur, but the disturbed areas are considered to have good potential for recovery.

Within the ZoMI the ecological tolerance limits of sensitive receptors for SSC are predicted to be exceeded for 10% of the time or the ecological tolerance limits for sedimentation thickness are predicted to be exceeded at the end of the simulation (INPEX, 2018). In addition, the maximum sedimentation thickness predicted at any time throughout the simulated trenching operations was compared to the sedimentation tolerance limits. This was to account for the variable nature of the sedimentation with tidal cycles and the strong currents in Darwin Harbour which may cause larger amounts of sedimentation earlier in the trenching program.

The predicted ZoMI based on exceedances of the thresholds for SSC was evaluated over the duration of each trenching scenario by:

+ Creating a three-dimensional time series (hourly) of trenching-excess SSC values in each model grid cell for the entire trenching program.
+ Calculating the 90th percentile SSC value of each cell (i.e. the value that is exceeded 10% of the time).
+ Assessing the 90th percentile data against the seasonal threshold SSC values for each sensitive receptor habitat type and trenching impact reporting zone.

The predicted ZoMI based on exceedances of the thresholds for sedimentation was evaluated over the duration of each trenching scenario by:

+ Calculating the maximum trenching-excess sedimentation thickness values in each model grid cell for the entire trenching program. A density of 700 kg/m^2 was assumed for newly deposited sediments in the modelling based on field observations of the in-situ density of surface material present over the mangrove areas of Darwin Harbour (INPEX, 2009).
+ Assessing the maximum trenching-excess sedimentation thickness data against the seasonal threshold sedimentation thickness values for each sensitive receptor habitat type and trenching impact reporting zone.

The overall predicted ZoMI for each scenario was then calculated by combining both predicted ZoMIs SSC and sedimentation thickness.

6.5.3.3 Zone of Influence

The ZoI is defined as the area where sensitive receptor communities are predicted to be indirectly influenced by elevated SSC and sedimentation (INPEX, 2018). Sensitive receptor communities may, at some time experience detectable elevations in SSC and sedimentation (beyond expected background levels). However, no sublethal stress or mortality of benthic communities is expected to occur (INPEX, 2018).

Sensitive receptor communities are predicted to be indirectly influenced where their respective ecological tolerance limits for SSC are exceeded for 5% of the time or where the simulated sedimentation thickness exceeds 3 mm at the end of the simulation (INPEX, 2018). In addition, the maximum sedimentation thickness predicted at any time throughout the trenching operations was compared to the 3 mm sedimentation tolerance limit to account for the potentially larger amounts of sedimentation that may occur earlier in the trenching program.

The predicted ZoI based on exceedances of the thresholds for SSC was evaluated over the duration of each trenching scenario by:

+ Creating a three-dimensional time series (hourly) of trenching-excess SSC values in each model grid cell for the entire trenching program.
+ Calculating the 95th percentile SSC value of each cell (i.e. the value that is exceeded 5% of the time).
+ Assessing the 95th percentile data against the seasonal threshold SSC values for each sensitive receptor habitat type and trenching impact reporting zone.

The predicted ZoI based on exceedances of the thresholds for sedimentation was evaluated over the duration of each trenching scenario by:

+ Calculating the maximum trenching-excess sedimentation thickness values in each model grid cell for the entire trenching program. A density of 700 kg/m^2 was assumed for newly deposited sediments in the modelling based on field observations of the in-situ density of surface material present over the mangrove areas of Darwin Harbour (INPEX, 2009).
+ Assessing the maximum dredge excess sedimentation thickness data against the 3 mm tolerance limit.

The overall predicted ZoI for each scenario was then calculated by combining both predicted ZoIs for SSC and sedimentation thickness.

6.5.3.4 Management zone maps

The calculated extents of the defined management zones – ZoI and ZoMI – over the entire program of trenching and disposal operations for the winter/dry season scenario are presented in **Figure 6-16** and **Figure 6-17**; and for the summer/wet season scenario in **Figure 6-18** and **Figure 6-19**. The predicted ZoMI for the trenching and disposal operations for both seasonal scenarios are restricted to within or very close to the trenching and spoil disposal footprints. The predicted ZoI for the trenching and disposal operations for both seasonal scenarios are also generally restricted to the trenching and spoil disposal footprints, with the exception of a very small patch in the shallows at South West Vernon Island during the summer/wet season scenario. However, this isolated patch may be attributable to the combined effects of model bathymetry and hydrodynamics, representing sediments that are transported into the shallowest possible grid cells and then trapped upon reversal of the tide. While there is a potential for sediments released at the spoil disposal ground to be found in the indicated area, the persistence of material remaining at the water-land boundary in this location may be overstated.

The management zones shown are the result of exceedance of the sedimentation thresholds only; no exceedance of the SSC thresholds occurred at the predicted 90th (ZoI) and 95th (ZoMI) percentile depth-averaged SSC levels for both modelled seasonal scenarios.

Santos

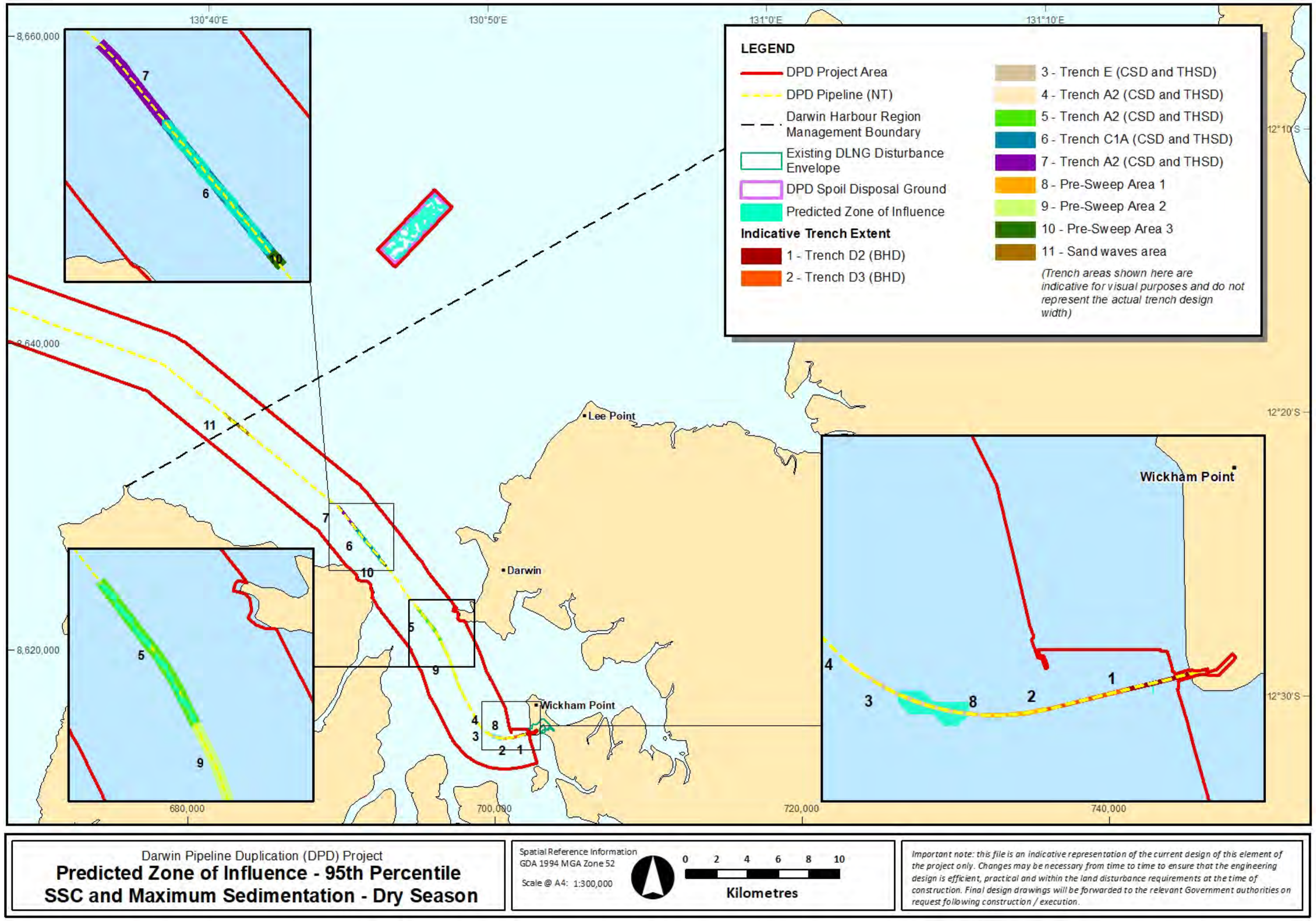


*Figure 6-16: Predicted Zone of Influence following application of the appropriate spatial thresholds in **Table 6-1** to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (1 April to 10 May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1***

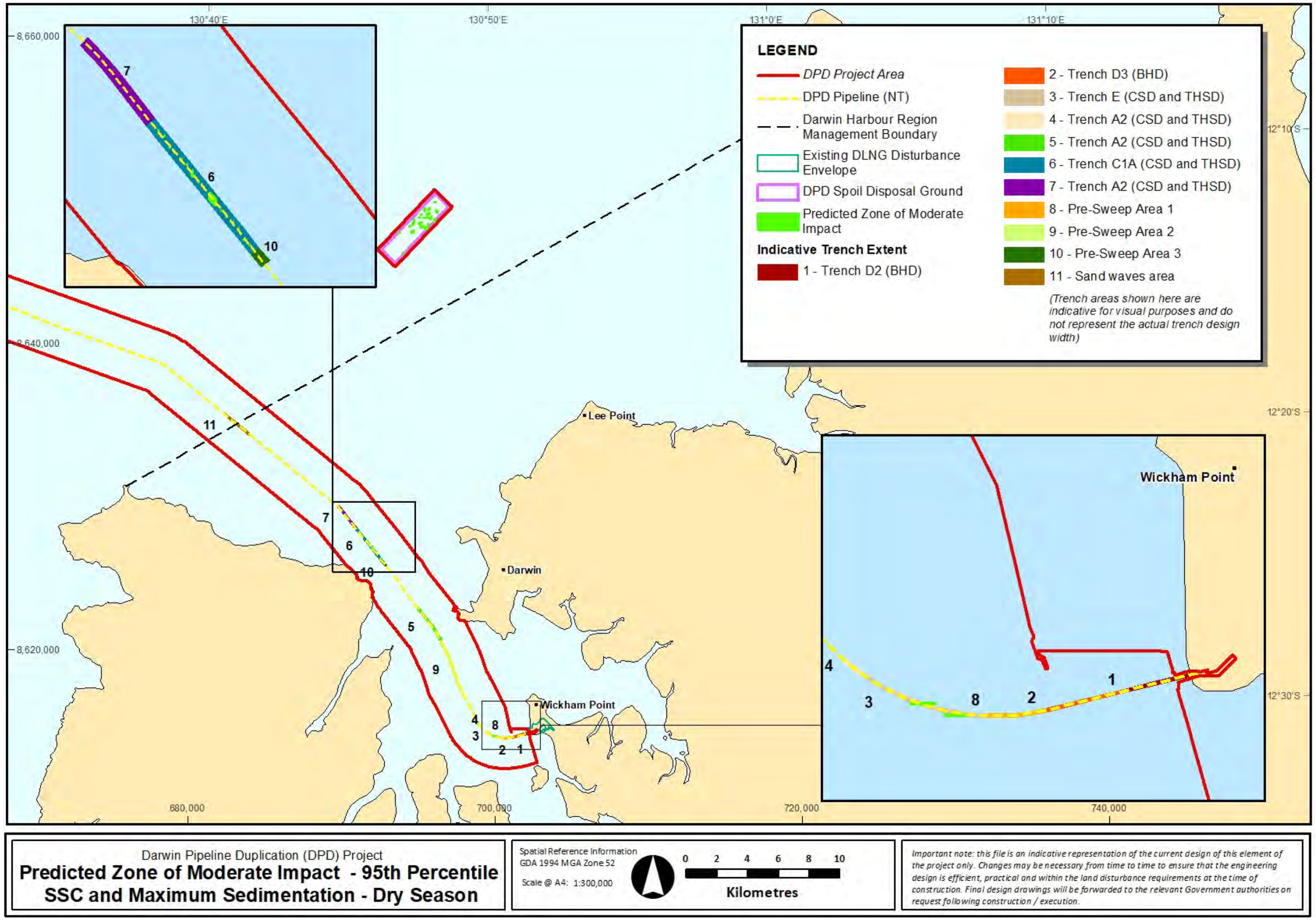


*Figure 6-17: Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in **Table 6-1** to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the winter/dry season scenario (1 April to 10 May 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1***

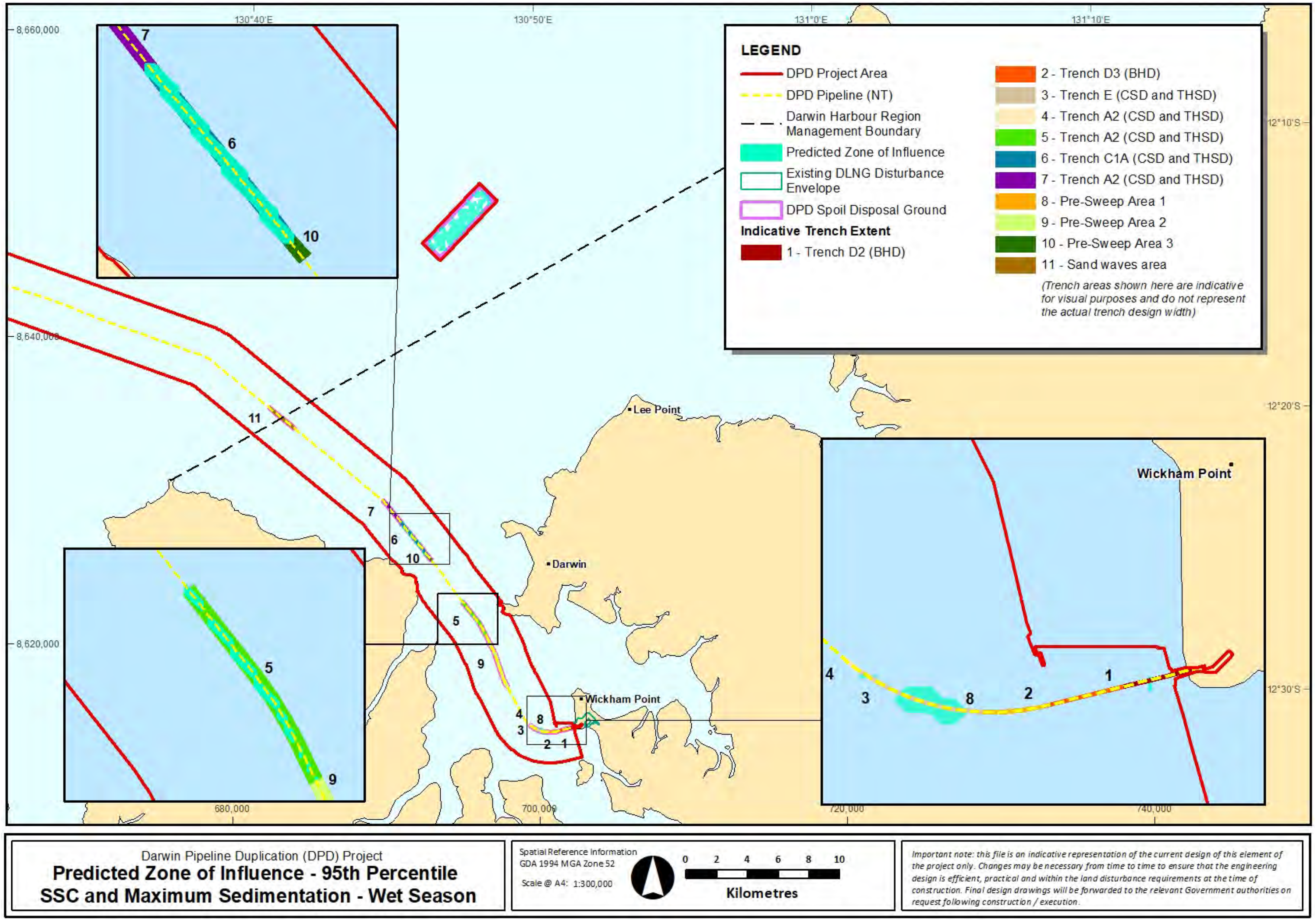


Figure 6-18: Predicted Zone of Influence following application of the appropriate spatial thresholds in ***Table 6-1*** *to the 95th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (1 October to 9 November 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in* ***Figure 2-1***

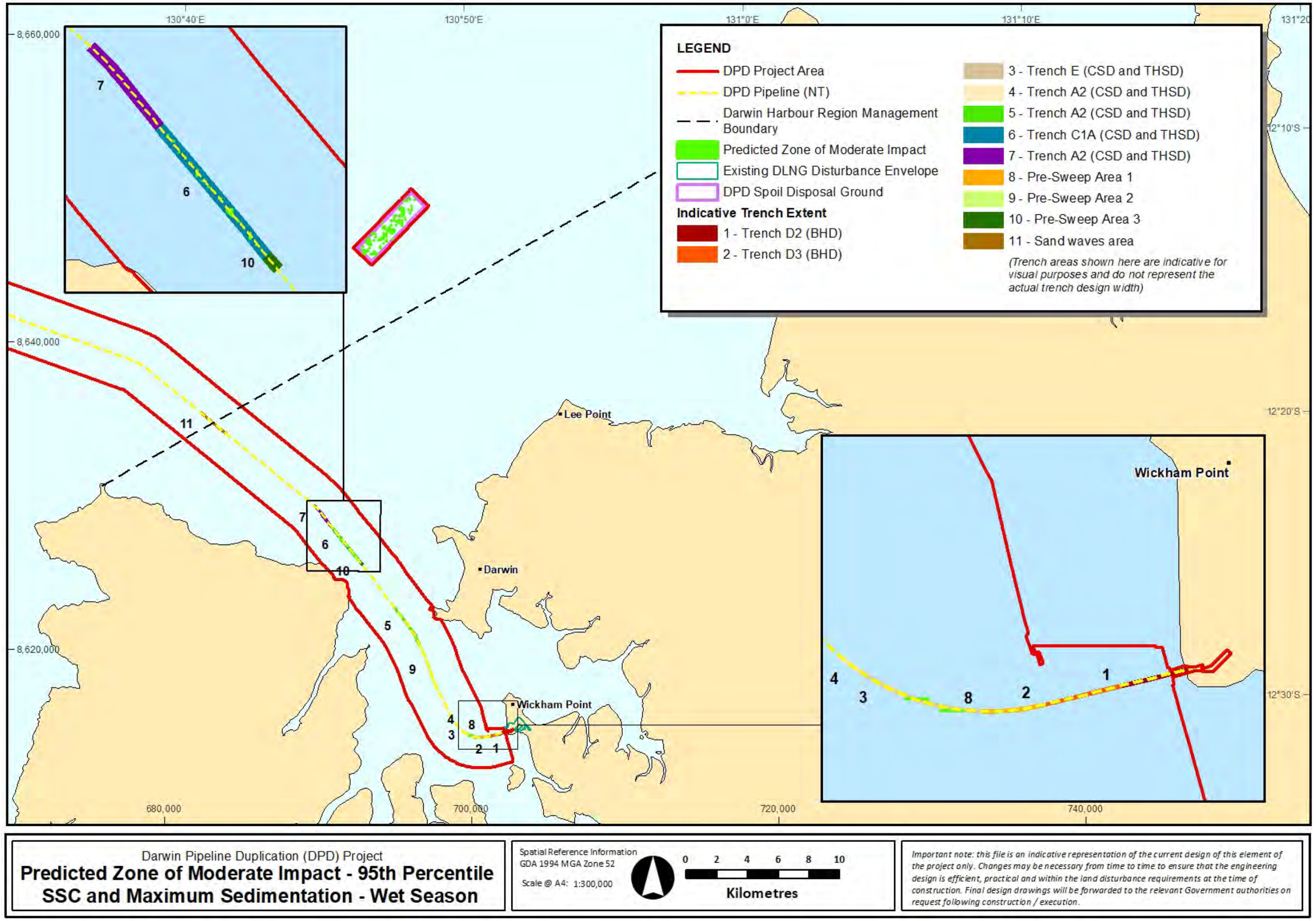


*Figure 6-19: Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds in to the 90th percentile SSC and maximum sedimentation throughout the entire trenching program for the summer/wet season scenario (1 October to 9 November 2019). Note modelling was based on the indicative trench extents depicted, however these have been superseded as shown in **Figure 2-1***

6.6 Predicted habitat impacts

Direct impacts are only expected to occur at the ZoHI which includes the trenching zone and spoil ground with a 20 m buffer extending outwards from these areas. Direct habitat loss is expected to occur within these areas. No sensitive receptor habitat (hard corals and seagrasses) overlap the or are adjacent to these zones based on benthic habitat mapping and therefore these habitats are not predicted to be impacted. The predicted ZoHI does overlap sponges and filter feeder (and to a lesser extent, macroalgae) habitat, therefore loss of these habitats is expected (**Table 6-3**). Further detail on the mapping used to inform direct habitat loss calculations is provided within the DPD Project Supplementary Environmental Report (BAS-210 0020).

No indirect impact (i.e., ZoMI) or influence (i.e., ZoI) from increased SSC is predicted as no exceedance of SSC thresholds is predicted to occur at the predicted 95th or 90th percentile depth-averaged SSC levels for either then winter/dry season, or the summer/wet season. In contrast, zones of impact and influence were predicted for sedimentation. However, the predicted ZoMI for sedimentation for both seasonal scenarios is restricted to the trenching and spoil disposal footprints (**Figure 6-17** and **Figure 6-19**), that is, within the ZoHI. The predicted ZoI for sedimentation is also restricted to within or immediately adjacent to the trenching footprints and spoil disposal footprints, (**Figure 6-16** and **Figure 6-18**). Consequently, the restricted spatial extent of sedimentation above impact thresholds and the lack of sensitive primary producer biota (i.e. seagrass and hard coral) within or adjacent to these zones indicates that indirect impacts to benthic habitats from trenching and offshore spoil disposal are not likely.

Table 6-3: Summary of the areal overlap of Project trenching zone and spoil ground Zones of High Impact (ZoHI) with different benthic habitats. Areal extent of benthic habitat impacted by different activities was calculated by overlaying DPD Project infrastructure over the combined AIMS 2019 and 2021 habitat mapping

Benthic habitats	Trenching zones ZoHI		Spoil ground ZoHI	
Areal extent	Ha	%	Ha	%
Bare ground	23.6	19.3	53.4	8.2
Hard coral	-	-	-	-
Seagrass	-	-	-	-
Macroalgae	7.4	6.1	-	-
Sponge or sponges/filterers/octocorals	91.4	74.6	596.4	91.8

7 Impact and Risk Assessment

This TSDMMP has employed a systematic impact and risk assessment process for the environmental management of trenching and spoil disposal activities. The impact and risk assessment process has been developed in line with Santos' Environmental Impact Identification (ENVID) process and is consistent with the requirements the NT EPA Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015).

7.1 Conceptual site model

A Conceptual Site Model as required by the NT EPA, is a written or illustrated representation of the nature, fate and transport of discharges, wastes or contaminants that allows assessment of potential and/or actual exposure of the environment to contaminants (NT EPA, 2015). The Conceptual Site Model for this TSDMMP is embedded within the impact and risk assessment as it details receptors and pathways, refer **Table 7-7**.

7.2 Impact and Risk assessment methods

The TSDMMP environmental impact and risk assessment was performed consistent with the Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02) and identification of management actions was consistent with Santos' Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02). An environmental aspect, for the purpose of this environmental management plan, is defined as characteristics of the construction activities that could potentially affect the environment.

7.2.1 Identification of environmental hazard

Environmental hazards for this TSDMMP were identified using Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021), DPD Project Basis of Approval (BAS-210 0005; Santos, 2022) and discussion by DPD Project team and environmental specialists. Key DPD Project construction activities and associated hazards and results from key technical studies were presented during ENVID workshops to inform the impact and risk assessment process.

7.2.2 Standard controls

The standard controls identified in **Table 6 6** were drawn from:

+ Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021)
+ Santos' environmental plans and procedures for similar activities
+ Regulator approved management plans developed by other proponents.

Additional controls were provided by ENVID workshop attendees based on their relevant experience.

7.2.3 Impact and risk assessment

All hazards identified were assigned a consequence level following the six levels and criteria outlined in Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02). More detailed criteria were developed to assist in addressing NT EPA Key Environmental Factors. These are the NT EPA consequence descriptors shown in **Table 7-1**.

The consequence is defined as the resulting impact from an event occurring. Consequence level for this assessment was based on the credible worst-case scenario and assumed no management actions were in place. Categories of environmental consequence and detailed definitions of each severity level are outlined in **Table 7-2**.

The likelihood can be described as the probability that that the described consequence will occur. When determining the likelihood of consequences, proposed prevention and mitigation controls identified to mitigate potential impacts were considered. A detailed description of likelihood levels is outlined in **Table 7-3**.

The consequence and likelihood levels are not presented in this TSDMMP but are contained in the ENVID documentation. **Section 7.3** and **Table 7-7** outline the residual consequences and likelihoods which is the outcome after standard and additional (as low as reasonably practicable; ALARP) management actions are applied.

A likelihood level was only assigned to unplanned events as per the Santos Risk Matrix Procedures (SMS-LRG-OS01-TP02), shown in **Table 7-4**. The consequence and likelihood for each impact was then assessed to determine the residual risk that remained after proposed standard controls were considered.

Table 7-1: NT EPA consequence descriptors

	Consequence Level	I	II	III	IV	V	VI
	Acceptability	Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
	Consequence Level Description	**Negligible** No impact of negligible impact	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors Localised effect	**Moderate** Significant impact to local population industry or ecosystem factors	**Major** Major long-term effect on local population industry or ecosystem factors	**Severe** Complete loss of local population industry or ecosystem factors AND/OR extensive regional impacts with slow recovery	**Critical** Irreversible impacts to regional population industry or ecosystem factors
Environmental Receptors	**Marine Ecosystems** Fauna, habitat, conservation significant areas and ecological function, processes and integrity	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of habitat critical / disruption to the breeding cycle/ vales of a protected area. No introduction of disease and no reduction in habitat area/function.	Detectable but insignificant decrease in local population size and threat to local population viability. Insignificant disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area. Detectable but insignificant loss of area/function of habitat with rapid recovery within 2 years.	Moderate. Significant decrease in local population size but no threat to overall population viability. Significant behavioural disruption or disruption to the breeding cycle of local population / Significant reduction in area of occupancy of species / loss of habitat critical to survival of a species. Modify, destroy, remove or decrease availability of quality habitat to the extent that a long-term decline in local population or function of habitat is likely with recovery over medium term (2-10 years) Introduction of disease likely to cause significant population decline	Long term decrease in local population size and threat to local population viability. Major disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area Fragmentation of existing population / Loss or change of habitat to the extent that a long-term decline in local population and function of habitat is likely with slow recovery over decades Introduction of disease likely to cause long term population decline	Complete loss of local population, habitat critical to survival of local population or protected area/conservation significant area Widespread (regional) decline in population size or habitat critical to regional population Extensive destruction of local habitat with no recovery or long term (decades) or widespread loss of area or function of primary producers on a regional scale	Complete loss of regional population Complete loss of habitat critical to survival of regional population
	Marine Environmental Quality Water quality, sediment quality, ecosystem health and parameters that support fishing, aquaculture, recreation, aesthetics and cultural/spiritual values	Negligible. No or negligible reduction in physical environment nor decrease in ecosystem function/health. No or negligible loss of value to socio-economic activities	Detectable but localised, short term and insignificant impact to physical environment or ecosystem function/health or value to socio-economic activities. Rapid recovery evident within ~ 2 years.	Significant wide-scale medium term impact to physical environment, decrease in ecosystem function/health or value to socio-economic activities. Recovery over medium term (2-10 years).	Wide-scale, long term impact to physical environment, long term decrease in ecosystem function/health or value to socio-economic activities. Slow recovery over decades.	Extensive impact to/destruction of physical environment with no recovery or shutdown of socio-economic activities Long term (decades) and widespread loss of ecosystem function/health on a regional scale that damages value to socio-economic activities.	Complete destruction of regional physical environment / habitat with no recovery Complete loss of area or function of primary producers on a regional scale

Consequence Level		I	II	III	IV	V	VI
	Coastal Processes Geophysical processes, primary productivity/ nutrient cycling, conservation significant areas/coastal landforms and cultural, aesthetic or recreation values	Short term changes to local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale	Detectable but insignificant loss or change to local geophysical/hydrological processes, area or function of primary producers/nutrient cycling or conservation significant areas with rapid recovery within 2 years.	Moderate. Significant modification, destruction, removal or change of local geophysical/hydrological processes, wide-scale loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with recovery over medium term (2-10 years).	Long term loss or change of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with slow recovery over decades	Extensive destruction of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with no recovery or long term (decades)	Complete loss or change of geophysical/hydrological processes. Complete loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale.
	Community and Economy Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping	No or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry. Significant medium-term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry. Permanent loss of key natural features or populations supporting the local industry.	Permanent shutdown of local or regional industry Permanent loss of key natural features or populations supporting the local or regional industry
	Culture and heritage Includes: Indigenous heritage and maritime heritage (i.e. shipwrecks)	No or negligible impact on the area's cultural or heritage values. No or negligible alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Detectable but insignificant impact on one or more of the area's cultural or heritage values. Detectable but insignificant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Significant impact on one or more of the area's cultural or heritage values. Significant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Major long-term effect on one or more of the area's cultural or heritage values. Major alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Complete loss of one or more of the area's cultural or heritage values.	Permanent loss of one or more of the area's cultural or heritage values with no recovery.

Table 7-2: Summary environmental consequence descriptors

Consequence Level	Consequence Level Description
I	**Negligible** – No impact or negligible impact
II	**Minor** – Detectable but insignificant change to local population, industry or ecosystem factors
III	**Moderate** – Significant impact to local population, industry or ecosystem factors
IV	**Major** – Major long-term effect on local population, industry or ecosystem factors
V	**Severe** – Complete loss of local population, industry or ecosystem factors AND/OR extensive regional impacts with slow recovery
VI	**Critical** – Irreversible impact to regional population, industry or ecosystem factors

Table 7-3: Likelihood description

No.	Matrix	Description
f	Almost Certain	Occurs in almost all circumstances OR could occur *within days to weeks*
e	Likely	Occurs in most circumstances OR could occur *within weeks to months*
d	Occasional	Has occurred before in Santos OR could occur *within months to years*
c	Possible	Has occurred before in the industry OR could occur *within the next few years*
b	Unlikely	Has occurred elsewhere OR could occur *within decades*
a	Remote	Requires exceptional circumstances and is unlikely even in the long term

Table 7-4: Risk assessment matrix

		Consequence					
		I	**II**	**II**	**IV**	**V**	**VI**
Likelihood	**F**	Low	Medium	High	Very High	Very High	Very High
	E	Low	Medium	High	High	Very High	Very High
	D	Low	Low	Medium	High	High	Very High
	C	Very Low	Low	Low	Medium	High	Very High
	B	Very Low	Very Low	Low	Low	Medium	High
	A	Very Low	Very Low	Very Low	Low	Medium	Medium

7.3 Residual impacts and risks

7.3.1 Planned events

The residual consequence levels from the planned impacts following implementation of standard and additional ALARP management actions (detailed in **Section 8**) are summarised in **Table 7-5**. Given the likelihood of a planned event occurring is 100% (in other words, it will occur), the risk ranking is not assessed. A comprehensive impact assessment for each of the planned events, and subsequent management actions proposed by Santos to reduce the impacts to ALARP are detailed in the following sections. The demonstration of ALARP and/or acceptable levels is discussed in the overarching Offshore CEMP (BAS-210 0024). Within the ENVID developed by Santos some environmental aspects had multiple residual consequence ratings since multiple environmental factors were assessed against, in these cases the residual consequence of greatest severity was chosen for this summary.

Table 7-5: Summary of the residual consequence levels associated with planned impacts

TSDMMP section	Planned event impact	Residual consequence
9.2	Seabed and benthic disturbance	II – Minor
8.3.1.1	Interactions with other marine users – construction activities and Project infrastructure	II – Minor
8.3.1.2	Noise emissions	II – Minor
8.3.1.3	Light emissions	II – Minor
8.3.1.4	Routine vessel discharges	I – Negligible
8.3.1.5	Atmospheric emissions	I – Negligible

7.3.2 Unplanned events

The residual risk levels from unplanned events following implementation of standard and additional (ALARP) management actions (detailed in **Section 8**) are summarised in **Table 7-6**. Comprehensive risk assessments for each of the unplanned events, and subsequent management actions proposed to reduce the risk to ALARP and acceptable levels are detailed in the following sections. The demonstration of ALARP is discussed in the overarching Offshore CEMP (BAS-210 0024). Within the ENVID some unplanned events had multiple residual risk ratings; in these cases the residual risk of greatest severity was chosen for this summary.

Table 7-6: Summary of the residual risk level associated with unplanned risks

TSDMMP section	Unplanned event risk	Residual risk level
8.3.2.1	Dropped objects (including accidental release of non-hazardous waste)	Low
8.3.2.2	Introduction of invasive marine species	Low
8.3.2.3	Unplanned marine fauna interaction	Low
8.3.2.4	Release of hazardous liquids	Low
8.3.2.5	Release of hydrocarbon (offshore vessel bunkering or vessel tank rupture	Low
8.3.2.6	Release of dry natural gas from Bayu-Undan to Darwin pipeline	Very Low

7.4 Demonstration of ALARP

Demonstration of ALARP for each planned and unplanned event is outlined within the Environmental Management Strategies (EMS') in Section 7 of the Santos DPD Project Offshore CEMP (BAS 210-0024; Santos, 2022).

7.5 Impact/risk assessment summary

The outcomes of the impact / risk assessment are presented in **Table 7-7**, and where relevant includes reference to the relevant management strategy within this TSDMMP proposed to manage individual environmental aspects.

Table 7-7: Summary of risk assessment outcomes

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
Planned events							
Interaction with other marine users – construction activities and Project infrastructure	Trenching and spoil disposal with + Cutter Suction Dredger (CSD) + Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) + Split Hopper Barges (SHBs) disposal	The movement of vessels in the operational area has the potential to result in interactions with other marine users or exclude other marine users (i.e., through implementation of exclusion zones) from some areas of Darwin Harbour and the spoil disposal grounds during trenching and spoil disposal operations. The marine spread for trenching includes: + TSHD and CSD (nominal duration will be approximately 6 weeks) + Split Hopper Barges/BHD + Support vessels – Approx. 11 vessels in total for trenching activities.	**Spatial** Localised around the Project vessels (and vessel exclusion zones as applicable) pipeline route and shore crossing activities including temporary causeway structures. Vessel exclusion zones are typically 500 m and will apply to Project vessels, including pipelay vessel, construction vessels and dredging vessels. **Temporal** Temporary and intermittent interaction with presence of project vessels within the Project Area over the trenching and spoil disposal campaign (indicatively 2 – 3 months).	+ Interactions with other marine users including displacement from commercial, recreation and tourism areas + Turbidity generated from trenching activities may dissuade other users from the area while it is present	+ **Community and economy** (commercial fishers, traditional fishing, tourism and recreational activities, shipping traffic and oil and gas activities)	II-Minor	**Section 8.3.1.1**
Seabed and benthic habitat disturbance	Trenching and spoil disposal with: + Cutter Suction Dredger (CSD) + Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) Trenching at intertidal/shore crossing with excavators up to the shore pull termination point Spoil Disposal at: + Spoil ground + In situ intertidal disposal to manage	**Trenching and spoil disposal** Direct impact to seabed in trenching locations (**Figure 2-8**) Spoil from trenching areas will be transported to and disposed of in the DPD spoil disposal area in offshore NT waters, which will result in disturbance from smothering due to sedimentation. Spoil from trenching activities at the shore crossing in the intertidal area will be placed *in situ* in the lower intertidal area to provide a mitigation to potential acid sulfate soil risk (i.e., to keep wet under most tidal conditions). Dependent upon access by BHD this build-up of spoil will be subsequently removed (if not already dispersed) for offshore spoil disposal to the DPD spoil disposal area in offshore NT waters using a	**Spatial** There will be direct disturbance within the ZoHI around trenching areas (131 Ha) and spoil disposal area (649.8 Ha**)** with areas of substrate removal and smothering occurring. There will additionally be indirect disturbance to benthic habitats from sedimentation within the ZoMI and ZoI. The spatial extent of the predicted ZoI and ZoMI from segmentation is within the trenching footprint or immediately adjacent to the trenching footprint. Sensitive benthic habitats such as seagrasses and hard corals are not predicted to occur within these areas. Refer to **Section 6.5.3.** **Temporal** Within the trenching ZoHI, impacts will be permanent and non-recoverable. Sedimentation and turbidity effects outside	+ Change to seabed topography and potential changes to water currents and associated changes to erosion/deposition of sediments + Increase in sedimentation and reduction in water quality and visual amenity + Trenching nearshore in intertidal muds may expose acid sulfate soils resulting in oxidation and leaching of acidic by-products + Direct and indirect impact to benthic habitats, including removal, smothering of and light reduction to benthic habitats + Reduction in available food for marine species utilising affected benthic habitats + Potential to impact fish health and other fauna	+ **Marine environmental quality** (water quality, physical parameters that support fishing, aquaculture, recreation and aesthetics, sediment quality) + **Marine ecosystem** (Potential loss of the following habitats: macroalgae, sandy sediment with filter feeders and sponges, infauna, epifauna and biota quality, benthic habitats and primary producer habitat, including mangroves)	II-Minor	**Section 8.2**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
	risk of acid sulfate soils	BHD and SHB. Note – impacts associated with the construction and presence of potential rock causeway/s to support trenching in the intertidal area are assessed in the DPD Project Offshore CEMP. Alteration of seabed/intertidal zone bathymetry from trenching activity and spoil disposal potentially resulting in local alteration of hydrology (i.e., seabed currents).	the ZoHI are expected to be temporary only. The combined duration of trenching activities across areas is expected to be in the order of 2 – 3 months.	+ Potential disturbance to maritime heritage and sacred sites	+ **Coastal processes** (Bathymetry and seabed features) + **Community and economy** (Impacts to demersal fish habitats) + **Culture and heritage** (Heritage areas, Shipwrecks, Maritime archaeology and sacred sites)		
Noise emissions	Trenching and spoil disposal noise emissions from: + Cutter suction dredge (CSD) + Trailer suction hopper dredge (TSHD) + Backhoe Dredge (BHD) for excavating with potential used of hydraulic tools (Xcentric Ripper, hydraulic hammer) for fracturing rock + Excavators Support operations noise emissions including: + General vessel operations during all DPD Project activities + Vessel and subsea positioning equipment e.g. MBES, SSS, LBL) / USBL)	Vessel noise is considered non-impulsive (continuous) and broadband and includes vessel thrusters, engines and propellers, as well as noise emitted onboard which is converted to underwater noise through the hull. The main source of vessel noise will be from propellers or dynamic positioning (DP) thrusters (deeper water pipelay only). Project vessels (excluding trenching vessels) may emit noise up to ~180 dB re 1 µPa at 1 m. Trenching will be completed using different trenching vessels, including a BHD, a TSHD and a CSD. Noise includes operation of vessel engines for propulsion (as applicable), onboard equipment, pumps and interaction of trenching equipment with the seabed. The following source levels are considered representative of trenching vessel non-impulsive noise: + TSHD: 184 dB re 1µPa @1m + CSD: 182 dB re 1µPa @1m + BHD: 175 dB re 1µPa @1m BHD rock breaking tools will be either non-impulsive from Xcentric Ripper tool or impulsive from hydraulic hammer (contingency	**Spatial** For TSHD, CSD and BHD trenching and Xcentric Ripper tool use, permanent threshold shift (PTS) SEL24 hour ranges for dolphins, dugongs and turtles modelled at <50 m. Equivalent threshold range for hydraulic hammer modelled at 100 – 160 m. For TSHD, CSD and BHD trenching and Xcentric Ripper tool use, temporary threshold shift (TTS) SEL24 hour ranges for dolphins, dugongs and turtles modelled at 40 – 350 m. Equivalent threshold range for hydraulic hammer modelled at 950 – 2,500 m. The PTS and TTS ranges were shown to decrease with reduced hammering time (per 24 hours) for the hydraulic hammer. For behavioural response thresholds, ranges for marine mammals (dolphins and dugongs) varied from 100s of metres to 10s of kilometres for scenarios modelled at MSL. Spatial scales for other activities are as follows: + Localised: A support vessel using main engines and bow thrusters to maintain position will become inaudible above background noise within thousands of metres.	Project activities including trenching additional vessel operations and will add to the existing underwater noise profile inside and outside Darwin Harbour during construction. The use of sound in the underwater environment is important for marine animals, particularly cetaceans, to navigate, communicate and forage effectively, along with reptiles, sharks/rays and other fish, for a range of functions such as social interaction, foraging and orientation. Underwater noise could result in: + Acoustic masking: – Disruption to underwater acoustic cues – Masking of vocalisations and signals from predators and prey + Behavioural response: – Modification of fauna behaviour (avoidance, attraction and disruption of normal behaviour) – Disturbance, leading to behavioural changes or displacement from areas – Indirectly by inducing behavioural and physiological changes in predator or prey species.	+ **Marine ecosystem** (marine mammals particularly cetaceans, marine reptiles, sharks, rays, pelagic and demersal fish) + **Marine environmental quality** (impact to parameters that support fishing, aquaculture, recreation, aesthetics and cultural/ spiritual values) + **Community and economy** (commercial and recreational fisheries) and tourism).	II-Minor	**Section 8.3.1.2**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
	+ Helicopter operations	only). Representative source levels are: + Xcentric Ripper: 184.8 dB re 1 µPa2 s m^2 + Hydraulic hammer: 192 dB 1 µPa2s m^2	+ Localised: A conservative estimate is that survey equipment (MBES/SSS) will be inaudible within thousands of metres, depending on the activity characteristics. Localised: Helicopter noise will be highly localised and most of the noise will not transfer into the water. **Temporal** Trenching vessel noise expected over indicative period of 2-3 months.	+ Physiological impacts: – Increased stress levels – Physical injury to fauna from exposure to excessive noise (barotrauma, hearing loss including TTS and PTS – Onshore construction activities are not expected to have an impact as they will not occur in water.			
Light emissions	Trenching and spoil disposal light emissions from: + Cutter Suction Dredger (CSD) + Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) + Split Hopper Barges (SHBs) Support operations light emissions including: + General vessel operations during all DPD Project activities	Potential impacts from light emissions may occur from: + Operational, safety and navigational lighting + Spot lighting that may also be used as needed, such as equipment deployment and retrieval. Lighting will typically consist of bright white (e.g., metal halide, halogen, fluorescent) lights typical of existing commercial vessels using Darwin Harbour.	**Spatial** Localised: Limited light 'spill' or 'glow' on surface waters surrounding a vessel. Light spill modelling conducted for an offshore pipelay vessel and an offshore construction vessel, considered ''worst-case'' in terms of vessel lighting for the DPD Project, indicates that vessel light spill intensity is around 10 times that of a full moon at 150-200m from these vessels (either individually or side by side) and drops to the intensity of a full moon at 500-1000m (Pendoley, 2022). At a distance of 2.5-4.5km, light spill was modelled to have dropped to 0.1 (10%) of a full moon. At this level, lighting is considered unlikely to have any impacts on marine turtle hatchlings (which are considered particularly sensitive to lighting impacts) (Pendoley Environmental, 2022). **Temporal** Navigational and task lighting is required 24 hours a day for the duration of the trenching activities (indicatively 2 – 3 months).	Change in fauna behaviour due to light emissions from vessels could potentially include: + Disorientating turtle hatchlings emerging from nests + Increased predation of turtle hatchlings at sea within vessel light spill zones + Attraction of seabirds and shorebirds to light + Attraction and increased predation of fish within vessel light spill zone	+ **Marine ecosystem** (marine turtles, seabirds and shorebirds, fish) + **Marine environmental quality** (Impact to parameters that support fishing, aquaculture, recreation, aesthetics and cultural/spiritual values) + **Community and economy** (Fisheries and Tourism)	II-Minor	**Section 8.3.1.3**
Routine vessel discharges	All vessel activities	Only those discharges allowable under maritime regulations will be permitted as would apply to other commercial vessel using Darwin Harbour and NT waters.	**Spatial** Localised: The environment that may be affected by operational discharges within permissible discharge areas will likely be localised on a scale of metres to 10s of	The small volumes discharged may cause localised nutrient enrichment, organic and particulate loading, thermal impacts and increased salinity.	+ **Marine environmental quality** (Water quality) + **Marine Ecosystem** (Ecosystem health)	I-Negligible	**Section 8.3.1.4**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
		Planned discharges from vessels to the marine environment may include: + Deck drainage/run off including residual chemicals + Sewage and grey water – disposed in accordance with Marine Order 96. + Food wastes – disposed in accordance with AMSA and Marine Order 95, and MARPOL Annex V. + Cooling water + Bilge water – disposed in accordance with MARPOL Annex 1/Marine Order 91. + Brine (if a reverse osmosis unit is used for water treatment).	metres in the upper 5 m of the water column. **Temporal** Any permissible discharges will be intermittent over the period of trenching and spoil disposal (indicatively 2 – 3 months) and effects will be very short-term.		+ **Community and economy** (Fisheries (commercial and recreational) and tourism)		
Atmospheric emissions	Atmospheric emissions from vessels combustion engines impacting on air quality	Potential impacts from atmospheric emissions may occur in the Project Area from the following sources: + Operation of trenching and support vessel engines, helicopters, and excavators. These emissions will include greenhouse gas (GHG) emissions, such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), and non-GHG emissions, such as sulphur oxides (SOX) and nitrogen oxides (NOX). + Operation of incinerators on vessels. Although the vessels may use ozone-depleting substances (ODS), this will be in a closed rechargeable refrigeration system and there is no plan to release ODS to the atmosphere.	**Spatial** Localised: The quantities of gaseous emissions are relatively small and will, under normal circumstances, quickly dissipate into the surrounding atmosphere. **Temporal** Intermittent for the duration of the trenching activities.	Atmospheric emissions from activity vessels can result in deterioration of local air quality. Emissions of GHG can cause an incremental increase in global GHG concentrations. Given the nature and scale of DPD Project construction activities (low frequency and relatively short duration), both risks are considered to have a negligible impact on air quality.	+ **Marine environmental** quality (Local air quality) + **Community and economy** (Tourism)	I-Negligible	**Section 8.3.1.5**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
Unplanned events							
Dropped objects (including accidental release of non-hazardous waste)	Trenching and spoil disposal with + Cutter Suction Dredger (CSD) + Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) + Split Hopper Barges (SHBs) disposal Support operations including: + General vessel operations during all DPD Project activities	Solid objects such as those listed below can be accidentally released to the marine environment: + non-hazardous solid wastes, such as paper, plastics and packaging, PPE, small tools, vessel anchors and unsecured deck equipment + hazardous solid wastes, such as batteries, fluorescent tubes, medical wastes, and aerosol cans; and + equipment and materials, such as hard hats, tools or infrastructure parts (e.g., pipe joints, mattresses and frames).	**Spatial** The event would only occur within the Project Area, and all non-buoyant waste material or dropped objects are expected to remain within the Project Area. Buoyant objects could potentially move beyond the Project Area. **Temporal** Disturbance is expected to be temporary only with unplanned release of solids only occurring during construction activities	If an object is dropped overboard, potential impacts would be limited to minor and localised disturbance of the seabed and benthic habitats near the dropped object. Benthic habitat loss. Potential damage to subsea infrastructure or cultural heritage sites. Potential damage to cultural heritage objects and sites.	+ **Marine environmental quality** (Water quality and Sediment quality). + **Marine ecosystem** (Benthic habitats, infauna and epifauna and protected areas (Charles Point RPA)) + **Community and economy** (Oil and gas operations, other users, e.g. fisheries, tourism and recreational fishers and other industries e.g. telecommunications)	Low	**Section 8.3.2.1**
Introduction of invasive marine species	The mobilisation of trenching and spoil disposal vessels to the Project area.	Introduction of IMS may occur due to: + Biofouling on vessels and external/internal niches (such as sea chests, seawater systems) + Biofouling on equipment that is routinely submerged in water (such as survey equipment) + Discharge of high-risk ballast water + Cross-contamination between vessels. Once established, IMS have the potential to out-compete indigenous species and affect overall native ecosystem function.	**Spatial** Localised (seabed and water column within the Project Area) to widespread if successfully translocated to new areas via ocean currents or project equipment transit. **Temporal** Temporary to long-term (in the event of successful translocation).	Potential establishment of IMS in the marine environment as a result of the project requires IMS to: + Be present on a vector (biofouling on activity vessels and ballast water are considered credible vectors) + Be released from the vector + Establish in the receiving environment. If established, impact could include localised (seabed and water column near the Project Area) to widespread impacts, if successfully establishes to new areas. IMS could displace and outcompete local species	+ **Marine environmental quality** (Ecosystem health) + **Marine ecosystem** (Benthic habitats, benthic communities and Ecological function and processes) + **Coastal processes** (Ecological processes) + **Community and economy** (Other users e.g. commercial and recreational users and ports and shipping)	Low	**Section 8.3.2.2**
Unplanned marine fauna interactions	Trenching and spoil disposal with + Cutter Suction Dredger (CSD)	There is the potential for vessels or equipment (for example, associated with the TSHD, CSD and ROV) involved in trenching activities to	**Spatial** Within the Project Area, in the immediate vicinity of the vessels or subsea equipment. **Temporal**	Collisions may result in behavioural impacts, physical injury to, or the death of the fauna involved.	+ **Marine ecosystem** (Marine fauna – marine mammals,	Low	**Section 8.3.2.3**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
	+ Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) + Split Hopper Barges (SHBs) disposal Support operations including: + General vessel operations during all DPD Project activities	interact with marine fauna, including potential strike or collision, potentially resulting in severe injury or mortality.	The risk is present during trenching and spoil disposal activities. Interactions with individual would be temporary.	Marine fauna may be entrained into or entangled by trenching equipment.	reptiles, fish and sharks)		
Release of hazardous liquids	Trenching and spoil disposal with + Cutter Suction Dredger (CSD) + Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) + Split Hopper Barges (SHBs) disposal Support operations including: + General vessel operations during all DPD Project activities	Hazardous liquids used on the DPD Project include fuels and oils for equipment and machinery and other task-specific chemicals required for trenching activities. Resulting in the accidental liquid releases (other than marine diesel oil or marine gas oil) include: + hydraulic fluids, lubricant oils and stored waste oils + stern tube oil (non-hydrocarbon-based lube oil) from the vessel thruster/propeller stern tube (approximately less than 1 m³) + Chemicals, including corrosion inhibitor, cleaning and cooling agents, recovered solvents, stored or spent chemicals, leftover paint materials and used greases + Causes of hazardous liquid releases include: – Vessel pipework failure or rupture, hydraulic hose failure and inadequate and bunding – Spills or leaking machinery accidentally discharged	**Spatial** Volumes are likely to be small and limited to the volume of individual containers (such as IBCs, 44 gallon drums) stored on the deck of supply vessels or limited to tank/hose volumes within equipment/machinery. The worst-case credible spill for this scenario is considered to be the loss of an intermediate bulk container (1 m³). Concentrations below toxic or harmful thresholds are expected to occur at short distances from the release point. Should a spill occur, potential impacts beyond the Project area are not expected in the event of a worst-case spill. **Temporal** Potentially toxic or harmful threshold concentrations limited to a very short period immediately following an instantaneous release.	Decreases to water quality Decreases in sediment quality, and impacts to fauna from contact or ingestion. Given the nature and scale of the source of risk, the potential impacts to water and sediment quality are expected to be localised and temporary given the types of hazardous liquids that may credibly be lost overboard. Impacts to fauna may result in injury or mortality through contact and/or ingestion, however while this would reasonably be expected to impact upon individual animals; no population-scale impacts would credibly occur.	+ **Marine environmental quality** (Water quality and sediment quality) + **Marine ecosystem** (Marine fauna – marine mammals, reptiles, fish, sharks, seabirds and shorebirds)	Low	**Section 8.3.2.4**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
		– overboard in deck drainage water – Overflow of the open and closed drainage systems – Loss of primary containment (drums, tanks, IBCs) due to handling, storage and dropped objects (such as swinging load during lifting activities). – Oily water from vessels includes bilge water and deck drainage water. The relative low volumes are expected to rapidly disperse into the marine environment					
Release of hydrocarbon (offshore vessel bunkering or vessel tank rupture	Trenching and spoil disposal with: + Cutter Suction Dredger (CSD) + Trailer Suction Hopper Dredger (TSHD) + Backhoe Dredger (BHD) + Split Hopper Barges (SHBs) disposal Support operations including: + General vessel operations during all DPD Project activities	A minor spill (up to approximately 10 m³) of marine gas oil (MGO) or marine diesel oil (MDO) could occur during vessel to vessel refuelling resulting in a loss of hydrocarbons to the marine environment at sea surface. This scenario has been modelled within Darwin Harbour to inform the risk assessment (BAS-210 0030; RPS, 2022). Spills during refuelling can occur through several pathways, including fuel hose breaks, coupling failure or tank overfilling. It is considered credible that a release of diesel to the marine environment could occur from a vessel fuel tank rupture. For the purpose of risk assessment, discharges of 700 m³, 300 m³ and 87.5 m³ have been modelled to represent a range of spill scenarios considered worst case for different vessel sizes used on the DPD Project, including trenching and spoil disposal vessels.	**Spatial** MDO spill trajectory modelling (BAS-210 0030; RPS, 2022) at KP 91.5 (just outside Darwin Harbour) indicated that there was some probability of a 700 m³ marine diesel oil (MDO) spill, extending as follows (using the moderate exposure thresholds): + Shoreline loading was predicted to occur at Cox-Finniss, Outer Harbour West and West Arm in the dry season and Cox-Finniss, East Arm, Outer Harbour East and Outer Harbour West in the wet season. + Surface oil was predicted to occur within approximately 19.9 km (Dry season) and 19.3 (Wet season) of the release location. + Total submerged oil was predicted to occur within approximately 36.9 km (Dry season) and 51.3 km (Wet season) of the release location + Dissolved hydrocarbons were predicted to occur with approximately 10 km (Dry season) and 13.7 km (Wet season) of the release location.	A spill of MDO could result in a reduction in: + water quality + sediment quality + ecosystem health and impact to parameters supporting commercial and recreational uses Behavioural/ physiological impact to marine fauna (particularly those associated with the surface such as cetaceans and marine turtles) and plankton within the upper water column only. Impact to other users due to spill response activities Impacts to benthic habitats, including intertidal habitats and primary producers Impact to culture and heritage areas	+ **Marine environmental quality** (Water quality, physical parameters that support socio-economic activities) + **Marine ecosystem** (Marine fauna, benthic habitats, intertidal habitats, protected areas (Charles Point RPA)) + **Coastal processes** (primary productivity e.g. mangroves) + **Community and economy** (Community and economy e.g. commercial and recreational users) + **Culture and heritage** (Impacts to sacred sites or important	Low	**Section8.3.2.5**

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
			MDO spill trajectory modelling for vessel fuel tank rupture (RPS, 2022) at KP 114 (in the middle of Darwin Harbour) indicated that there was some probability of a 300 m³ marine diesel oil (MDO) spill respectively, extending as follows (using the moderate exposure thresholds): + Shoreline loading was predicted to occur at East Arm, Middle Arm, West Arm and Wickham Point in both wet and dry seasons. During the wet season shoreline loading is also expected at outer harbour east and outer harbour west + Surface oil was predicted to occur within approximately 19.6 km (Dry season) and 18.9 km (Wet season) of the release location. + Total submerged oil was predicted to occur within approximately 30.3 km (Dry season) and 32.4 km (Wet season) of the release location + Dissolved hydrocarbons were predicted to occur with approximately 0.6 km (Dry season) and 7.3 km (Wet season) of the release location. The extent of shoreline loading, and distance travelled of MDO from smaller spills of 87.5 m³ and 10 m³ modelled at KP 114 will be lower than that described for the 300 m³ scenario **Temporal** The duration of a hydrocarbon spill would depend upon the specifics and severity of the incident. For the purpose of hydrocarbon spill modelling, the vessel tank rupture scenarios were modelled as 6-hour releases and the refuelling incident modelled as an instantaneous release. Once released, MDO disperses rapidly within the marine environment (on a scale of hours to several days) through entrainment, dissolution and evaporation leaving a smaller residual component		cultural heritage significance)		

Aspect	Activity	Description of Hazard	Spatial and temporal scale	Potential Impacts	Sensitive receptors	Residual risk	Management strategy
			(approximately 5%) to break down over a longer period through biodegradation (BAS-210 0030; RPS, 2022).				
Release of dry natural gas from Bayu-Undan to Darwin pipeline	Trenching activities resulting in impact to the Bayu-Undan to Darwin pipeline.	Damage to the Bayu-Undan to Darwin pipeline (located approximately 50 – 100 m from the proposed DPD pipeline route) due to objects/equipment dropped or dragged onto the pipeline from vessels associated with trenching activities.	**Spatial** The scale of a pipeline leak is dependent on the nature of the damage. Small 'pinhole' leaks will result in a stream of bubbles which may dissolve before reaching the surface. A major rupture (e.g. catastrophic failure) would result in the discharge of a large of dry gas forming a large plume in the water column and dispersing into the atmosphere. A catastrophic failure is considered to be the worst-case credible release from the Pipeline. **Temporal** The duration of the release would be dependent upon the scale of damage with smaller leaks releasing more slowly than larger leaks. Once released the gas would disperse rapidly to the atmosphere.	The gas cloud may result in impacts to air-breathing fauna, such as marine mammals, marine reptiles and birds. Animals breathing in the immediate vicinity of the release may be asphyxiated, potentially resulting in mortality. Given the dispersion of gas into the atmosphere, this potential effect would be highly localised to the release location. Toxic impacts from entrained/dissolved gas (predominantly methane) within the water column is considered unlikely given it is a dry gas. The gas cloud poses a risk to the health and safety of other marine users. A gas cloud could potentially form an explosive mix which, if ignited, result in injury/death and damage to property. However, all other marine users will be excluded from the exclusion zone and therefore will not expected to be within 500 m of an event, if it occurs	+ **Marine environmental quality** (Water quality, ecosystem health and physical parameters that support socio-economic activities) + **Marine ecosystem** (Marine fauna and protected areas (Charles Point RPA) + **Community and economy** (Other users e.g. commercial and recreational activities)	Low	**Section 8.3.2.6**

7.6 Assessment of potential for cumulative impacts

7.6.1 Marine Environmental Quality

This TSDMMP's activities have the potential to elevate turbidity levels within Darwin Harbor due to sediment suspension. Sediment dispersion modelling completed for the DPD Project (BAS-210 0036; RPS, 2020) predicted that there will be no exceedance of suspended sediment concentration (SSC) zone of impact or influence thresholds where influence or impact to sensitive benthic habitats (hard corals and seagrass) could occur, and with modelling showing that sedimentation threshold exceedance would be restricted to within or immediately adjacent to the trenching footprint (refer to **Section 6.5.3**).

While these impacts are not predicted to be significant, if multiple dredging programs were to occur concurrently, or if nearby dredging programs were to occur in close succession to one another, there is an increased risk that the cumulative impacts may be greater than from any one activity. There are numerous variables which influence the potential magnitude of these impacts including proximity, duration and dredging methodology, as well as the volumes and type of dredged material. The type, sensitivity and resilience of the different receptors present are also factors that influence the potential for cumulative impacts. External factors such as weather and seasons can also influence the potential for cumulative impacts, as well as the availability of the appropriate dredging vessels and equipment which can limit a proponent's ability to schedule activities at a practical level to reduce or avoid concurrent activities.

The potential for cumulative impacts from marine dredging from proposed dredge programs in Darwin Harbour determined to have high or medium risk of cumulative impacts with the DPD project (refer to the SER for further details; BAS-210 0020) is shown in Figure 7-1 and summarised in **Table 7-8**.

This TSDMMP outlines the management strategies for trenching and disposal activities (refer to **Section 8**). The implementation of these strategies will assist in reducing the risk of adverse impacts that may result from the DPD Project and its interaction with other projects that may occur at the same timeframes or location.

Santos will liaise with relevant proponents and authorities on timeframes and locations and will work with these stakeholders to minimise the potential for adverse cumulative impacts where possible through their stakeholder engagement process (refer to **Section 11**)

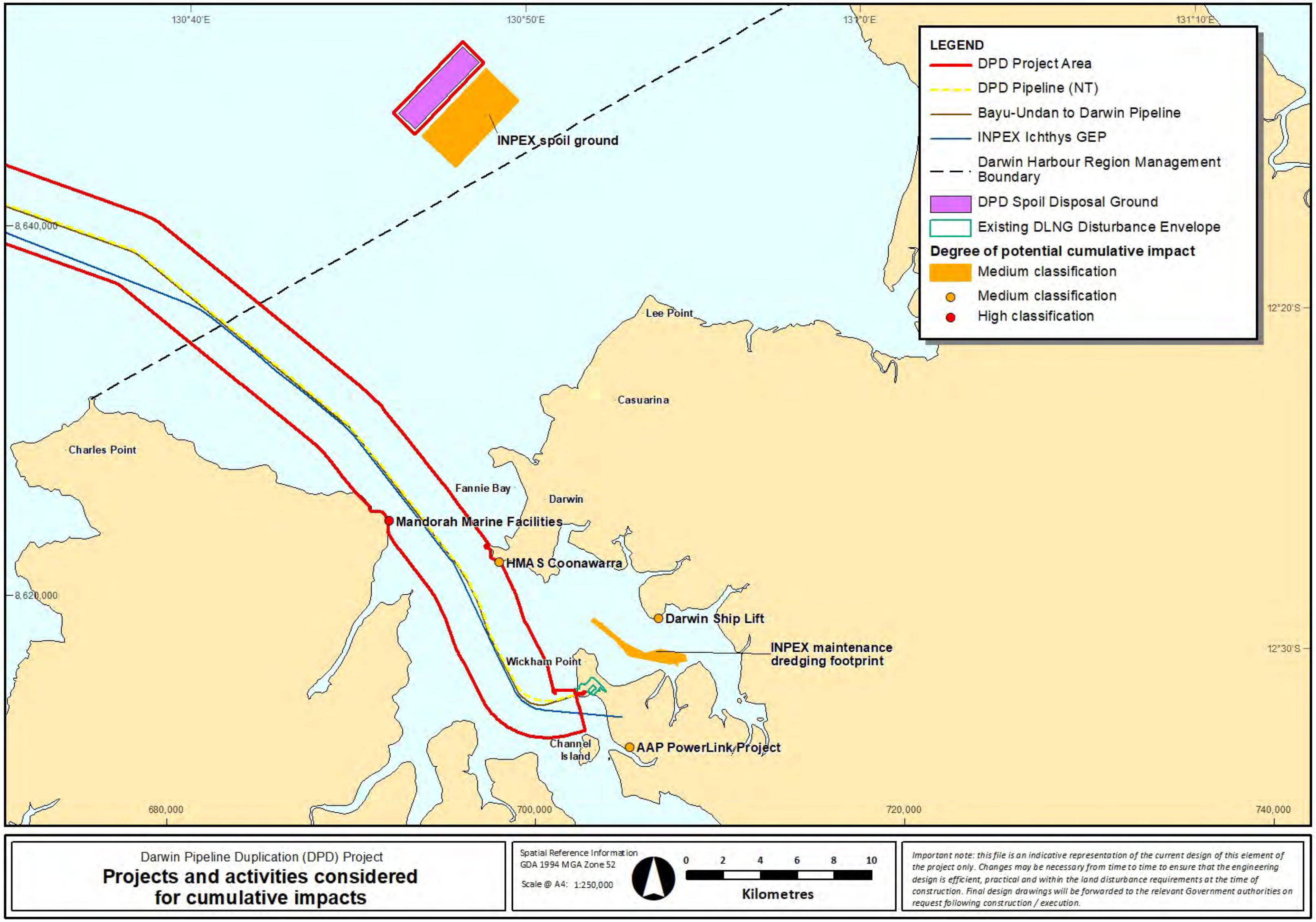


Figure 7-1: Projects and activities considered for cumulative impacts

Table 7-8: Potential for cumulative impacts from marine dredging from proposed dredge programs in Darwin Harbour

Proposed Project	Description
Mandorah Marine Facilities	The proposed Mandorah marine facilities (Mandorah project) covers an area of approximately 6 ha and involves dredging of an access channel, turning basin and berthing areas. The dredging footprint is approximately 1.5 km from the DPD Project pipeline route at its closest point (**Figure 7-1**). The draft dredging and spoil disposal management plan for the project states that 15,000 m^3 of unconsolidated marine sediments in Stage 1 and 70,000 m^3 of rock materials will be dredged for the project. Onshore disposal will occur for the rock and offshore for the unconsolidated sediments (Cardno, 2022c). Dredging of the unconsolidated marine sediments will be undertaken with a CSD and spoil will be disposed of by piping it offshore to a disposal site located approximately 600 m from the DPD Project pipeline route at its closest point and approximately the same distance from the nearest DPD Project trenching area (Trenching zones C1A and Pre-sweep Area 3, labelled as Trench Extent 6 and 10 respectively in **Figure 2-8**). The next closest trenching zone for the DPD Project is approximately 3 km south-east of the Mandorah project dredging footprint. To determine the potential for influence and impact to Marine Environmental Quality, sediment transport modelling (Cardno, 2022b) was undertaken using a similar approach to that used by Santos for the DPD Project. The modelling was used to identify potential impact zones including a Zone of High Impact (ZoHI), a Zone of Moderate Impact (ZoMI) and a Zone of Influence (ZoI) using thresholds for SSC and sedimentation for both dry and wet seasons, that were informed by INPEX Ichthys baseline water quality data (Cardno, 2022b; Cardno, 2022c). To evaluate the potential for cumulative impacts if both activities were to occur concurrently, the spatial extents of the worst case Zones of Influence (e.g. both wet and dry) from the spoil disposal site of the Mandorah project and the worst case Zone of Influence for the closest DPD Project trenching activities (CSD and TSHD trenching zones C1A and Pre-sweep Zone 3, labelled Trench Extent 6 and 10 respectively on **Figure 2-8**) were compared. This revealed that these Zones of Influence do not overlap and are separated by more than 400 m. Given this separation, the fact that the ZoI does not indicate impact, and the lack of sensitive receptor habitat (i.e. hard corals or seagrasses) between these areas, it is unlikely that there will be (or have any potential for) cumulative impact on water quality to the extent where this would influence benthic habitat. In a temporal context, dredging for the Mandorah project is currently scheduled for 2023 into 2024, and may occur concurrently with the overall DPD trenching program. The likelihood of concurrent and proximal trenching shall be established and temporal separation of the two capital dredging programs will be explored in collaboration with the Mandorah project to further minimise the potential for any cumulative impacts occurring.

Proposed Project	Description
	While there is predicted to be no overlap in zones of influence between Mandorah and DPD Project dredging/trenching activities, there could be interaction of turbidity plumes at very low concentrations, i.e. below the ZoI thresholds. It is considered that the greatest risk for interaction of turbidity between the Mandorah project and DPD Project activities is if the offshore disposal of sediments for the Mandorah project occurs concurrently with DPD Project trenching at the closest trenching and pre-sweep zones. Through consultation with DIPL, Santos understands the discharge is expected to be 3 – 6 weeks duration. Therefore, there is a reduced likelihood of this discharge and DPD trenching to be occurring at the same time and same place. Through continued consultation, opportunities to avoid spoil disposal/trenching operations at the same time in the same area will be explored.
INPEX – Ichthys Maintenance Dredging	INPEX is proposing to undertake maintenance dredging in East Arm, adjacent to the onshore Ichthys LNG facility and East Arm Wharf. The footprints of the proposed maintenance dredging and DPD trenching zones are > 5 km apart at their closest point near Wickham Point, and the spoil disposal area for each program are adjacent, with INPEX disposal grounds abutting the DPD disposal grounds to the southeast. Maintenance dredging proposed for INPEX shall occur in 2024 following completion of trenching for the DPD Project. The INPEX Maintenance Dredging and Spoil Disposal Management Plan (2023 – 2027) (INPEX, 2022) contemplates a scenario where the INPEX maintenance dredging and the DPD Project trenching operations could occur concurrently. The INPEX dredging area is over 4.5 km from the DPD Project pipeline route at its closest point and based on sediment transport modelling for both projects, there is no overlap of the ZoIs from these activities. When considering the INPEX spoil disposal activities at its offshore disposal site located over 15 km north-east of the closest DPD Project trenching zone (trenching zone C1A), there is no overlap of the ZoIs, however there is potential for excess suspended sediment (below ZoI threshold concentrations) to overlap. However, the concentration of the overlapping plume associated with trenching and spoil disposal is negligible (e.g. ≤1 mg/L) and over areas of soft bottom benthos/sediment so the potential for cumulative impact is not likely. The only exception are small, localised areas off Wagait Beach and the DLNG facility where modelling predicts small, localised areas of excess suspended sediment concentration plumes up to 2.5 mg/L. There is a small area of potential overlap of these modelled outputs, in particular the 3 – 5 mg/L contour in both the wet and dry season off Wagait Beach and 5 – 10 mg/L contour in both the wet and dry season adjacent to the DLNG facility. Based on this overlap, there is potential for cumulative 95th percentile excess suspended sediment plumes for the Project's maintenance dredging and DPD trenching to reach 7.5 mg/L off Wagait Beach and 12.5 mg/L adjacent to the DLNG facility for short periods of time. This is on the basis that the most intensive dredging for both campaigns is undertaken simultaneously, which is unlikely. Even if it were to occur, the area that the suspended sediment concentration overlap occurs over is soft bottom benthos/sediment, with no overlap with coral or seagrass habitat.

Proposed Project	Description
HMAS Coonawarra - Dredging and Dredged Material Management	Department of Defence proposes to carry out two capital dredging campaigns of approximately 100,000 m^3 – 120,000 m^3 as part of upgrades to the Royal Australian Navy wharf facilities and basin navigation area at HMAS Coonawarra, which is approximately 1.8 km from the closest part of the DPD Project pipeline route (**Figure 7-1**). The first of those campaigns is referred to as NCIS-5 and is expected to occur in 2023, prior to commencement of DPD Project construction. The proposed action includes ongoing maintenance dredging at HMAS Coonawarra in the order of 10,000 m^3 to 15,000 m^3 every 5 – 7 years (NT EPA, 2022). Dredged spoil from operation of a CSD will be pumped via a pipeline to a location approximately 300 m southwest of HMAS Coonawarra breakwater for disposal into the channel. This location is approximately 1.5 km away from the nearest part of the DPD Project pipeline route and approximately the same distance away from the nearest pre-sweep area (labelled Trench Extent 5 in **Figure 2-8**). A small amount of hard pegmatite rock may need to be removed by BHD if the CSD cannot remove, if this is the case, associated BHD spoil will be disposed onshore. The NCIS-5 - HMAS Coonawarra Draft Dredging and Disposal Management Plan (KBR, 2022) presents modelled ZoIs and ZoMIs informed by sediment dispersion modelling. Comparing the worst-case extent for a Zone of Influence from the NCIS-5 dredging with a worst-case ZoI for the DPD Project (i.e. associated with pre-sweep in Trench Extent 5) reveals that these zones do not overlap and are approximately 900 m separated at the closest point which is west of the disposal site. Given this separation and the lack of sensitive receptor habitat (i.e., hard corals or seagrasses) between these areas, it is unlikely that there will be a cumulative water quality (turbidity/sedimentation) influence on either water quality or benthic habitat from these projects, noting also they are not expected to be occurring at the same time. It is expected that Coonawarra dredging will be separated in time with DPD Project dredging, with NCIS-5 dredging expected to occur during 2023 and over a period of 2 months while DPD Project trenching will not occur until 2024. Given this, and also the spatial separation of zones of influence between these projects there is considered to be a low likelihood of impacts to benthic habitats from cumulative effects on water quality from these dredging/trenching campaigns. Santos will consult with the Department of Defence on the timing of dredging programs and management of any potential cumulative impacts.
Darwin Ship Lift and Marine Industries Project	The NT Government is proposing to deliver the Darwin Ship Lift and Marine Industries Project, which includes the construction of northern Australia's largest common user ship lift and adjacent maintenance facility in East Arm (AECOM, 2021). Construction requires the dredging of approximately 500,000 m^3 to create an access channel, manoeuvring/turning basin and berth pockets. All dredged material will be placed onshore, and where possible utilised for land reclamation. At its closest point, Ship Lift facilities are >5 km (closest straight line distance) from the DPD Project shore crossing, although Middle Arm lies between these two points. The

Proposed Project	Description
	original construction schedule indicates dredging operations will occur between Q4 2022 and Q2 2024 inclusive (AECOM 2021), however the main construction contractor, Clough, went into voluntary administration in December 2022 and was acquired by Webuild in February 2023. This may delay the Project. This small overlap on proximal projects modelled in a worst-case credible scenario suggest that the potential for cumulative impact with the DPD Project, which is at its closest point 5.5 km to the southwest, is unlikely. As per the Draft Dredging and Spoil Disposal Monitoring and Management Plan (AECOM, 2022) the modelled distribution of dredging and tailing disposal turbidity and sedimentation are very localised to the Ship Lift construction footprint and the closest ZoI from dredging is >5 km away from the closest ZoI from DPD Project trenching. Therefore there is no overlap in areas where water quality could potentially influence benthic habitat.
Australia-Asia Powerlink Project	The Australia-Asia PowerLink (AAPowerLink) by Sun Cable proposes to install three subsea cable systems extending from a cable transition facility near Gunn Point, to Singapore (Sun Cable, 2022). There are currently two proposed cable routes, both run west from Gunn Point and either pass to the approximately 3 km south or 1 km north of the dredge spoil disposal areas of the DPD project and INPEX. The AAPowerLink alignments cross the DPD alignment approximately 16 km and 30 km offshore respectively. Installation requires open trenches (one for each cable) to be excavated through the intertidal zone using conventual excavators (shore or barge based), which will be back filled with excavated material once cable pull is complete. Subtidal cable once laid, will be buried using high-pressure water injection or jet trenching, with the latter suited to intertidal and shallow water sections. The jetting system works by fluidising the seabed sediment causing the cable to sink under its own weight through the fluidised sediment, with sediment returning to their pre-jetted condition once jetting ceases. Jetting and subsequent fluidisation causes sediment to enter the water column where it can be transported to the far-field and potentially impact sensitive receptors similar to dredging and spoil disposal. Modelling of jetting was completed assuming simultaneous burial of all three cables starting at the Gunn Point shore crossing moving along the cable route for 50 km over a seven-day period and repeated three times (i.e. three passes of jet trencher) to achieve modelled burial depth (Sun Cable, 2022). The modelling used predicted turbidity levels to identify High, Medium and Low risk zones (for impact), but none of these zones overlap the DPD Project Zone of Influence for the spoil disposal site. While there is no overlap in the ZoIs predicted, if the activities were to occur concurrently, there could be interaction of turbidity plumes at very low concentrations, i.e. below the ZoI thresholds. However, even if this were to occur, the lack of sensitive habitats in the area means there is a very low likelihood of potential for cumulative impacts.

Proposed Project	Description
	Given the recent decision for Sun Cable to enter into voluntary administration, the likelihood of concurrent dredging in areas in proximity to the DPD Project dredging and spoil disposal area is low. Nonetheless Santos will remain in consultation with Sun Cable to determine likelihood of any potential conflicting or concurrent dredging programs with a view to minimising the potential for any cumulative impacts where possible.

7.6.2 Marine Ecosystems

Impacts to Marine Ecosystems have been presented in the SER (BAS-210 0020) and summarised in **Section 7.5** and the residual impacts from the DPD planned activities were assessed to be Minor or Negligible. Consequently, it is unlikely that the Project activities could contribute towards a significant impact. However, the potential for cumulative impact from direct and indirect seabed disturbance and from noise and unplanned vessel interactions has been assessed in the following sections.

7.6.2.1 Cumulative direct habitat disturbance

Direct impacts to seabed habitats from planned events will be restricted to the DPD Project infrastructure footprints, including the spoil disposal ground which do not overlap with other current, or proposed project activities. The benthic habitats under the DPD Project infrastructure footprints comprise predominately filter feeders which are widely represented elsewhere in Darwin Harbour and the wider region. No sensitive hard coral or seagrass habitats are at risk from direct impact. Consequently, direct impact is not expected to have a significant impact to the function of the ecosystem and while other current and proposed activities will also have direct impacts to benthic habitats, overall spatial overlap is minor and indicates cumulative impacts are unlikely to be significant.

Based on the calculations presented in (BAS-210 0020), the direct and indirect impact to benthic habitats from the Project make up ~ 0.12% of the bare ground, <0.12% of the macroalgae and <0.18% of the sponge or sponges/filterers/octocoral habitat in Darwin Harbour. The habitat loss predicted by the Mandorah Marine Facilities (Cardno, 2022a) is <0.001% of coral, 0.04% of sponge and 0.02% of seagrass along the east side of Darwin Harbour (Note, as the percentage loss is given as a proportion of the habitat along the east side of Darwin Harbour, the loss as a percentage of habitats across Darwin Harbour would be considerably smaller). In the Ichthys EIS supplement (INPEX Browse Ltd, 2011) predicted the loss of 0.9% of coral and filter-feeder habitat, 0.8% loss of macroalgae, and <5% of sand, mud and gravel. While no data for the Bayu-Undan to Darwin pipeline were available, a conservative approach would be to base habitat loss on the current Project given its parallel alignment and similar installation methods.

When the benthic loss from each of these projects is combined (conservatively), less than 5% of the bare ground, <1% of hard coral, seagrass macroalgae and sponges or sponge/filterer/octocoral habitat found across Darwin Harbour has or will be lost from these developments. Other projects that are proposed, such as the INPEX maintenance dredging, the Ship Lift and Marine Industries Project and the HMAS Coonawarra dredging programme all predict no impact to seagrass, coral or macroalgae, suggesting any cumulative impact to benthic habitats would be the loss of bare sediment or to be very conservative, loss of filter feeder habitat which is the most abundant habitat type found across Darwin Harbour.

However, while there has been/would be loss of particular benthic habitats, these habitats have been/will be replaced by additional hard substrate in the form of pipelines and other infrastructure. Recent studies investigating habitats and fish associated with oil and gas infrastructure, including the existing Bayu-Undan to Darwin pipeline (McLean *et al.*, 2021) documented that the sessile biota growing on the pipeline, which included potential prey for marine turtles such as soft corals and sponges, had much higher densities compared to the habitats surrounding the pipeline where such biota were wither absent, or present at much lower densities. Furthermore, the fish assemblages observed on and around subsea pipelines, are of higher diversity than those found off the pipelines (McLean *et al.*, 2020) and there is evidence in the literature that the presence of such subsea infrastructure can promote biodiversity and abundance through an increase in habitat complexity and crevices (McLean *et al.*, 2022).

7.6.2.2 Cumulative indirect habitat disturbance

Indirect impacts to marine ecosystem, e.g., from increased SSC and sedimentation from the DPD Project will be temporary and have been predicted to be low. As the spatial extent of potential indirect impacts have also been predicted to be restricted to footprints where direct impacts will occur, and similarly ZoIs are within or very localised around footprints, it is unlikely that the DPD Project could contribute to significant cumulative indirect impacts. While other current and proposed activities will also have indirect impacts to benthic habitats, as there is no overlap in ZoIs form other dredging project and the DPD Project (refer to **Section 7.6.1**) and the habitats that may be impacted from other dredging projects are well represented across Darwin Harbour, there is a low likelihood that cumulative impacts could become significant.

This argument extends into the assessment as to whether cumulative impact (direct and indirect) of benthic habitats could indirectly impact marine fauna. While some of the habitats that will be impacted by current and proposed activities provide foraging material and habitat for a range of marine fauna including reptiles and fish, the proportionately small loss of habitat as a percentage of that available in Darwin Harbour (quantified above) is unlikely to have an indirect impact on those fauna or the wider ecosystem function, especially where habitat is being replaced with infrastructure which can improve diversity and provide hard substrate that can be exploited by sessile biota which in turn can become a source of food for marine fauna.

8 Environmental Management Strategies

This section outlines the environmental management strategies (EMSs) that will be implemented for trenching and spoil disposal activities to reduce and mitigate impacts and risks to the environment.

The EMSs to be implemented as part of this TSDMMP comprise of the following:

+ Management of trenching related water quality and benthic habitat impacts (**Section 8.2**)
+ Management of other trenching-related impacts (Section 8.3)

These EMSs outline environmental performance objectives (EPOs), measurable targets and the management actions (MA) in place to ensure that the EPOs and targets are met. Performance Indicators and monitoring activities (where applicable) are used to quantify success in meeting targets and identify the need for corrective actions. This provides a mechanism for improving the effectiveness of the Project's EMSs. The EMSs define the reporting requirements, terms, and responsibilities.

All EMSs are structured to align with the template presented in **Table 8-1**.

Table 8-1: Environmental management strategy template derived from the NT EPA Draft Guideline for the Preparation of an Environmental Plan (NT EPA, 2022)

Item	Content
Environmental Performance Objectives (EPO)	Environmental management goal(s) tailored to each aspect per NT EPA requirements.
Target	Aspect specific measurable performance necessary to successfully achieve objective. Part 1 of NT EPA required performance criteria.
Performance Indicator	Quantitative or qualitative measures representing the performance related to Target(s). Part 2 of NT EPA required performance criteria.
Management actions	Measures or actions that will be used to achieve objective/s. For example, trained and competent anchor handling operators will be used

8.1 NT EPA environmental management hierarchy

In the development of the management strategies outlined within this TSDMMP Santos applied the Environmental Decision-Making Hierarchy outlined within the EP Act. This hierarchy being:

a. To ensure that actions are designed to avoid adverse impacts on the environment

b. To identify management options to mitigate adverse impacts on the environment to the greatest extent practicable

b. And if appropriate, provide for environmental offsets in accordance with the EP Act for residual adverse impacts on the environment that cannot be avoided or mitigated[3]

[3] No offsets were deemed appropriate for this project.

8.2 Management of trenching-related water quality and benthic habitat impacts

This EMS does not cover management measures associated with potential acid sulfate soils within the shore crossing area. This is outlined specifically within the ASSDMP (BAS-210 0049).

Management of sediment related impacts has been informed by the sediment related management framework developed in INPEX Ichthys Project: Dredging and Spoil Disposal Management Plan and INPEX Ichthys Project: Maintenance Dredging and Spoil Disposal Management Plan (INPEX, 2014; INPEX, 2018; INPEX, 2022).

8.2.1 Environmental performance objectives, performance criteria and management actions

The EPOs and performance criteria relevant to this impact are described in **Table 8-2**.

Table 8-2: Seabed and benthic habitat disturbance EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Minimise direct impacts to sensitive marine habitat, cultural and socio-economic sensitivities	Pipeline alignment and trench areas designed to minimise trenching requirements and direct footprint of seabed disturbance	+ Quantitative risk assessment (BAS-201 0925) + Nearshore pipeline route selection report- Darwin Harbour (BAS-200 0642)
	No trenching outside the boundaries of the trench areas	+ Nearshore pipeline trench and trench backfill alignment details 34in northern route (BAS-200 0523 001) + Trenching out-survey reports
	No anchoring on sensitive seabed areas	Incident reports of anchoring inside anchoring exclusion zone
	No damage to known heritage sites of significance or existing submerged infrastructure	Incident reports of damage to heritage sites/ artefacts of significance, or existing infrastructure
	All unexpected finds managed as per Unexpected Finds Protocol (BAS-201-0051)	Records indicating unexpected finds are managed per the Offshore Development Unexpected Finds Protocol (BAS-210 0051)

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Avoid sediment dispersion and sedimentation related impacts on seagrass and hard coral habitats from trenching and spoil disposal activities	No DPD Project related impact to seagrass or hard coral from trenching or spoil disposal turbidity	+ Water quality and benthic habitat monitoring data (refer to **Section 9**) + Attributability assessments
Minimise impacts from spoil disposal	No spoil disposal outside of DPD spoil disposal ground	+ During and post spoil disposal Hydrographic surveys + Spoil disposal logs

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Coastal processes – Protect the geophysical and hydrological processes that shape coastal morphology so that the environmental values of the coast are maintained.
+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.
+ Culture and heritage – Protect culture and heritage.

The management actions for this impact are detailed in **Table 8-3**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-3: Management action for trenching related seabed and benthic habitat disturbance

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA12	Pipeline route was surveyed (geophysical and geotechnical) to evaluate the seabed and designed to avoid seabed features, known heritage sites and to minimise trenching/rock protection as far as possible while maintaining safety requirements Trenching will only be undertaken at identified areas (using standard positional accuracy measures used in the industry)
Mitigation	
DPD-MA13	Overflow from the TSHD will be undertaken through the adaptive management processes (if triggered) There will be 'environmental valve', 'green valve' where available (attached to O/F to reduce air entrained, to reduce billowing and facilitates sediment sinking) as standard which will be used as a first step
DPD-MA14	Standard operating procedure for spoil disposal will be used.
DPD-MA15	Spoil will not be disposed of in a single location, to avoid developing a single large mound.
DPD-MA16	Spoil will only be placed *in situ* within a short section of trenching within intertidal zones to keep wet under most tidal conditions and will be removed subsequently where accessible by BHD and SHB for offshore disposal
DPD-MA18	Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, trenching and other support activities in the vicinity of sensitive habitats and nearshore heritage or sacred sites
DPD-MA29	Trained and competent anchor handling operators will be used
DPD-MA20	Anchors exclusion areas will be implemented to avoid sensitive habitats and heritage sites
DPD-MA21	Independent cultural heritage and habitat assessment have been undertaken to identify potential important heritage sites and habitat along the pipeline route and to avoid sensitive benthic habitats and cultural objects where practicable. Maritime cultural heritage objects that cannot be avoided will be managed as per NT Heritage Branch requirements
Monitoring	

MA reference	Management actions
DPD-MA28	Adaptive management process as defined in Section 8.6.2.4 which includes environmental monitoring of water quality with management measures applied if water quality exceeds trigger levels

Table 8-4: Additional management action not adopted for trenching related seabed and benthic habitat disturbance

Additional management actions not adopted		Reasoning for rejection
1	No trenching using CSD	It is not technically feasible to stabilise and protect pipeline without trenching. The use of CSD is a mitigation for dredging consolidated material and variations from design in realised conditions. Not utilizing the CSD may pose substantial schedule and cost impacts if harder soil types are encountered on the operating limits of the TSHD and BHD.
2	No trenching using TSHD	It is not technically feasible to stabilise the pipeline without trenching.
3	No trenching using BHD	It is not technically feasible to stabilise the pipeline without trenching.
4	Restrict timing of activities to operate outside of known sensitive periods only. Flatback turtle peak nesting period is May to October and Dolphin peak calving is October to April.	The beaches closest to the Project Area (Casuarina Beach, Cox Peninsula) are not considered regionally significant turtle nesting beaches. It is also not considered ALARP to prevent trenching in peak dolphin calving period due to cost and schedule implications. Monitoring programs have been unable to determine spatial and temporal patterns in occurrence and abundance of dolphins in Darwin Harbour or any links to anthropogenic activities and behavioural disruption. Trenching areas are adjacent high use areas for vessels and the effects of turbidity are expected to be minor in the context of natural variability.
5	No offshore spoil disposal	The only alternative is for onshore disposal of spoil, however the additional time in the field that would be required, would be prohibitive and greatly prolong impact to other users of Darwin Harbour. Given the minor impacts predicted from the offshore disposal of spoil, this control is rejected. There are currently no viable options for the re-use of spoil available.
6	Spoil to be disposed of in a manner to create a uniform thickness of spoil	Spoil will not be disposed in one area only however it cannot be guaranteed to be uniformly spread. The additional time and effort to ensure uniform thickness of spoil is not reasonably practicable in comparison to any potential benefits. Sediment modelling has not identified re-suspension and ongoing transportation of sediments to be significant.

8.2.2 Adaptive monitoring/management strategy

The adaptive monitoring/management strategy for trenching related water quality and benthic habitat impacts has been developed to adapt management actions if associated triggers are exceeded to ensure EPOs are met. The strategy includes a tiered pressure-response strategy (in accordance with the NT EPA Draft Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory; NT EPA, 2013) based on turbidity monitoring, with management response escalation proportionate to the risks to sensitive receptor communities. The environmental monitoring program (**Section 9**) is therefore based on turbidity data as the lead indicator for environmental quality deterioration resulting from trenching activities. This allows trenching operations to be managed appropriately to prevent or mitigate the potential ecological impacts to an agreed level and remove the requirement for immediate/intensive sensitive receptor monitoring. A three-tiered approach to trigger levels, consistent with that included in INPEX Ichthys dredge management plans, has been applied as follows (refer to **Figure 8-1**, **Table 8-6** for adaptive management decision tree and adaptive management actions):

1. **Level 1 triggers** are early warning indicators. They indicate when environmental quality conditions are nearing the limits of the background conditions that receptors are naturally exposed to. Exceedance of Level 1 triggers does not require any alterations to the trenching operation but does necessitate an attributability assessment to determine if the exceedance is related to the DPD Project trenching activity and investigation into potential improvements to optimise trenching work method.
2. **Level 2 triggers** are the limits of the background conditions that receptors are naturally exposed to. Exceedance of Level 2 triggers (if attributable to dredging) result in the implementation of responsive management actions to reduce turbidity measurements to within Level 1 triggers. Once implemented adaptive management can only cease and normal operations recommence once turbidity measurements have returned below Level 1 trigger values.
3. The **Level 3 trigger** is an exceedance of an allowable duration. If a Level 2 trigger has been reached, and found to be attributable to dredging, and turbidity does not return to below the Level 1 trigger within seven days after the implementation of Level 2 responsive management, contingency management actions must be implemented until turbidity has returned below Level 1 trigger values. Normal operations cannot recommence until turbidity has returned below Level 1 trigger values.

To reduce the potential impacts resulting from the cumulative impact of increased SSC and increased water temperatures on coral communities' trigger values for water temperature will be implemented. If the 21-day rolling average for water temperature exceeds the trigger value outlined of 31°C at the reactive sites, then appropriate responsive management actions will be implemented (**Table 8-6**).

A habitat trigger will not be adopted as part of the adaptive management for trenching. The time lag between surveys and data analysis means is too long for reactive management given the total proposed duration of trenching, i.e., trenching in any specific area would have been completed before results are returned. Instead, the proposed WQ monitoring would report any exceedance of triggers within 24hrs of occurrence. Additionally, WQ is a leading indicator and the triggers defined are conservative and will therefore effectively mitigate any potential impacts to benthic habitats.

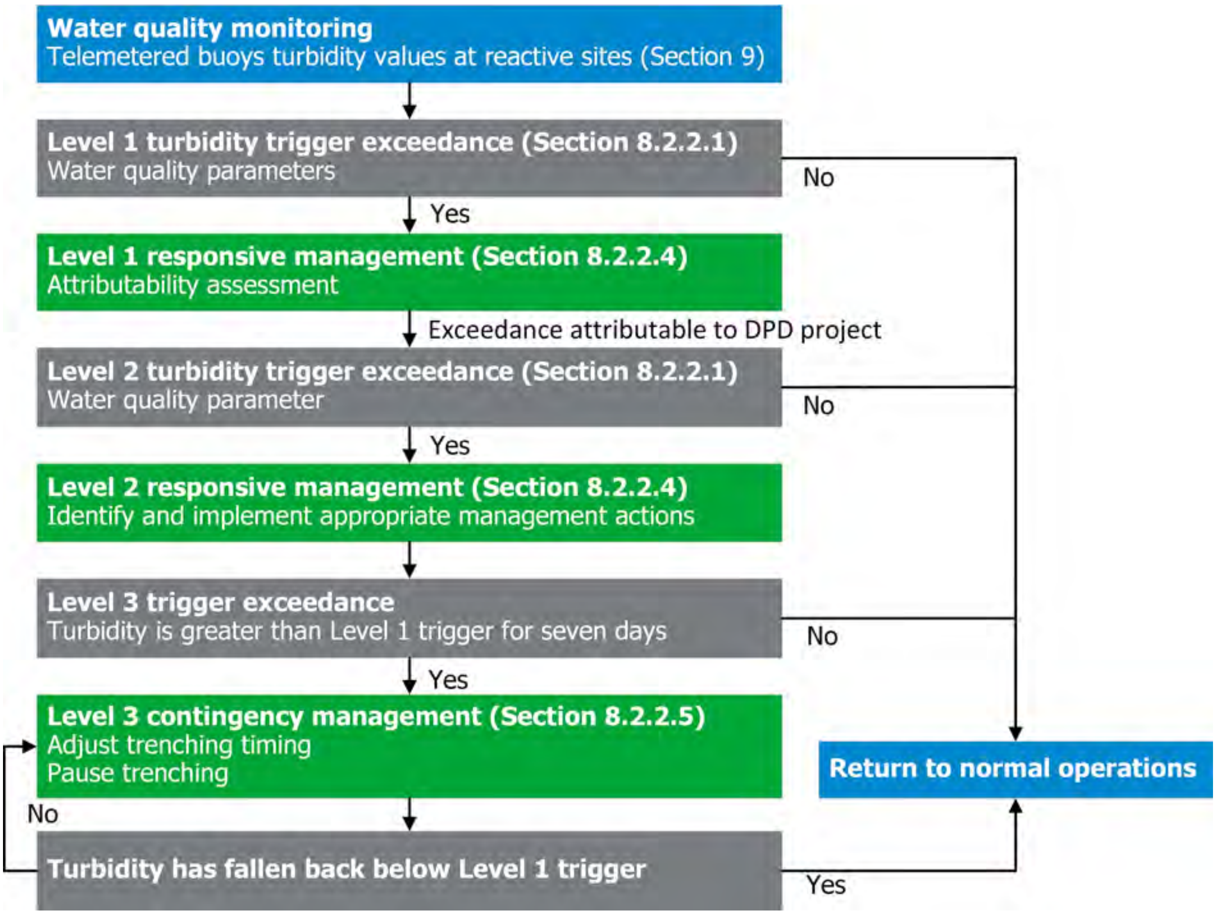


Figure 8-1: Decision tree outlining practise for turbidity triggers

8.2.2.1 Management triggers values

Management trigger values for this TSDMMP are based upon the methods used to develop triggers for INPEX's Maintenance Dredging and Spoil Disposal Management Plan (INPEX, 2018; INPEX, 2022). As there were no recorded declines in sensitive receptors (seagrass and coral) health attributed to dredging activity detected during INPEX's capital dredging campaign, triggers could not be derived based on dredging-related turbidity and impacts to sensitive receptors. Therefore, the following conservative method of establishing turbidity triggers has been implemented for this TSDMMP.

A habitat trigger will not be adopted as part of the adaptive management for trenching. The time lag between surveys and data analysis means is too long for reactive management given the total proposed duration of trenching, i.e., trenching in any specific area would have been completed before results either do or do not indicate an impact. Instead, the proposed water quality monitoring (**Section 9**) would report any exceedance of triggers within 24hrs of occurrence. Additionally, water quality is a leading indicator and the triggers defined are conservative and will therefore effectively mitigate any potential impacts to benthic habitats.

The method used by INPEX was based on McArthur *et al.* (2002) and Jones *et al.* (2015), and summarised as follows:

- The use of local data within which water quality is to be maintained.
- Recognition that impacts to sensitive receptors are not solely caused by increased turbidity, but also the duration and frequency of exposure events, relevant to natural ranges.
- Management triggers to be developed for both acute and chronic events.

In line with INPEX's DSDMP, only acute triggers are deemed relevant due to the relatively short duration of Santos' trenching campaign.

The management triggers were derived for this TSDMMP are site-specific and based on long-term baseline turbidity data collected at sites relevant to the DPD Project from January 2010 to January 2011 and August 2012 to January 2015, excluding periods of dredging activity (INPEX, 2018). Data recorded during extreme rainfall events were also excluded from the dataset used to develop triggers as it was noted that these events led to the calculated trigger being much greater at certain sites. Therefore the exclusion of these data has resulted in more conservative trigger values. Extreme rainfall events were defined as exceedances of the 95th percentile for wet season mean daily rainfall events and were developed from the rainfall data collected at the Bureau of Meteorology Channel Island weather station between 1991 – 2018. Refer to **Section 9.3.1** for details of the sites selected for the derivation of management triggers and therefore trigger exceedance monitoring (termed reactive sites).

Level 1 and Level 2 turbidity triggers were developed from daily average turbidity and are comprised of a turbidity value and allowable duration that both need to be exceeded for an exceedance to occur.

Level 1 trigger turbidity values are the 95th percentile of the daily average turbidity data recorded. The allowable duration was then developed by reviewing the dataset to determine the number of consecutive days the turbidity values were exceeded, collectively known as individual event. The 95th percentile for individual events was then identified as the allowable duration. Therefore, providing the allowable number of consecutive days the turbidity value can be exceeded.

Level 2 trigger turbidity and allowable duration values were developed using the same method as Level 1 triggers, except the turbidity values are represented by the 99th percentile of daily average turbidity data. Allowable duration trigger was then developed by reviewing the dataset to determine the number of consecutive days the 99th percentile turbidity value was exceeded (i.e., individual events). The 95th percentile for individual events was then identified as the allowable duration.

Table 8-5: Level 1 and 2 turbidity management trigger criteria for trenching related seabed and benthic habitat disturbance

Monitoring site	Season	Level 1 trigger (daily average) >intensity value & >duration or > frequency			Level 2 trigger (daily average) >intensity value & >duration or > frequency		
		Intensity (95th %ile)	Duration (consecutive days)	Frequency (days per 7 day rolling period)	Intensity (99th %ile)	Duration (consecutive days)	Frequency (days per 7 day rolling period)
Channel Island	Wet season	24 mg/L	7	6	49 mg/L	3	3
	Dry season	15 mg/L	4	4	19 mg/L	3	3
Weed Reef	Wet season	31 mg/L	7	6	67 mg/L	2	2
	Dry season	11 mg/L	5	4	15 mg/L	3	3
Woods Inlet	Wet season	16 mg/L	2	2	20 mg/L	1	1
	Dry season	15 mg/L	4	4	20 mg/L	2	2
Charles Point	Wet season	22 mg/L	3	3	27 mg/L	1	1
	Dry season	23 mg/L	4	4	26 mg/L	2	2
Mandorah	Wet season	13 mg/L	1	1	15 mg/L	1	1
	Dry season	16 mg/L	4	4	20 mg/L	2	2

8.2.2.2 Adaptive management actions

Adaptive management actions that will be implemented following the exceedance of a trigger are detailed in **Table 8-6**.

Table 8-6: Adaptive Management Mechanism for trenching related seabed and benthic habitat disturbance following trigger exceedance

MA reference	Management Actions
Level 1 exceedance responsive management actions	
DPD-RMA01	Santos will conduct attributability assessment and liaise with other proponents with concurrent dredging operations in Darwin Harbour.
DPD-RMA02	Dredging Contractor in consultation with Santos (and other concurrent Darwin Harbour dredging operations, as applicable) will assess potential opportunities for continuous improvement
Level 2 exceedance (attributable to trenching) responsive management actions	
DPD-RMA04	Dredging Contractor in consultation with Santos (and other concurrent Darwin Harbour dredging operations, as applicable) will: + Implement applicable responsive management actions from the following: – Investigate potential changes to dredge methods to improve water quality – Changing location of trenching to another trenching zone – Reduce dredge overflow – Change disposal location within spoil disposal ground + Where applicable prepare an implementation strategy for adaptive management actions.
DPD-RMA05	Santos will inform NTEPA and DEPWS of exceedance and management actions taken
Level 3 exceedance (attributable to trenching) contingency management actions	
DPD-CMA01	Dredging contractor in consultation with Santos (and other concurrent Darwin Harbour dredging operations, as applicable) will: + Implement applicable contingency management actions (identified based on investigation of impacts): – Trenching operation timing e.g. night/day – Pause trenching activities
DPD-CMA02	Implementation of benthic habitat monitoring at exceedance site/s and control sites to determine if any trenching-related impacts to hard corals and/or seagrass condition has occurred

MA reference	Management Actions
DPD-CMA03	– Santos will notify NT EPA and DEPWS within 24 hours
DPD-CMA04	Santos will demonstrate that applicable contingency management action/s are suitable for mitigation of impacts.
DPD-CMA05	Santos to review telemetered environmental quality data to ensure implemented contingency management action/s are effective.
Coral temperature trigger exceedance responsive management actions	
DPD-RMA01	Conduct attributability assessment to determine if trenching is raising turbidity at the site/s showing the coral temperature trigger exceedance. If trenching is attributable to an increase in turbidity, dredging Contractor in consultation with Santos will: + Implement applicable responsive management actions from the following: – Investigate potential changes to dredge methods to improve water quality – Changing location of trenching – Reduce dredge overflow – Change disposal location within spoil disposal ground

8.2.2.3 Attributability to trenching

If triggers are exceeded the cause of the exceedance needs to be investigated initially to define whether it is attributable to DPD Project trenching and/or spoil disposal activities. The attributability process is initially started by determining whether the data collected is reliable. If an exceedance is found to not be valid due to data quality issues (e.g. fouling on sensors), then management actions are limited to those required to reduce the likelihood of future data quality issues.

If data is considered reliable then multiple lines of evidence will be explored to investigate the cause of exceedance per the recommendations from ANZG (2018). Below is all information considered in attributability investigation:

+ Weather and oceanographic conditions prior to and during exceedance.
+ Water quality from telemetered buoy sites and from regional remote sensing imagery
+ Sediment characteristics at dredging sites
+ Location of monitoring site recording exceedance in relation to recent DPD Project trenching and spoil disposal activities
+ Relationship between the nature of recent DPD Project trenching activities and start of exceedance
+ The activities of any other concurrent dredging operations within Darwin Harbour and the potential effect on water quality from these concurrent operations.

This assessment of evidence will likely utilise published scientific literature and tools including:

+ Hydrodynamic model outputs such as predicted current speed and direction
+ Sediment dispersion modelling predictions of excess SSC occurrence related to trenching activities (RPS 2022).

If following the investigation of attributability, the exceedance is found to be attributable to trenching activities, then appropriate responsive management actions will be implemented if Level 2 triggers are exceeded (**Section 8.2.2.4**). It is important to note that an exceedance attributable to trenching activity may not always indicate adverse ecological impacts. This particularly applies to Level 1 exceedances as they are an early warning indicator, identifying that turbidity levels are approaching the limits of natural conditions. Level 2 exceedances will result in the identification and execution of responsive and if necessary, contingency management actions and will consider multiple factors that are discussed in the following sections.

Where an exceedance of the Level 2 triggers occurs but the attributability assessment has determined it is due to natural events (i.e. not attributable to dredging), the relevant NT EPA and Northern Territory Government departments will be notified and no further action will occur.

8.2.2.4 Responsive management

If a Level 2 exceedance occurs and is determined to be attributable to DPD Project trenching activities, responsive management actions will be implemented. Trenching activities return to normal operations once turbidity has returned to below Level 1 trigger values. A summary of adaptive responsive management actions considered practicable to reduce and/or mitigate turbidity have been listed in **Table 8-6**. Where there are concurrent dredging operations in Darwin Harbour, and there is evidence that concurrent dredging operations are affecting water quality at monitoring sites, responsive management will be done in consultation and coordination with other dredging operators.

8.2.2.5 Contingency management

If turbidity values do not return below Level 1 exceedance triggers within seven days of adaptive management actions being implemented, the Level 3 trigger is exceeded and contingency management actions will be implemented. Trenching activities can only return to normal operations once turbidity returns below Level 1 exceedance trigger. A summary of contingency management actions considered practicable to reduce turbidity are listed in **Table 8-6**. Additional to management measures, benthic habitat monitoring will be conducted at monitoring site/s showing a Level 3 exceedance, and at reference sites, to determine if exceedances have impacted seagrass and/or hard corals present at the sites. Monitoring results will be compared to baseline results collected prior to trenching (refer to **Section 9**)

Where there are concurrent dredging operations in Darwin Harbour, and there is evidence that concurrent dredging operations are affecting water quality at monitoring sites, contingency management will be done in consultation and coordination with other dredging operators. The NT EPA will be notified of proposed additional contingency management actions by Santos prior to their implementation. The appropriateness of contingency management actions will be interpreted, validated, and justified by dredging contractor and approved by Santos prior to notification of NT EPA.

8.3 Management of impacts and risks

8.3.1 Other planned events impacts

Santos' environment assessment identified an additional five potential sources of environmental impact associated with the planned activities to be undertaken in the Project Area. Management strategies have been adopted in the TSDMMP based on the ENVID undertaken for DPD Project trenching and spoil disposal activities in May/June 2022 (Refer to **Section 7.2**).

8.3.1.1 Interaction with other marine users – construction activities and Project infrastructure

8.3.1.1.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact including performance criteria are described in **Table 8-7**.

Table 8-7: Interaction with other marine users (including construction activities and Project infrastructure) EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Avoid incidents resulting from interaction with other marine users	Zero incidents resulting from interactions.	Incident records of interactions with other marine users
Minimise impacts to other marine users	Zero impacts to other marine users on completion of DPD trenching and spoil disposal activities	Number of complaints from other marine users following completion of DPD trenching and spoil disposal activities
Stakeholders are well-informed of the DPD Project and its associated restrictions	DPD Project stakeholder list is provided activity update/s and notification of commencement of trenching and spoil disposal activities	Stakeholder notification records

The EPOs detailed in this TSDMMP are in line with the following objective for the relevant NT EPA factor (NT EPA, 2021):

+ Community and economy – Enhance communities and the economy for the welfare, amenity and benefit of current and future generations of Territorians.

The management actions for this activity are shown in **Table 8-8**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-8: **Management actions for trenching vessel interaction with other marine users**

MA Reference	Management Action
Standard management actions	
Mitigation	
DPD-MA04	Activity vessels equipped and crewed in accordance with Australian maritime requirements
DPD-MA05	Ongoing stakeholder consultation with relevant stakeholders and marine users (including applicable notifications) to minimise adverse impacts on other marine users
DPD-MA06	Implementation of precautionary zones around DPD Project vessel to mitigate against adverse interactions
DPD-MA07	Vessels supporting the trenching operations will act as surveillance vessels when operating adjacent to the trenching vessels

8.3.1.2 Noise emissions

8.3.1.2.1 Environmental objectives, performance criteria and management actions

The EPOs relevant to this impact including performance criteria are described in **Table 8-9**.

Table 8-9: Noise emissions EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Avoid hearing injury impacts to protected marine species from underwater noise generated by DPD Project trenching and spoil disposal activities	Zero incidents of injury or mortality to EPBC Act listed marine fauna from noise generated during DPD trenching and spoil disposal activities	+ Incident reports of injured or dead EPBC Act listed fauna + MFO records of EPBC Act listed fauna within vessel observation/exclusion zones
	Zero incidents of dredging while protected marine fauna observed in exclusion zone	+ MFO records of EPBC Act listed fauna within vessel exclusion zone

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-10** and **Table 8-11**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

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Table 8-10: Management actions for noise emissions during routine construction including the use of an Xcentric Ripper tool

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA48	Observation and exclusion zones for marine fauna developed based on noise modelling results and standard protocols
Mitigation	
DPD-MA49	Vessel inductions for all crew to address marine fauna risks and the required management controls
DPD-MA50	Vessel and helicopter to complete Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA51	Personnel trained in MFO to be present on pipelay, dredge and rock installation vessels/barges during daylight hours, including one crew member with MFO training on the bridge at all times
DPD-MA52	All marine fauna interactions and observations to be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW as required
DPD-MA55	Maintenance of vessel, vehicle and equipment combustions engines and vessel incinerators as per planned maintenance system
Additional (ALARP) management actions	
Avoidance	
DPD-MA56	Observation and shut-down zones for marine fauna have been developed based on noise modelling results for trenching and standard protocols and include: + Observation (150 m) and exclusion (50 m) zones for marine mammals and turtles. + Observation zone monitored for 10 minutes prior to commencing trenching during daylight only. A Marine Megafauna Observation and Adaptive Management Protocol for routine trenching operations, including the use of Xcentric Ripper tool, is to be followed as per MMNMP (BAS-210 0045)
Mitigation	

MA reference	Management actions
DPD-MA57	+ Soft start (ramp-up) of hydraulic tools (rock breaking) by BHD, where practicable + Soft start (ramp-up) of trenching equipment, where practicable, will apply to the CSD and TSHD

Table 8-11: Additional environmental management actions for contingency rock breaking using hydraulic hammer

MA reference	Management actions
Contingency management actions	
1	Increased Observation and Exclusion Zones for hydraulic hammering based on noise modelling results will be applied as follows: + If up to 8 hours of rock breaking is required, an increased Observation Zone of 2.5km (marine mammals) and 1km (turtle) will apply and an increased Exclusion Zone of 150m for marine mammals and turtles will apply + If up to 6 hours of rock breaking is required, an increased Observation Zone of 2 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100m for marine mammals and turtles will apply + If up to 4 hours of rock breaking is required, an increased Observation Zone of 1.5 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100 m for marine mammals and turtles will apply + If up to 2 hours of rock breaking is required, an increased Observation Zone of 1 km (marine mammals) and 500 m (turtle) will apply and an increased Exclusion Zone of 50 m for marine mammals and turtles will apply
2	Contingency hydraulic hammering protocols for managing noise impacts will be followed as per MMNMP (BAS-210 0045)
3	Hydraulic hammering for no greater than 8 hrs over a 24 hr period.
4	No hydraulic hammering at night
5	A separate vessel with MFO onboard will be required to patrol the Observation Zone prior to and during hydraulic hammering

Table 8-12: Additional (ALARP) management actions not adopted for noise emissions

Additional management actions not adopted		Reasoning for rejection
1	Schedule trenching activities outside of peak flatback turtle nesting period (May to October) or outside of peak Darwin Harbour dolphin calving period (October to April).	+ It would not be possible to avoid both peak periods. + The potential benefit of avoiding locations of higher marine megafauna sensitivity at certain times of the year, such as nesting periods for turtles and dolphin calving periods, is considered disproportionately low compared to the implications to Project scheduling and costs – While there are known flatback turtle nesting sites (Cox Peninsula and Casuarina Beach), and a known period of increased nesting activity (May to October), the densities of nesting turtles in these areas are very low and not significant on a regional scale (Chatto and Baker, 2008). Furthermore, these sites are on a scale of 1000s of meters away from the pipeline route and trenching areas (as they are from existing vessel traffic using navigation channels) and the relative risk of behavioural effects to turtles at this scale from vessel noise is considered low (Popper et al., 2014). For dolphins, there is evidence that there is a peak in calving within Darwin Harbour between October and April (Palmer, 2010). Important areas have not been defined however and given the high mobility of dolphin species within Darwin Harbour and the use of adjoining coastal areas (Griffiths et al., 2019) it is unlikely that behavioural disturbance around DPD Project activities, relative to the total area of Darwin Harbour and surrounding coastal waters, would have a significant impact on calving behaviour.
2	The observation period for marine megafauna prior to commencing dredging and pile driving is 20 minutes and the MFO is solely dedicated to the task of sighting and recording marine megafauna interactions prior to, and during, dredging and pile driving operations.	+ A 20-minute observation period was considered excessive for the size of the Observation Zone (150 m) and a 10-minute observation period was considered sufficient to monitor this zone for marine fauna. An additional 10 minutes would prolong dredging operations without any appreciable benefit. + A MFO for the pre-start up observation period was considered warranted however a MFO solely to the task of sighting and recording marine megafauna for the entirety of dredging operations was not considered warranted given that the dredging vessel to have multiple crew with marine fauna observation training onboard during daylight hours and the vessel bridge to be constantly manned with at least one crew with MFO training on the bridge at all times.

Additional management actions not adopted		Reasoning for rejection
3	No use of DP vessels.	Not using DP vessels will cause additional seabed and benthic habitat impacts through the need to use anchoring to hold position during pipelay. The use of DP also decreases pipelay duration and reduces impact to other users through shorter timeframe.
4	Cease noise generating activities (e.g. DP) when near marine fauna.	Ceasing DP activities when near sensitive fauna may reduce the potential for impacts, however, the potential for impacts beyond behavioural disturbance are very low. Engine/DP thruster noise cannot reliably be ceased due to the safety critical role of vessel propulsion. It is also not practical to cease pipelay or other critical construction activities in a short timeframe as safely abandoning such operations can often take a number of hours (namely laying down the pipeline or disconnecting from a structure), during which time the impacted fauna will have left the area. Therefore, this control is not deemed feasible.
5	Soft start/power-up procedures for use of sonar equipment and use of fauna observation and shutdown zones.	The systems being used are at a low power or are an intermittent type such that the reduced cumulative exposure would reduce TTS or PTS impacts for marine fauna and behavioural impacts were not considered credible
6	No use of helicopters.	Use of helicopters required (e.g. vessel/crew transfers) and restriction will result in an overall longer duration construction activity and therefore noise impacts
7	Avoidance of night work for routine trenching and Xcentric Hammer use.	Avoidance will result in an overall longer duration construction activity and therefore noise impacts and also increase the safety risk profile. The cost of implementing this far exceeds the benefit gained.

8.3.1.3 Light emissions

8.3.1.3.1 Environmental objectives, performance criteria and management actions

The EPOs relevant to this impact including performance criteria are described in **Table 8-13.**

Table 8-13: Light emissions EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise light disturbance to fauna and fauna habitat (including to turtle nesting beaches and turtle hatchlings)	Non-navigational lighting is shielded and/or directed away from the marine environment where practicable.	+ Vessel lighting inspection records + Records of vessel light spill on Darwin Harbour turtle nesting beaches

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-14**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-14: Management actions for trenching and spoil disposal related light emissions

MA Reference	Management actions
Standard management actions	
Mitigation	
DPD-MA59	Shielding, where practicable, and/or orienting operational lights (excluding navigational lighting) on vessels to limit light spill to the environment
DPD-MA60	Housekeeping measures will be adopted, including requiring all crew to keep shutters on windows closed at night, to limit light emissions from vessels
Additional management actions	
Mitigation	
DPD-MA61	Vessel searchlights will only be operated in an emergency situation.
Monitoring	
DPD-MA62	Santos will document vessel light spill on Darwin Harbour turtle nesting beaches as part of the DPD Project's environmental monitoring program

Table 8-15: Additional management actions not adopted for trenching and spoil disposal related light emissions

Additional management actions not adopted		Reasoning for rejection
1	Crew transfers or loading of supplies which require direction of floodlights outside vessel will not occur during hours of darkness within 10 km of turtle nesting beaches during peak hatchling season.	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area.
2	Do not undertake trenching and spoil disposal activities during peak turtle nesting and hatchling emergence season.	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area.
3	Vessels shall be fitted with turtle friendly (low vapour sodium or LED) directional lighting (requirement applies to external lighting only).	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area. It is not practicable to change out vessel lights for short duration activities and also lighting must meet navigational requirements. White lights required for operational requirements will be directed onto work areas and/or shielded to limit external light spill.
4	Restrict lighting to navigation lights only	Operational lighting, including lighting of work areas and decks, is required for safe working conditions.

8.3.1.4 Routine vessel discharges

8.3.1.4.1 Environmental performance objectives and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-16**.

Table 8-16: Routine vessel discharges EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise environmental impacts from waste and liquid discharges generated during DPD construction activities	Zero recorded environmental incidents of vessel discharges not meeting regulatory requirements	Incident records of non-compliant discharges

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-17**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

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Table 8-17: Management actions for routine vessel discharges

MA reference	Management Action
Standard management actions	
Mitigation	
DPD-MA63	Vessels will comply with relevant Marine Orders with respect to planned discharges, including: + Marine Order 91 – Marine Pollution Prevention: Oil, which implements Annex I of the MARPOL + Marine Order 95 – Marine Pollution Prevention: Garbage + Marine Order 96 – Marine Pollution Prevention: Sewage, which implements Annex IV of the MARPOL
DPD-MA64	Santos Marine Assurance Process

Table 8-18: Additional management action not adopted for routine vessel discharges

Additional management actions not adopted		Reasoning for rejection
1	Storage and transport of sewage, putrescible and waste for disposal onshore regardless of legislative requirement.	Waste is managed in accordance with required legislative controls and discharge of sewage, greywater, and putrescible results in a negligible impact. The additional costs for transport and disposal, increased health, and safety risks (e.g., hygiene) and increased environmental impact (e.g., atmospheric emissions from vessels transporting waste) outweigh any environmental benefit gained.

8.3.1.5 Atmospheric emissions

8.3.1.5.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-19**.

Table 8-19: Atmospheric emissions EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	**Performance Indicator/s**
Minimise environmental impacts from atmospheric emissions generated during DPD construction activities	Compliance with preventative maintenance procedures for combustion engines, incinerators and ozone depleting substances (ODS) containing equipment	Planned maintenance records

The EPOs detailed in this TSDMMP are in line with the following objective for the relevant NT EPA factor (NT EPA, 2021):

+ Air quality – Protect air quality and minimise emissions and their impact so that environmental values are maintained.

The management actions for this activity are shown in **Table 8-20.** Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-20: Management actions for atmospheric emissions

MA reference	Management actions
Standard management actions	
Mitigation	
DPD-MA55	Maintenance of combustions engines and incinerators as per vessel's planned maintenance system
DPD-MA68	Atmospheric emissions from combustion, incinerators and ODS managed in accordance with standard maritime practice (MARPOL)
DPD-MA69	Monitoring and reporting of fuel consumption and calculated GHG emissions
DPD-MA70	Use of low sulphur diesel
Additional management actions	
N/A	

8.3.2 Unplanned events risks

Santo's environmental assessment identified six potential sources of environmental risks associated with the unplanned events for this activity. Management strategies have been adopted in the TSDMMP based on the ENVID undertaken for DPD Project trenching and spoil disposal activities in May/June 2022 (Refer to **Section 7.2**).

8.3.2.1 Dropped objects (including accidental release of non-hazardous waste)

8.3.2.1.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-21**.

Table 8-21: Dropped objects (including accidental release of non-hazardous waste) EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid environmental impact resulting from accidental release of non-hazardous solid waste and dropped objects	Zero incidents of loss of equipment/cargo/waste overboard from vessels resulting in a consequence II – Minor or above	Incident records

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-22.** Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-22: Management actions for release of dropped objects

MA reference	Management Actions
Standard management actions	
Avoidance	
DPD-MA63	Vessels will comply with relevant Marine Orders, including: + Marine Order 95 – Marine Pollution Prevention: Garbage
DPD-MA75	Implementation of Santos approved standards and procedures for outboard lifts
DPD-MA76	All lifting and winching equipment will undergo inspection, testing and certification as per Applicable Laws and Applicable Codes and Standards
Mitigation	
DPD-MA77	Dropped object recovered where safe and practicable to do so
Additional management actions	
Avoidance	
DPD-MA81	Pipeline route design selected where practicable to avoid the potential for impact to habitat / cultural seabed features or assets from a dropped object

8.3.2.2 Introduction of invasive marine species

8.3.2.2.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-23**.

Table 8-23: Introduction of invasive marine species EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid introducing invasive marine species (IMS) into NT waters	+ All DPD Project vessels assessed mobilising from outside of Darwin Harbour/Project Area assessed as low risk for IMS prior to entry into Project Area + Ballast water management will be done according to the Australian Ballast Water Management Requirements	+ Records of vessel IMS risk assessment + Ballast water records system maintained by vessels

The EPOs detailed in this TSDMMP are in line with the following objective for the relevant NT EPA factor (NT EPA, 2021):

+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-24.** Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-24: Management actions for introduction of invasive marine species

MA reference	Management Action
Standard management actions	
Avoidance	
DPD-MA82	Vessels equipped with effective anti-fouling coatings as required for class
DPD-MA83	Ballast water management will comply with MARPOL requirements (as applicable to class), Australian Ballast Water Management Requirements and *Biosecurity Act 2015*
DPD-MA84	Apply risk-based IMS management for vessels and immersible equipment – vessel and immersible equipment must be assessed as having a low risk of IMS prior to coming onto activity
DPD-MA85	Vessels having suitable anti-fouling coating (marine growth prevention system) in accordance with the *Protection of the Sea Act 2006*

Table 8-25: Additional management actions not adopted for invasive marine species

Additional management actions not adopted		Reasoning for rejection
1	Use of Australian vessels only	It is not feasible to only use Australian vessels given constraints on availability and suitability
2	All vessels to be dry docked, cleaned, and inspected for IMS	Santos requires a risk assessment to be undertaken for project vessels which considers factors that lessen the risk of IMS incursion and requires vessel to achieve a low-risk score. These factors include a vessel's history of dry-docking, cleaning and IMS inspection but these activities are not necessarily mandatory depending upon vessel history and other risk factors. The costs of applying mandatory dry-docking and cleaning is considered disproportionate given the existing risk-based approach being applied.
3	Heat or chemical treatment of ballast water to eliminate IMS	Cost and effort is considered to outweigh benefits given existing regulatory requirements for ballast exchange will be adhered to.

8.3.2.3 Unplanned marine fauna interactions

8.3.2.3.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-26**.

Table 8-26: Unplanned marine fauna interactions EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid interactions resulting in injury to or mortality of protected marine megafauna	Zero incidents of interactions resulting in the injury or mortality of EPBC Act listed marine megafauna	+ Incident reports relating to marine fauna injury or mortality + MFO reports of sightings of live, injured or dead marine megafauna

The EPOs detailed in this TSDMMP are in line with the following objective for the relevant NT EPA factor (NT EPA, 2021):

+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-27**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-27: Management actions for marine fauna interaction

MA reference	Management Actions
Standard management actions	
Avoidance	
DPD-MA50	Vessel and helicopter movements will comply with Part 8 of the EPBC Regulations 2000
DPD-MA51	Personnel trained in marine fauna observation present on trenching and spoil disposal vessels during daylight hours, always including one crew member with MFO training on the bridge at all times.
DPD-MA82	Inductions to include observing marine fauna (e.g., dolphins and turtles)
DPD-MA83	The TSHD shall be fitted with pre-sweeping mechanisms / chain curtains to mitigate turtle ingestion (fauna strike – unplanned)
Mitigation	
DPD-MA52	All marine fauna interactions and observations will be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW
Additional management actions	
Avoidance	
DPD-MA54	Observation and shut-down zones for marine fauna have been developed based on noise modelling results and standard protocols and include: + Observation (150 m) and exclusion (50 m) zones for marine mammals and turtles. A Marine Megafauna Observation and Adaptive Management Protocol will be included within the MMNMP (BAS-210 0022)

Table 8-28: Additional management actions not adopted for marine fauna interaction

Additional management actions not adopted		Reasoning for rejection
1	Restrict the timing of activities to operate outside of known sensitive periods only. Flatback turtle peak nesting period is May to October and Dolphin peak calving is October to April	Project schedule is unable to avoid sensitive periods. Beaches closest to the project area are also not considered significant turtle nesting beaches so this control is not considered relevant.
2	Activities will only occur during daylight hours	Construction works need to occur 24/7 to maintain project schedule. Increased project schedule may result in increase in vessel movements and potential for more cumulative impacts.

8.3.2.4 Release of hazardous liquids

8.3.2.4.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-29**.

Table 8-29: Release of hazardous liquids EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid significant environmental impact resulting from release of hazardous materials	Zero incidents of release of hazardous liquids to the marine environment during DPD construction activities	Number of recorded incidents
	Response to incident implemented as per the relevant emergency response plans	Incident report including details of response

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-30**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-30: Management actions for hazardous liquids releases

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA61	Vessels will comply with relevant Marine Orders, including: + Marine Order 95 – Marine Pollution Prevention: Garbage
DPD-MA84	Inspection and maintenance for all equipment using chemicals
DPD-MA86	ROV operations undertaken in accordance with good industry practise (in relation to hydraulic fluid control)
DPD-MA89	Chemicals will be managed in accordance with standard maritime practices as per vessel shipboard oil pollution emergency plan (SOPEP)
Mitigation	
DPD-MA85	Santos chemical selection procedure applied for chemicals planned to be discharged to the environment
DPD-MA98	Chemical storage areas designed to contain leaks and spills and inspected routinely
DPD-MA90	Spill clean-up kits available in high-risk areas
DPD-MA91	Bunding/secondary containment
Additional management actions	
N/A	

8.3.2.5 Release of hydrocarbon (offshore vessel bunkering or vessel tank rupture)

8.3.2.5.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-31**.

Table 8-31: Hydrocarbon and marine diesel release (offshore vessel bunkering or vessel tank rupture) EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No release of hydrocarbons to the marine environment as a result of the DPD Construction Activities	Zero incidents of unplanned discharge of hydrocarbons into the marine environment as a result of DPD construction activities	Number of recorded incidents
	Response to incident implemented as per the relevant emergency response plans	Incident report including details of response

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-32**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-32: Management actions for hydrocarbon release (offshore bunkering incident or vessel fuel tank rupture)

MA reference	Management Actions
Standard management actions	
Avoidance	
DPD-MA84	Inspection and maintenance for all equipment using hydrocarbons
DPD-MA86	ROV operations undertaken in accordance with good industry practice (in relation to hydraulic fluid control)
DPD-MA89	Hydrocarbons will be managed in accordance with standard maritime practices as per vessel (SOPEP)
DPD-MA92	Vessel-specific bunkering procedures and equipment consistent with Santos marine vessel vetting requirements including: + Use of bulk hoses that have quick connect 'dry break' couplings + Correct valve line-up + Defined roles and responsibilities, and the specific requirement for bunkering to be completed by trained personnel only + Visual inspection of hoses prior to bunkering to confirm they are in good condition + Testing of the emergency shutdown mechanism on the transfer pumps + Assessment of weather/sea state + Maintenance of radio contact with Vessel during bunkering operations + Bunkering checklist Visual monitoring during bunkering Marine Order 91 – Marine Pollution Prevention: Oil
DPD-MA93	Vessel equipped and crewed in accordance with Australian maritime requirements
DPD-MA94	Safety exclusion zone around DPD Project vessels and Notice to Mariners will be issued for offshore works advising all major shipping traffic formally.
Mitigation	
DPD-MA88	Hydrocarbon storage areas designed to contain leaks and spills and inspected routinely
DPD-MA90	Spill clean-up kits available in high-risk areas

MA reference	Management Actions
DPD-MA91	Bunding/secondary containment around hydrocarbon storage/transfer areas
DPD-MA95	No intermediate fuel oil (IFO) or heavy fuel oil (HFO) will be used in activity vessels working inside the Project Area
DPD-MA96	Implement tiered spill response as per DPD Project specific OPEP in the event of an MDO spill
Additional management actions	
DPD-MA97	Santos to make oil spill tracking buoys available on primary project vessel/s with Santos CSR/s and/or at local supply base for immediate deployment to assist with tracking of an oil spill

Table 8-33: Additional management actions not adopted for hydrocarbon release (offshore bunkering incident or vessel fuel tank rupture)

Additional management actions not adopted		Reasoning for rejection
1	No bunkering of fuel during the trenching and spoil disposal activity	Vessels will routinely bunker when in port, as this is the safest and most cost effective means to refuel vessels. However due to the gas export pipeline installation method, the pipelay vessel cannot bunker alongside port facilities and requires bunkering within the operational area to undertake the activity. Following implementation of the selected existing controls, the risk reduction associated with eliminating bunkering at sea is considered to be negligible. The potential impacts to schedule and associated cost of implementing the control is considered to be grossly disproportionate to the reduction in risk. The control has not been adopted.
2	Bunkering only during daylight hours	Bunkering only during daylight hours increases the likelihood of detecting a leak, as surface hydrocarbon sheens are typically more visible under sunlight. Bunkering operations are typically completed during daylight hours; however, circumstances may occur where bunkering is required during darkness (e.g., large volume transfers at slow rates or when bunkering is safer to perform at night due to prevailing metocean conditions). Bunkering will only commence in daylight hours however. Following implementation of the selected existing controls, the risk reduction associated with prohibiting bunkering during darkness is considered to be low. The cost of implementing the control is considered to be grossly disproportionate to the reduction in risk. The control has not been adopted.

3	Schedule activities to avoid coinciding with sensitive periods for marine fauna present in the operational area	Project schedule is unable to avoid sensitive periods. Beaches closest to the Project Area are also not considered significant turtle nesting beaches. The cost of limiting the timing of activities would be excessive compared to the little to no reduction in risk of oil spill to significant turtle nesting beaches.
4	Require all support vessels involved in the activity to be double hulled.	Cost and availability of double hulled vessels make this control not feasible.

8.3.2.6 Release of dry natural gas from Bayu-Undan to Darwin pipeline

8.3.2.6.1 Environmental performance outcomes and control measures

The EPOs relevant to this impact including performance criteria are described in **Table 8-34**.

Table 8-34: Release of dry natural gas environmental performance objectives and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid environmental impacts from the accidental release of dry natural gas from Bayu-Undan to Darwin pipeline	No releases of gas from the Bayu-Undan pipeline to the environment as a result of impact/drag or dropped object from the DPD construction activity	Incident records
	Response to incident implemented as per the relevant emergency response plans	Incident report including details of response

The EPOs detailed in this TSDMMP are in line with the following objectives for the relevant NT EPA factors (NT EPA, 2021):

- Air quality – Protect air quality and minimise emissions and their impact so that environmental values are maintained.
- Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
- Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this activity are shown in **Table 8-35**. Environmental Performance Standards for these management actions will be developed between Santos and Contractor prior to the finalisation of this TSDMMP.

Table 8-35: Management actions for release of dry natural gas

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA08	The proposed pipeline route will be marked on marine charts, in the same way that the existing pipelines are gazetted and marked on marine charts
DPD-MA75	Implementation of Santos approved standards and procedures for lifting
DPD-MA98	Trenching will only occur within pre-programmed areas (using standard positional accuracy measures used in the industry)
DPD-MA99	Exclusion zones programmed on all primary vessels associated with the works to clearly indicate no entry zones and nearby pipelines – this will clearly identify areas for spud placement, anchor positioning and trenching activities
Additional management actions	
Avoidance	
DPD-MA78	Identification of no lift zones or additional controls, where relevant, in proximity to subsea pipelines as documented in relevant lifting and operational procedure/s

9 Environmental Monitoring

9.1 Overview

Environmental monitoring is proposed within Project Area and in surrounding areas containing key sensitive receptors (i.e., seagrass and hard coral) to ensure that the EPO for the management of water quality and benthic habitats is met. The environmental monitoring program will focus on real-time measurements of turbidity for the protection of sensitive receptors, as turbidity is the primary indirect stressor resulting from trenching activities. Turbidity measurements will allow assessment of performance indicators i.e., determination if Level 1, 2 and 3 triggers within the adaptive monitoring/management strategy (**Section 8**) have been exceeded. Other parameters including Photosynthetic Active Radiation (PAR), salinity and water temperature will also be collected to provide environmental context and evidence to trenching activity attributability assessment (**Section 8.2.2.3**) and, in the case of temperature, to determine whether a hard coral temperature trigger has been exceeded.

Baseline and responsive habitat monitoring (if triggered) will also be undertaken to assess the health of sensitive receptors. Prior to the commencement of trenching activities monitoring will be completed to develop an environmental baseline for benthic habitat condition and to verify existing baseline water quality information already collected at the monitoring sites.

Lastly, MODIS satellite images will be used to add context to data collected by telemetered buoys and habitat monitoring. This information will assist the attributability assessment and to assess the spatial distribution of the visible plume.

Note, the final decision is yet to be made as to the exact trenching methodology to be adopted and, key components of the monitoring programme such as parameters to be monitored, monitoring locations, numbers of monitoring sites, and the durations and frequency of the monitoring programme may change depending on the final trenching methodology selected. Therefore, the monitoring programme presented herein should be considered as a draft at this stage. Once the final trenching methodology is selected the monitoring programme may be adapted and finalised to reflect the final trenching methodology selected.

The following sections describe the monitoring program proposed for the main and maintenance trenching operations.

9.2 Monitoring objectives

The key objectives of the monitoring program are to:

+ Verify the already existing environmental baseline turbidity dataset at water quality monitoring sites
+ Indicate the exceedance of triggers (turbidity and temperature) for responsive and contingency monitoring and management actions
+ Assess the environmental performance of responsive and contingency management actions.
+ Provide contextual information of Photosynthetically Active Radiation (PAR) levels that can be used as a line of evidence for assessing potential trenching and spoil disposal impacts. This will in turn improve understanding of PAR fluctuation and PAR vs turbidity relationship at multiple sites within Darwin Harbour.

- Collect baseline benthic habitat data (and reactive benthic habitat data, if triggered) to provide contextual information in the event of an exceedance of management triggers and to contribute to existing scientific knowledge of Darwin Harbour.
- To collect information on the distribution of turbidity plumes using remote sensing.

9.3 Environmental monitoring program

The environmental monitoring program, including sites, parameters, frequency and purpose are summarised in **Table 9-1**.

Table 9-1: Overview of proposed monitoring program

Monitoring	Sites	Methods	Purpose	Indicative schedule and frequency
Telemetry Water Quality Monitoring: + Turbidity + PAR + Temperature	Reactive sites[1] + Channel Island + Weed Reef + Woods Inlet + Charles Point + Mandorah Reference sites[2] + Channel Island + Fannie Bay + East Point + Wickham Point + Casuarina	Telemetered water quality monitoring buoys	+ Trigger monitoring + Environmental context + Development of turbidity vs PAR relationship + Reference sites used as a part of attributability assessment	Validation window of a few weeks to a month prior to trenching. Data collected in-situ and recorded x minutes during trenching activities.
Water Quality Profiling: + Salinity + Temperature + Depth	Reactive sites[1] + Channel Island + Weed Reef + Woods Inlet + Charles Point + Mandorah Reference sites[2] + Channel Island + Fannie Bay + East Point	Seabird CTD profiler	+ Environmental context + Inform attributability assessment + Reference sites used as a part of attributability assessment	During visits to telemetered water quality sites.

Monitoring	Sites	Methods	Purpose	Indicative schedule and frequency
	+ Wickham Point + Casuarina			
Seagrass Monitoring	+ Wood Inlet + Charles Point + Fannie Bay + Casuarina + East Point	ROV captured images/videos	+ Environmental context + Assessment of impact following an exceedance	Baseline – prior to trenching campaign during dry season Responsive – if Level 3 trigger exceeded
Coral Monitoring	+ Channel Island + Weed Reef + Mandorah + Charles Point	ROV captured images/videos	+ Environmental context + Assessment of impact following an exceedance	Baseline – prior to trenching campaign during dry season Responsive – if Level 3 trigger exceeded
Dredge plume monitoring	+ Location of trenching and spoil disposal	Aerial imagery via drone flight or satellite capture	+ Environmental context + Inform attributability assessment	Responsive – if Level 1 trigger exceeded as part of attributability assessment

Notes:

1. Reactive sites are not sites where an impact from dredging is expected, rather these are sites where sensitive receptors are located in closest proximity to the trenching zones.
2. Locations of reference sites may need to be adjusted based on other works in Darwin Harbour that may be undertaken concurrently by other proponents to ensure sites are not being impacted by other anthropogenic stresses.
3. The number and location of monitoring sites may be subject to change based on final route alignment and trenching methods.
4. Metal concentrations will be measured in water and sediment samples at selected sites.

9.3.1 Monitoring site selection

The sites for this proposed monitoring program and their designation are identified in Figure 9-1 and **Table 9-1**. The number and location of monitoring sites may be subject to change based on final route alignment and trenching methods.

Reactive sites are not sites where an impact from dredging is expected (i.e., none of the sites are within a zone of impact or influence as detailed in **Section 6.5.3**), rather the sites represent locations of sensitive receptors (seagrass and hard coral) in closest proximity to the proposed trenching activities, therefore have the potential to be influenced by trenching works. These reactive sites are existing INPEX monitoring sites that have historical baseline data associated and water quality is therefore well understood, resulting in high confidence in being able to detect exceedances outside of normal tolerance limits. They additionally have associated reactive trigger values that if exceeded and found to be attributable to trenching activity will trigger actions outlined in **Section 8.2**. Reference sites have been identified in areas of sensitive receptors further from trenching activities, within equivalent sections of Darwin Harbour, i.e., nearshore, mid-harbour and offshore. Data from these sites will be used to assess if trigger exceedances identified at the impact sites is attributable to Santos' trenching activities and to provide contextual information on the natural variability in water quality.

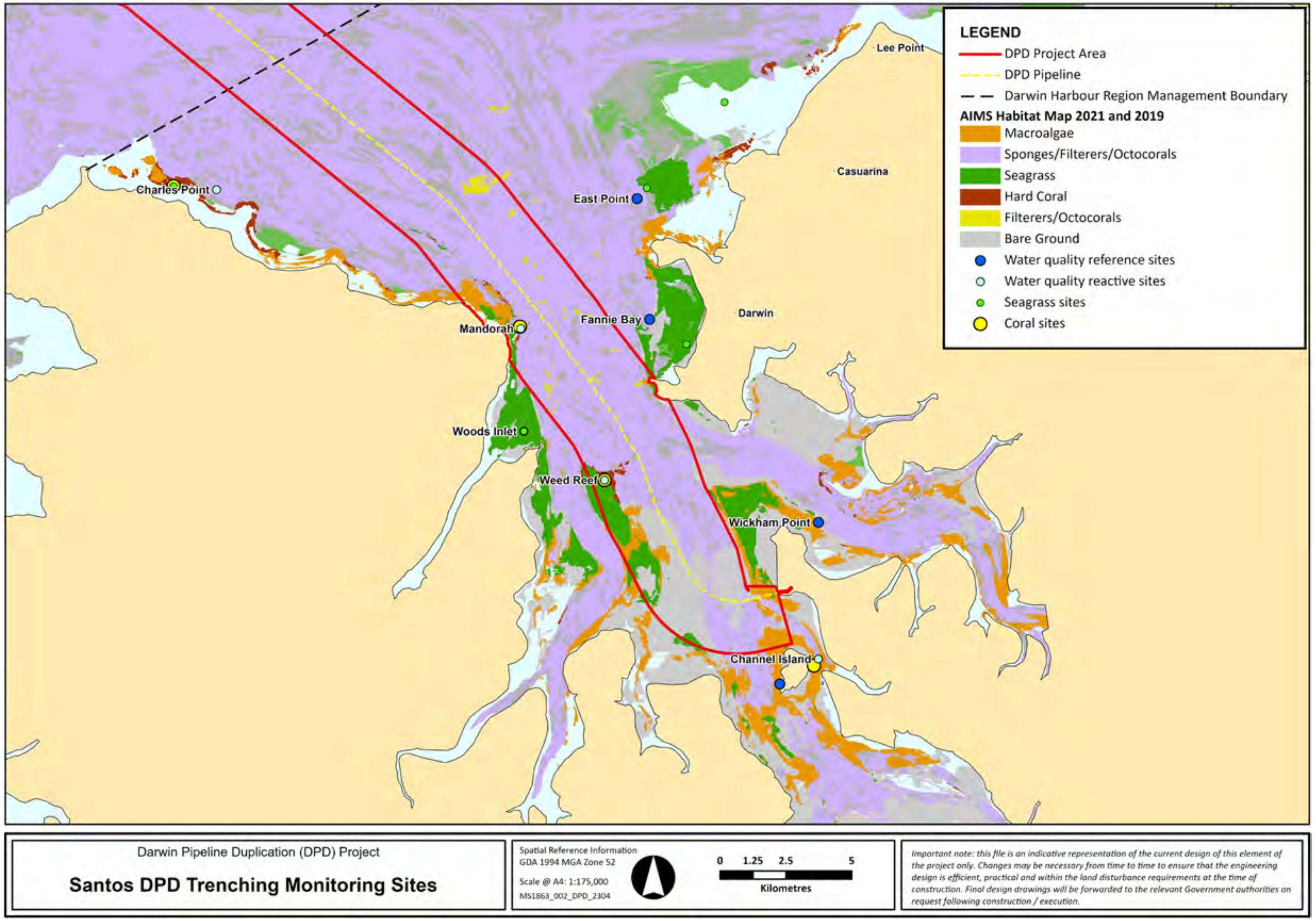

Figure 9-1: DPD Trench Monitoring sites. Note the number and locations of monitoring sites may be subject to change based on final route alignment and trenching methods

9.3.2 Methods and QAQC

The environmental monitoring program developed for this TSDMMP is based on INPEX's Maintenance DSDMPs water quality monitoring (INPEX, 2018).

This environmental quality monitoring program will be undertaken by qualified personnel.

9.3.2.1 Water quality monitoring

Telemetered water quality buoys will be used to record water quality with data being logged at regular intervals and uploaded to an online database for analysis.

The telemetered water quality buoys will be fixed moorings and recording instruments, where possible will be approximately 1 m above the seabed to create a standardised method, per INPEX's nearshore environmental monitoring program (Cardno, 2014). In line with INPEX's capital and maintenance dredging programs telemetered water quality buoys and water profiling equipment will be deployed adjacent to sensitive receptor habitat rather than directly within them to prevent damage upon deployment and retrieval. Water profiling equipment will be deployed on scheduled maintenance trips for telemetered buoys and will be used to collect water quality parameters throughout the water column providing further context to environmental data.

Water quality profile data will be collected using by lowering a calibrated conductivity, temperature and depth (CTD) profiler between the surface and seabed at monitoring site.

Water quality and sediment quality samples will also be collected at selected sites for laboratory analysis.

In line with INPEX's Maintenance DSDMP no sedimentation monitoring has been proposed, as there is not currently suitable methodology for acceptable resolution.

9.3.2.1.1 Water quality parameters

This environmental water quality monitoring program is based upon INPEX's Maintenance DSDMP (INPEX, 2018) and similarly focuses on real-time measures of turbidity (NTU) as a suitable early warning sign for potential impacts to coral and seagrass habitat. PAR, salinity, temperature and depth will also be measured (salinity and depth will not be telemetered) as informative measures to provide further context to changes in water quality. Temperature will additionally be monitored in real-time to indicate the presence of increased pressure upon hard coral communities. In addition, metal concentrations will be measured in water and sediment samples at selected sites. Parameters are listed in **Table 9-2**.

Turbidity is the main basis of environmental assessment as trenching activities will elevate turbidity and turbidity can negatively impact sensitive receptor habitats. Turbidity additionally provides a proxy of light available to sensitive receptor habitats. Furthermore, this monitoring program will operate on the assumption outlined in INPEX's Maintenance Dredging Spoil Disposal Management plan (INPEX, 2018; INPEX, 2022) that there is a relationship between turbidity and sedimentation rates, with turbidity measurements potentially providing an indication of sedimentation levels settling on the seabed. INPEX have previously established a 1:1 relationship between TSS and NTU which will be assumed for this monitoring program. However, this relationship will be verified by data collected by Santos.

PAR will measure the quantity of light potentially available to sensitive receptors (i.e., corals and seagrasses), which could be impacted by increased turbidity attributable to DPD Project trenching. This parameter will be used alongside turbidity data to identify whether trenching activities are responsible for changes in light availability. Telemetered water quality buoys and water sample analysis will be used during monitoring to determine the TSS vs PAR and NTU vs TSS relationship for specific sites.

Salinity was not found to be significantly impacted by INPEXs capital dredging activities (Cardno, 2015) Although conductivity measures could provide a good indication of natural changes to environmental conditions.

Trenching and spoil disposal activities will not have a significant effect on water temperature, although this parameter will be recorded in real-time at all sites as natural increases in water temperature alongside increased turbidity could result in coral bleaching events. Water temperature data will additionally be assessed against a temperature-based trigger value.

Table 9-2: Proposed water quality parameters and units

Parameters	Units
Turbidity	NTU
PAR	µE $m^{-2}s^{-1}$
Conductivity (as a proxy for salinity)	S/m
Temperature	°C
Depth	m
Total suspended sediments	mg/L
Metals in water	mg/L
Metals in sediment	mg/kg

9.3.2.2 Habitat monitoring

Habitat monitoring will be undertaken prior to trenching by way of Remote Operated Vehicle's (ROV) or towed video to collect video transects at designated seagrass and hard coral monitoring sites (**Figure 9-1** and **Table 9-1**). Images derived from footage will then be analysed by qualified personnel using a quantitative analysis technique (e.g., point counts) to assess parameters such as community composition, density, and health of biota at seagrass and hard coral sites.

A review of previous benthic habitat monitoring programs within Darwin Harbour will be undertaken to refine methodology and metrics used to assess condition of benthic habitats (hard coral and seagrass). At a minimum, the pre-trenching baseline state of benthic habitat (coral and seagrass) at monitoring sites will be determined. Additional monitoring to assess potential impacts will be undertaken if triggered by water quality monitoring (exceedance of Level 3 water quality monitoring trigger; **Section 8.2.2**).

9.3.2.3 Remote sensing

MODIS Satellite images (250 m pixel resolution) will be obtained to supplement data collected by telemetered buoys to provide greater spatial coverage (Kutser *et al.*, 2007; Evans *et al.*, 2012). Images will be used to add context to site-specific data where it is believed to add value to the analysis of attributability of exceedances and, where required, to assess the spatial distribution of the visible sediment plume (where images are cloud free). Where possible, satellite imagery with a finer pixel resolution (although infrequent passes) may also be utilised.

Aerial imagery of the visual plume will potentially also be captured by drone from shoreline or vessel as appropriate to supplement MODIS imagery. Automated sampling transects using flight planning software are to be flown in parallel lines with minimal image overlaps between each transect. Flight paths will maintain approximately the same height for each transect for image consistency. Where possible, drone sampling is to coincide in time and location with in-situ (e.g., water monitoring) sampling undertaken during dredging operations. Drone pilots will be required to have the appropriate commercial drone operating licencing (ReOC or RePL) for the type and weight category of drone in use.

9.3.2.4 Quality assurance and quality control

All water quality instruments will be calibrated and maintained per the suppliers and manufacturer's instructions. Telemetered water quality monitoring buoys will be implemented and will upload data to an online database; therefore, any malfunctions, losses/damage or fouling will be quickly identified. If malfunction, loss/damage, or fouling is identified, a system can be retrieved and replaced within five business days. Additionally, maintenance will be scheduled per supplier/manufacturer recommendations, with telemetered buoys systematically retrieved and replaced with clean systems maintaining the quality of data collected.

Other supporting parameters such as salinity temperature and depth will be collected in situ using water profiling equipment and therefore data loss is unlikely to be a significant issue.

All data collected will undergo quality assurance and quality control (QA/QC) procedures.

9.3.2.5 Data analysis

Water quality analysis will meet requirements outlines in the NT EPA Guideline for Reporting on Environmental Monitoring (NT EPA, 2016). Where applicable, best practise statistical and analysis techniques will be implemented based on the WAMSI dredging node studies (Jones *et al.*, 2015).

Following best practice, preliminary data checks will be undertaken prior to analysis to assess the integrity of data and as part of data QA/QC anomalous data will be removed using an objective function. Then QA/QC trigger assessment will be completed to assess measured turbidity data (NTU) against management triggers at each reactive site during the dredging phase, the following steps will be followed (based on methods outlined in INPEX's Maintenance DSDMP).

+ Daily average turbidity will be calculated using turbidity data recorded by telemetered buoys between 0:01am to midnight at each reactive site.
+ If there is a data loss and the period is less than 12 hours, then the daily average will be calculated based on remaining data as one tidal period should have been captured.
+ If there is a data loss and the period is greater than12 hours, then the daily average may be derived in one of the following ways:
+ Where data loss is greater than 12 hours but less than 24 hours:
    - Daily average turbidity will be calculated on the available data provided that the expected maximum turbidity period based on review of previous water trends is captures. If the expected maximum turbidity period is not captured, then if practicable a nearby monitoring site will act as surrogate.
+ Where data loss is greater than 24 hours:
    - Where practicable a nearby monitoring site will act as surrogate until equipment repair or replacement can occur.

- Note if telemetry function of buoys ceases to work the data in most instances will be recorded on the buoys for download and analysis post repair.
- Once daily average turbidity values are calculated for reactive sites, they will be compared against the trigger values in **Table 8-5**.
- Where a trigger value is exceeded for more than the allowable number of consecutive days (durations detailed in **Table 8-5**) then an exceedance event has occurred.
- If an exceedance trigger event has occurred, Santos, in consultation with the Monitoring Consultant and Dredging Contractor (as appropriate), will complete an attributability assessment (**Section 8.2.2.3**).

10 Implementation Strategy

This section presents the processes and procedures that will be implemented to ensure the environmental requirements within this TSDMMP will be met, including:

+ Specific systems, practices and procedures that ensure both environmental impacts and risks are reduced to ALARP and Environmental Performance Objectives (EPOs), Performance Criteria and Performance Standards of this TSDMMP are being met;
+ A clear chain of command, outlining roles and responsibilities of personnel involved in the implementation, management and review of this TSDMMP;
+ Measures to ensure that employees and/or contractors working in relation to this activity are aware of their responsibilities regarding the environment and have the appropriate skill and training;
+ Auditing, review and revision processes;
+ Incident recording and reporting in line with Santos and regulatory requirements;
+ Maintenance of quantitative records of discharges and emissions; and
+ Details of emergency response and oil spill arrangements.

This implementation strategy is consistent with the Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

Stakeholder engagement is assessed separately for the requirements of the activity. Ongoing stakeholder management strategies are discussed in **Section 11**.

10.1 Leadership, accountability and responsibility

To enable the DPD Project to succeed in meeting environmental objectives as outlined within this TSDMMP, the following measures apply:

+ Appropriately skilled and qualified DPD Project team is established with HSE accountabilities, responsibilities, and resources clearly defined;
+ Setting of EPOs and Performance Criteria (incl. Targets and Performance Indicators) and establishment of the practices and tools used to measure performance and drive continual improvement (**Section 8**); and
+ Implementing HSE Leadership Teams with key contractors to discuss HSE performance and improvement

The Barossa Project Director is responsible for delivery of the Barossa Development, including the DPD Project, and has responsibilities for:

+ Accountability for project HSE performance
+ Demonstrating strong and visible HSE leadership
+ Endorsing HSE performance indicators and targets
+ Communicating HSE performance and events to the Chief Operating Officer, Upstream Oil & Gas
+ and Group Executive Committee.
+ Providing HSE resources.

+ Engaging with senior regulatory managers.

The Barossa Project Director is supported by the Barossa Project Management Team. The effective implementation of this TSDMMP requires collaboration and cooperation among Santos Barossa Team personnel and contractors. The accountabilities of key Santos and contractor personnel in relation to the implementation, management and review of the TSDMMP is outlined in **Table 10-1**.

Table 10-1: Chain of command, key leadership roles and responsibilities

Title (role)	Environmental responsibilities
Office-based personnel	
Santos Barossa Subsea and Pipelines Manager	+ Confirm that the campaign is undertaken in accordance with this TSDMMP. + Provide sufficient resources to implement the management controls in this TSDMMP. + Confirm Contractor personnel attend an environmental induction upon commencing work on the campaign (Section 10.2). + Action the management actions, as detailed in the Environmental performance standards (EPS) in this TSDMMP (Section 8), as required, prior to the commencement of the activity. + Confirm the Contractor meets the requirements of the Santos management system and relevant standards/procedures.
Santos Barossa HSE Manager	+ Provide assurance that adequate resources are provided to support all environmental activities associated with this TSDMMP. + Develop a program to implement and monitor TSDMMP commitments. + Liaise with NT EPA, DITT, DCCEEW and other regulators. + Ensure incident notification process is in place and investigations completed to identify root causes. + Review and submit environmental performance reports and external environmental incident notification reports.
Santos Barossa GEP Package Lead	+ Confirm the campaign is undertaken in accordance with this TSDMMP. + Communicate any changes to the activity that may affect the risk and impacts assessment, EPOs, EPSs and MAs detailed in this TSDMMP to the Santos HSE team. + Coordinate resources required to enable the commitments in this TSDMMP to be maintained. + Confirm the reporting of environmental incidents meets both external and Santos' incident reporting requirements. + Liaise with Santos Environmental Advisor on environmental incidents and what constitutes a reportable incident. + Track and close out of any corrective actions raised from environmental audits as required by this TSDMMP.

Title (role)	Environmental responsibilities
Santos Marine Manager	+ Confirm vessel vetting as per the Santos Offshore Marine Assurance Procedure (SO 91 ZH 10001). + Ensure relevant inspections are undertaken to confirm vessels comply with relevant Marine Orders and Santos marine standards/procedures and on boarding requirements to meet safety, navigation and emergency response requirements.
Santos Barossa Crisis and Emergency Management Specialist	+ Develop Santos Crisis Management and Emergency Response Plans and procedures. + Ensure emergency response drills are undertaken as per Santos Crisis Management and Emergency Response plans and procedures.
Santos Emergency Response Coordinator	+ Undertake Santos Incident Management Team (IMT) drills and exercises in accordance with the Crisis and Incident Management Exercise Schedule. + Undertake assurance activities on oil spill response arrangements + Review Santos Emergency Response Plans and procedures.
Santos Barossa Environmental Advisor/s	+ Develop offshore environmental approval documents, including DPD Project EMPs and OPEP, for submission and acceptance by DITT. + Provide environmental inductions to contractor personnel. + Ensure environmental inspections and audits are undertaken against TSDMMP commitments as per the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635). + Review and approve chemical products that will be discharged to the marine environment and require assessment. + Review biofouling risk assessments undertaken by Contractors. + Prepare environmental performance reports. + Advise on environmental incident reporting requirements, including what constitutes a reportable incident
Santos Barossa External Relations Advisor	+ Prepare and implement the relevant and interested persons consultation program for the DPD activity. + Manage and report on any relevant and interested persons consultation received in relation to the activity. + Undertake ongoing engagement with relevant and interested persons, for the duration of the activity, as required.

Title (role)	Environmental responsibilities
Contractor Project Manager	+ Undertake the pipelay installation in accordance with this TSDMMP. + Provide the resources required to enable the commitments in this TSDMMP to be maintained. + Confirm vessel management system and procedures are implemented and comply with the requirements detailed in this TSDMMP. + Confirm personnel receive an environmental induction that meets the requirements outlined in this TSDMMP + Ensure invasive marine species and pests are risk assessment on all vessels mobilised to the operational area. + Ensure that all crew attend HSE inductions and that attendance records saved. + Ensure incidents are reported and investigated, as required.
Site and offshore based personnel	
Santos Senior Client Site Representative	+ Confirm contractors undertake the activity in a manner consistent with the EPOs and environmental management procedures detailed in this TSDMMP. + Confirm the management measures detailed in this TSDMMP are implemented. + Communicate any changes to the activity to the Santos Environmental Advisor. + Confirm all subsea chemical components and other fluids that may be discharged to the marine environment are approved for use. + Confirm that the Vessel Master and all crew adhere to the requirements of this TSDMMP. + Advise the Santos GEP Package Lead of any changes in activities that may lead to nonconformance with the EPOs in this TSDMMP. + Report environmental incidents to Santos GEP Package Lead.

Title (role)	Environmental responsibilities
Vessel Master (contractor personnel)	+ Confirm vessel management system and procedures are implemented and comply with the requirements detailed in this TSDMMP. + Confirm personnel receive an environmental induction that meets the requirements outlined in this TSDMMP on commencing work on the vessel. + Confirm crew personnel are competent to undertake the assigned work tasks. + Confirm SOPEP drills are undertaken in accordance with the vessel's schedule. + Comply with vessel entry and movement requirements within exclusion zones. + Maintain ballast water management plan, valid ballast water management certificate, ballast water management records, and Antifouling System Certificate specific to the vessel. + Maintain records of fuel use and vessel discharges/ transfers (including waste, sewage and oily water) as per MARPOL and Santos requirements + Confirm vessel crew are provided with sufficient training to implement the SOPEP/SMPEP (as appropriate to vessel class). + Ensure supervision of all bunkering/transfer operations to the vessel. + Report any environmental incidents or non-conformance with the EPOs, EPSs or MA in this TSDMMP in accordance with Santos and statutory requirements.
Offshore Construction Superintendent (Contractor Personnel)	+ Responsible for ensuring that pipeline construction activities are performed in accordance with this TSDMMP.

Title (role)	Environmental responsibilities
Offshore HSE Advisors (Santos and/or Contractor)	+ Support the Santos Senior Client Site Representative to ensure that the controls detailed in this TSDMMP relevant to offshore activities are implemented and assist in collection and recording of evidence of implementation (other controls are implemented and evidence collected onshore). + Support the Santos Senior Client Site Representative to ensure environmental incidents or breaches of objectives and/ or standards outlined in this TSDMMP, are reported, and corrective actions for incidents and breaches are developed, tracked and closed out in a timely manner. + Ensure periodic environmental inspections/reviews are completed and corrective actions from inspections are developed, tracked and closed out in a timely manner. + Review Contractors procedures, input into Toolbox talks and JSAs. + Provide day to day environmental support for activities in consultation with the Santos Environmental Advisor.
All Project personnel	+ Act in an environmentally responsible manner. + Undertake work in accordance with accepted HSE systems and procedures. + Comply with this TSDMMP and all regulatory requirements as applicable to assigned role. + Report any unsafe conditions, near misses or environmental incidents immediately to supervisors. + Attend environmental inductions and HSE meetings, and complete training as required. + Report marine megafauna sightings as applicable to role in accordance with Project requirements

10.2 Workforce training and competency

This section describes the mechanisms that will be in place, so all Project personnel (including employee and contractor roles) are aware of his or her responsibilities in relation to the TSDMMP and has appropriate training and competencies.

10.2.1 Inductions

Santos and its contractors will develop a mandatory project induction, which will detail TSDMMP requirements. Project induction attendance will be logged and held with the Project Administration Assistant. Santos personnel will be required to complete required contractor site and facility inductions, including DLNG facility inductions, including permitting requirements, as applicable for working in and around the DLNG facility.

All Project site roles will complete an induction that will include a component addressing their TSDMMP responsibilities. Induction attendance records for all personnel will be maintained. Inductions will include information about:

+ Environment, Health and Safety Policy
+ Regulatory regime
+ Operating environment (for example, nearby marine protected areas)
+ Activities with highest risk
+ TSDMMP EPOs, Performance Indicators and management commitments (**Section 8**)
+ Incident reporting and notifications
+ Regulatory compliance reporting
+ Importance of marine communications regarding any potential interactions with other marine users
+ Process for assessing changes to TSDMMP activities
+ Oil pollution emergency response.

10.2.2 Training and competency

The implementation of training requirements will ensure project personnel have the skills, knowledge and competencies to conduct work in a safe manner without harm to their health or the environment.

All members of the workforce will complete relevant training and/or hold relevant qualifications and certificates for their roles.

Santos and its contractors are individually responsible for ensuring that their personnel are qualified and trained. The systems, procedures and responsible persons will vary and will be managed using online databases, staff on-boarding process and training departments, etc.

Personnel qualification and training records will be sampled before and/or during an activity. Such checks may be performed during the procurement process, inductions, crew change, and operational inspections and audits.

Crew trained in marine fauna observation will ensure marine megafauna can be reliably identified to species during observation periods.

10.2.3 Workforce involvement and communication

Daily operational meetings will be held at which HSE will be a standing agenda item. It is a requirement that supervisors attend daily operational meetings and that all personnel attend daily toolbox or pre-shift meetings. Toolbox or pre-shift meetings will be held to plan jobs and discuss work tasks, including HSE risks and their controls.

HSE performance will be monitored and reported during the activity, and performance metrics (including environmental performance indicators and the number of environmental incidents) will be regularly communicated to the workforce. Workforce involvement and environmental awareness will also be promoted by encouraging offshore personnel to report marine fauna sightings and marine pollution (for example, oil on water, dropped objects). Findings, learnings and corrective actions identified from assurance activities and incident investigations will be communicated to project personnel to drive continuous improvement (e.g., through HSE Alerts, pre-shift / toolbox meetings).

10.3 Audits and inspections

Environmental Audits and Inspections undertaken to provide assurance of requirements within this TSDMMP are being met may include:

+ Vessel pre-mobilisation inspections
+ Routine vessel environmental inspections (weekly / monthly during Project execution)
+ Contractor Environmental Audits
+ Regulator Inspections and Audits (as required by Regulator)

For this TSDMMP the environmental audit and inspection processes are described in the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635).

An Environmental Assurance Activities Schedule (EAAS) will be developed and maintained by the Barossa HSE Team which will align with the Barossa Project Integrated Audit Schedule. The EAAS will provide an overview and schedule of assurance (verification) activities required to meet compliance for each activity (e.g., inspections, audits, assessments, and reviews). Additionally, it will allow Santos and the Barossa HSE Team to plan and resource appropriately to ensure all environmental assurance requirements can be met.

Audit criteria, as included within a terms of reference (ToR), will typically include a selection of management actions and environmental performance standards and outcomes; however, may also include parts of the activity description, stakeholder consultation and implementation strategies.

Audit findings may include opportunities for improvement and non-conformances (requirements not met). Audit non-conformances are managed as described in below.

10.3.1 Environmental Incident Reporting Internal incident reporting

All personnel will be informed through inductions and daily operational meetings of their duty to report HSE incidents and hazards. Reported HSE incidents and hazards will be shared during daily operational meetings and will be documented in the incident management systems as appropriate. HSE incidents will be investigated and reported in accordance with the Santos Incident Reporting and Investigation Procedure (SMS-HSS-OS07-PD01) and contractor procedures.

The incident reporting requirements will be provided to all crew on-board the facilities and support vessels with special attention to the reporting time frames to provide for accurate and timely reporting.

10.3.2 External incident reporting

Certain incidents will require notification to external Regulatory authorities under NT and Commonwealth legislation. This includes requirements below; additional requirements may apply as conditions of approval of the DPD Project.

10.3.2.1 Reportable incident – Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)

While the NT P*etroleum (Submerged Lands) Act 1981* and subordinate Commonwealth Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 do not technically apply to the activity area of this TSDMMP, for consistency with other DPD activities that do fall within the jurisdiction of this legislation Santos intends on following the reportable incident definition and reporting requirements described below for this TSDMMP.

Reportable Incidents, defined as "…an incident arising out of operations for the activity that is not within the parameters of the environmental performance standards in the environment plan in force for the activity", will be reported to DITT in accordance with Part 3 of the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 which requires the following:

+ The operator of an activity must give notice of a reportable incident (either oral or written), with all material details of the incident that are reasonably available to the operator, to the Designated Authority as soon as possible after the first occurrence of the incident.
+ The operator must give a written report of the incident to the Designated Authority:
+ if the Designated Authority specifies a reasonable period for giving the report — within that period; or
+ in any other case — as soon as practicable after the first occurrence of the incident.
+ The report must set out fully:
+ all the material facts and circumstances of the incident that the operator knows or is able, by reasonable search and inquiry, to find out; and
+ the action (if any) taken to avoid or mitigate any adverse effects of the incident on the environment; and
+ the corrective action that has been taken, or is proposed to be taken, to prevent another incident of that kind.
+ The operator must keep a record of reports of each reportable incident, and of the details, in each case, of any corrective action taken.

10.3.2.2 Reportable incident – Waste Management and Pollution Control Act 1998 (NT)

As per Part 3 Section 14 of the Waste Management and Pollution Control Act 1998 (WMCA Act 1998), incidents causing, or that may threaten to cause, pollution resulting in material environmental harm or serious environmental harm, will be reported to the NT EPA as soon as practicable after (and in any case within 24 hours after) becoming aware of the incident. An incident includes "*an accident, emergency or malfunction and a deliberate action, whether or not that action was taken by the person conducting the activity in the course of which the incident occurred*".

A notification to the NT EPA of an incident as per Part 3 Section 14 of the WMCA Act 1998 will specify:

+ the incident causing or threatening to cause pollution;
+ the place where the incident occurred;
+ the date and time of the incident;
+ how the pollution has occurred, is occurring or may occur;
+ the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
+ the identity of the person notifying.

10.3.2.3 Wildlife incident reporting

Any incident resulting in a significant impact to a species listed as threatened or migratory under the *Environmental Protection and Biodiversity Protection Act 1999* (EPBC Act 1999) is to be reported to DCCEEW as soon as practicable (and in any case within 24 hours) of becoming aware of the event occurring. For the Project Area, marine species listed as threatened or migratory under the EPBC Act include marine turtles (all species), dolphins, dugongs and crocodiles.

The report will contain:

+ time, location and description of the incident
+ a summary of the response being undertaken
+ details of the relevant contact person.

Any occurrences of stranded, injured or entangled marine megafauna are also to be reported to NT Marine Wild Watch (1800 453 941) (DEPWS) as soon as practicable after observing.

10.3.2.4 Hydrocarbon/ hazardous substance spill reporting

External reporting requirements will include reporting to Darwin Port (for incidents within Darwin Port limits), NT EPA (as above) and the Australian Maritime Safety Authority (AMSA), including completion of a marine pollution notification (POLREP). Oil spill reporting is to follow any additional reporting requirements outlined within the DPD Project Oil Pollution Emergency Plan (BAS-210 0026).

10.3.3 Corrective actions

Corrective actions identified from environmental assurance activities and incident investigations will be derived in collaboration with contractors. For this TSDMMP, corrective actions and contingency processes are described as per the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635) and Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

TSDMMP non-conformances will be addressed and resolved by a systematic corrective action process as outlined in Santos' Management System. Santos' incident and action tracking management system (HSE Toolbox) will be used to track corrective actions in the following instances:

+ Where there has been or potentially been a reportable incident
+ Where there has been a non-compliance in accordance with a statutory plan
+ Where any corrective action requires notification to an external regulatory or statutory body
+ Where there are corrective actions from formal audits (Contractor Pre-Start Audit, external regulator audit etc.).

Once entered, corrective actions, time frames and responsible persons (including action owners and event validators) will be assigned. Corrective action 'close out' will be monitored using a management escalation process.

Environmental corrective actions identified through compliance assurance activities are to be promptly managed to ensure timeframes for external reporting are met and that decision making is made visible.

10.3.4 Continuous improvement

For this TSDMMP, continuous improvement will be driven by the list below and may result in a review of the TSDMMP, with changes applied in accordance with **Section 10.6**.

+ Improvements identified from the review of business-level HSE key performance indicators
+ Actions arising from Santos and departmental HSE improvement plans
+ Corrective actions and feedback from HSE audits and inspections, incident investigations and after-action reviews

+ Opportunities for improvement and changes identified during pre-activity reviews and MoC documents
+ Actions taken to address concerns and issues raised during the ongoing stakeholder management process (**Section 11**).

Identified continuous improvement opportunities will be assessed in accordance with the MoC process (**Section 10.6**) to ensure any potential changes to this TSDMMP are managed in a controlled manner.

10.4 Emergency preparedness and response

Emergency preparedness and response arrangements, applicable to activities covered by this TSDMMP, including for oil spill response, will be included in Santos and Contractor procedures.

10.4.1 Contractor emergency and oil spill response plans

DPD Project contractors are responsible for having comprehensive Emergency Response Plans (ERPs) that address emergency response actions associated with all credible incidents for the activity. These will describe the interface arrangements between Contractor and Santos Incident Management structures and cover all aspects of emergency response including technical, logistical and medical support.

Contractor ERPs will outline roles and responsibilities of contractor personnel for emergency events. The ERPs are accepted by Santos and reviewed on an annual basis by the contractor or if a significant change has occurred to the incident management or emergency response arrangements.

Scenario-based drills are performed to test the emergency response arrangements and updates are made to improve the ERPs, if required.

Contractor vessels undertaking activities covered by this TSDMMP are required, where applicable to vessel class, to have Shipboard Oil Pollution Emergency Plans (SOPEP) and/or Shipboard Marine Pollution Emergency Plans (SMPEPs) outlining hydrocarbon/ hazardous substance spill response arrangements, including response actions and equipment requirements. Vessels are required to conduct regular spill response drills as per arrangements detailed in these plans.

10.4.2 Santos incident management and oil spill response arrangements

Santos maintains Incident and Crisis Management Teams (IMT and CMT) and support arrangements to respond to all-hazard incidents, including oil spill incidents, at its sites and for activities under its control or influence, including activities covered under this TSDMMP. Santos' crisis and incident management arrangement are outlined within the Crisis, Incident Management & Emergency Response Procedure (SMS-HSS-OS05-PD01) and Incident Management Plan – Upstream Offshore (SO-00-ZF-00025). IMT and CMT training and exercise requirements, including OPEP exercises, are included within an annual training and exercise plan and schedule.

Specific oil spill response support strategies and arrangements for hydrocarbon spill scenarios covered in this TSDMMP will be outlined within the DPD Project Oil Pollution Emergency Plan (BAS-210 0026). This will include roles and responsibilities and response strategies / resources applicable for responding to worst case spill scenarios for DPD activities covered by this TSDMMP. The arrangements within the OPEP will provide support to, and interface with, response activities undertaken by onsite personnel (e.g., vessel oil spill response activities), as well as response activities coordinated by designated NT Control Agencies.

10.5 Reporting and notifications

Environmental reporting for the DPD Project construction activities will include reports between Subcontractors and Contractors, Contractors and Santos, and Santos and Stakeholders, including Regulatory authorities. Reports will be delivered within agreed upon timeframes. **Table 10-3** outlines an initial assessment of reporting requirements relevant to this TSDMMP.

External reporting requirements may be dictated by approval conditions associated with the DPD Project and finalisation of this TSDMMP will include all relevant external regulatory reporting requirements.

A detailed schedule of reporting requirements and submission dates for the DPD Project will be developed as per the Barossa Project Environmental Compliance Plan (BAA-200 0635).

10.5.1 Internal reporting

10.5.1.1 Routine reporting

Internal reporting will occur between trenching and environmental consulting contractors and Santos. This reporting will be undertaken on a daily and weekly basis and will include trenching operation and environmental performance reports.

Daily reports will be provided by contractors to Santos, this will include:

+ Dredge log
+ Telemetered turbidity data recorded at monitoring sites for 24-hr period prior to reporting, including the daily rolling average turbidity value (**Section 9**)
+ Turbidity data trigger exceedance (Section 9)
+ Telemetered water temperature data recorded at coral monitoring sites for 24-hr period prior to reporting, including the 21-day rolling water temperature average (**Section 9**)
+ Coral water temperature trigger exceedance
+ Marine megafauna interactions
+ Changes to weekly trenching plan

Weekly reports will be provided by the contractors to Santos, this will include:

+ Weekly dredge report
+ Telemetered turbidity data recorded at monitoring sites for the week prior to reporting, including daily rolling average turbidity value (**Section 9**)
+ Responses to turbidity and coral water temperature trigger exceedances
+ Responses to marine megafauna interactions
+ Changes to overall dredge plans
+ Summary of environmental events
+ Inspection and/or audit outcomes and status of actions/findings

10.5.1.2 Environmental event reporting and investigation

Environmental incidents, hazards, non-compliances and near misses are deemed by Santos as environmental events. All seas will report all environmental events related to trenching and spoil disposal activities in accordance with contractual requirements. Environmental events will be documented and investigated as appropriate. Actions taken to prevent and or mitigate environmental events will be documented and tracked by the contractor until close-out.

10.5.2 External reporting

10.5.2.1 Exceedance reporting

In the event that Level 2 trigger values (detailed in **Section 8.2.2.1)** are exceeded during trenching and spoil disposal activities, and exceedance is attributable to trenching activity, Santos will notify DITT and NT EPA/DEPWS as soon as practicable (within 24 hours after becoming aware of exceedance).

Indicative notification and reporting timeframes (in business days) for each step is summarised in **Table 10-2.**

Table 10-2: Trigger exceedance notification and reporting summary

Communication	Trigger Level	Time	Content
Initial exceedance notification	Level 2	Within 24 hours following identification of exceedance	Notify stakeholders of exceeded triggers.
Attributability notification	Level 2	Within 5 days of exceedance	Notify stakeholder attributability
Exceedance is attributable to dredging			
Exceedance report	Level 2	Weekly	Report including management actions implemented and their effectiveness (where practicable)
Lessons learnt report	Level 2	15 days after return to below Level 1 trigger level	Report on exceedance management, including lessons learnt.

10.5.2.2 Monitoring reporting

DITT and NT EPA/DEPWS will be provided with a comprehensive and interpretive water quality report following the conclusion of monitoring, unless otherwise agreed upon with regulator.

This water quality report will be formatted following the National Water Quality Management Strategy, Australian Guidelines for Water Quality Monitoring and Reporting, no. 7 (ANZECC and ARMCANZ, 2000) and will include assessment of likely impacts to sensitive receptors from the release of fine material.

10.5.3 Summary of reporting

Reporting required in association with Santos' DPD Project, including that detailed above, is summarised in **Table 10-3**.

Table 10-3: Summary of reporting requirements.

Report/ Notification	Responsibility	Content	Frequency	Recipient
Pre-start				
OVID inspection reports	Santos Marine Assurance Team	Provides a summary of the findings of the support vessel inspection which assesses compliance with relevant international (e.g. MARPOL 73/78), Australian and Santos requirements.	Prior to commencement of the activity	Santos
Pre-start contractor audit	Santos Barossa Team	Confirmation of compliance with TSDMMP commitments relating to operational procedures and processes that Santos require to be in place prior to the commencement of the activity.	Prior to commencement of the activity	Santos
Pre-start notifications	Santos Barossa Team / Contractors	Details on DPD Project commencement to meet requirements of stakeholders (including Regulatory authorities)	Prior to commencement of the activity	Various stakeholders
Execution and completion				
Regular Stakeholder updates	Santos Barossa Team	Regular updates on DPD Project during planning and execution as per Stakeholder Management Plan (refer **Section 11**)	Throughout planning and execution	Various stakeholders
Contractor environmental execution audit	Santos Barossa Team	Confirmation of compliance with TSDMMP commitments relevant to execution of the activity.	Prior to completion of the activity	Santos
Vessel Daily Reports	Contractor Vessel Master	Update on day's activities, including any identified non-conformance against this TSDMMP, and any issues that may need addressing.	Daily	Santos
Vessel Environmental Reports/Checklists	Contractor Vessel Master	Compliance against key regulatory and contractual commitments (including TSDMMP commitments). Reporting of fuel usage, vessel discharges and emissions etc.	Weekly/ Monthly[1]	Santos

Report/ Notification	Responsibility	Content	Frequency	Recipient
HSE Meetings Records	Contractor and Santos Barossa Team	Monthly, dedicated HSE meetings are held with the offshore and Perth-based management (including contractor management) and advisors to address targeted health, safety and environment incidents and initiatives. Minutes of these meetings are produced and distributed as appropriate.	Monthly	Santos
Completion notifications	Santos Barossa Team / Contractors	Details on DPD Project completion to meet requirements of stakeholders (including Regulatory authorities)	Following completion of the activity	Various stakeholders
Unexpected Finds Notification	Contractor and Santos Barossa Team	Notification by Contractor of potential unexpected find of heritage value. Further notification to Maritime Archaeologist and NT Heritage Branch, as required, following Unexpected Finds Protocol.	Dependent upon occurrence of unexpected find of cultural value	NT Heritage Branch
Environmental Monitoring Reports	Santos Contractor and Santos Barossa Team / Environmental Monitoring Contractor	Reporting on the outcomes of environmental monitoring activities (including water quality and benthic habitat monitoring) associated with the DPD Project construction activities.	Various dependent upon program	Santos DEPWS DITT NT EPA DCCEEW (if required)
Environmental Performance/ Compliance Assurance Report	Santos Barossa Team	Provides a summary of compliance performance, including the environmental performance objectives, standards and measurement criteria within this TSDMMP and any other conditions of approval on the DPD Project.	At completion of the activity and not less than annually	DITT NTEPA (DEPWS) DCCEEW (if required)
Incident reporting				

Report/ Notification	Responsibility	Content	Frequency	Recipient
Incident Report – Internal	Contractor and Santos Barossa Team	Provides framework for Internal notification of incidents including spills. The first report contains tools for assessing the severity of the incident and escalating as per the incident notification procedure. Incident reporting will also be undertaken through Santos' online EHS Toolbox system.	Incident specific	Santos
Incident Report – Reportable Environmental Incident (P(SL)(MoE) Regs 1999)	Santos Barossa Team	Reporting of Reportable Incidents as per Part 3 of the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (P(SL)(MoE) Regs 1999) (Refer **Section 10.3.2.1**)	Incident specific	DITT
Incident Report – Reportable Environmental Incident (WMPC Act 1998)	Santos Barossa Team	Reporting of Reportable Incidents as per Part 3 of the Waste Management and Pollution Control Act 1998 (WMPC Act 1998) (**Section 10.3.2.2**)	Incident specific	NT EPA
Incident Report – Wildlife Incidents	Santos Barossa Team	Reporting of incidents involving EPBC Act species and reports of stranded, injured or entangled marine megafauna (**Section 10.3.2.3**)	Incident specific	DCCEEW DEPWS
Incident Report – Hydrocarbon/ hazardous substance spill	Contractor and Santos Barossa Team	Reporting of NT oil spill incidents to Darwin Port (within port limits), AMSA and NT EPA. Additional oil spill reporting requirements as stated within the DPD Project Oil Pollution Emergency Plan (BAS-210 0026)	Incident specific	Darwin Ports AMSA NT EPA
Incident Report – Egress into wreck exclusion zone	Santos Barossa Team	Reporting of any egress into or disturbance of the exclusion zones of the Booya and Catalina 6 wrecks	Incident specific	Darwin Ports Harbour Master
Environmental reporting specific to the TSDMMP				

Report/ Notification	Responsibility	Content	Frequency	Recipient
Initial exceedance notification	Santos Barossa Team	Notify stakeholders of exceeded triggers.	Incident specific Within 24 hours following identification of exceedance	Santos DEPWS DITT NT EP
Attributability notification	Santos Barossa Team	Notify stakeholder attributability	Incident specific Within 5 days of exceedance	Santos DEPWS DITT NT EPA Relevant other proponents
Exceedance report	Santos Barossa Team	Report including management actions implemented and their effectiveness (where practicable)	Weekly	Santos DEPWS DITT NT EPA
Lessons learnt report	Santos Barossa Team	Report on exceedance management, including lessons learnt.	15 days after return to below Level 1 trigger level	Santos DEPWS DITT NT EPA

Notes:

1. As per the Barossa compliance assurance plan

10.6 Document management

This TSDMMP will be revised based on conditions of environmental approvals and/or licences and submitted to the appropriate regulator, for review and approval as required, prior to DPD Project implementation (i.e., commencement of construction activities).

10.6.1 Information management and document control

This TSDMMP, as well as any approved management of change (MoC) documents, are controlled documents and current versions will be available on Santos' document control system and made available to Project contractors.

As per the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)* the TSDMMP and all records associated with monitoring and reporting against TSDMMP commitments will be maintained for a period of five years. This includes revisions of the TSDMMP, and subordinate EMPs, written reports relating to environmental performance (monitoring, audit and review), records of emissions and discharges, records of calibration and maintenance of monitoring devices and records of reportable incidents.

The management and transfer of environmental assurance evidence between Santos and the primary construction contractor will be undertaken as per the Barossa Project Gas Export Pipeline (GEP) Environmental Compliance Assurance Plan (ECAP) Evidence Management and Transfer Procedure (BAS-210 0050).

10.6.2 Management of change

Following regulatory review and approval of this TSDMMP any changes to Project activities as described in this document, which have the potential to materially increase environmental impacts and risks, will be evaluated and controlled following the impact and risk assessment process followed in **Section 7**. The documentation and approval of management of change (MoC) assessments will follow the process outlined within the Santos Management of Change Procedure (SMS-LRG-OS01-PD04). MoC records will be retained and details of MoCs outlined within Regulatory compliance/performance reports.

As per the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)*, if a significant new environmental effect or risk is identified, or a significant increase in environmental effect of risk identified, which is not already provided for in the TSDMMP, a revision of the plan will be submitted to DITT as soon as practicable after the occurrence or identification of the significant effect or risk.

If there is a change in the petroleum instrument holder, or operator for the activity, a revision of the TSDMMP will be submitted to DITT as soon as practicable after the change.

10.6.3 Reviews

This TSDMMP addresses a temporary construction activity. The TSDMMP will be reviewed annually, or as required in response to regulatory requirements and any changes to impacts, risks or management actions raised in Santos' assurance processes, incident response, stakeholder engagement or contractor engagement. These changes will be evaluated through the MoC process, and any updates communicated to regulators for review and approval as required.

11 Stakeholder Engagement and Communications

The stakeholder engagement approach used for the Project is in accordance with Santos's corporate approach to stakeholder engagement and industry leading standards and practice. The approach recognises and is aligned with the NT EPA's Guidance for Proponents – Stakeholder Engagement (NT EPA, 2021a), the NT EPA's guidance for Preparing a Supplementary Environmental Report (NT EPA, 2021b) and the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement (IAP2, 2015).

Due to the iterative nature of the stakeholder process all relevant details have been contained in one document, the SER (BAS-210 0020), to contain updates to one location. The SER provides an outline of the objectives, process and key stakeholders consulted for the DPD Project. Additionally, the Stakeholder Engagement Plan (SEP) is attached to the SER. It details all consultation undertaken to date and information on future engagement activities.

Prior to the start of consultation formally commencing in late 2021, Santos identified the need to engage with other organisations proposing to undertake future trenching activities on an ongoing basis throughout the planning and assessment periods. The aim of this specific engagement was to share information and seek collaboration across a range of aspects including the undertaking of environmental studies, data sharing, spoil disposal and re-use, contracting of vessels and equipment and project schedule. The organisations involved are the NT Department of Infrastructure, Planning and Logistics (covering three projects), INPEX and the Commonwealth Department of Defence.

The SER provides a summary of the issues raised relevant to the Project and Santos' assessment and response to these issues. A full register with all submissions and responses is provided in the SER in Appendix 2 and a summary can be found in Table 5.1 in the SER. Specifically, the register includes submissions and responses related to both the impacts and risks associated with trenching activities and collaboration with other proponents of projects involving trenching activities in Darwin Harbour.

The NT DIPL is developing a reference group that will provide information and advice on its preparation of a future dredge management plan for Darwin Harbour. Santos has indicated its willingness to be part of these efforts in addition to the other ongoing engagement activities specifically for the DPD project. Further details of the planned engagement following the assessment period, including the construction and operation periods, is provided as part of the SEP (Appendix 3 of the SER). Sections of the SEP specific to the lead-up to and execution of trenching activities are shown in **Table 11-1**.

In preparing the SER, and project management plans, Santos has considered and assessed each submission individually, and taken into consideration the issues raised when engaging with stakeholders to assess potential impacts and proposed management measures.

The SER provides a summary of the issues raised relevant to the Project and Santos' assessment and response to these issues. A full register, with all submissions and responses, is provided as an attachment to the SER.

Table 11-1 Sections of the SEP specific to the lead-up to and execution of trenching activities

Stage	Aims and Activities	Deliverables
Public Comment Period on SER and ongoing engagement awaiting final NT EPA decision	Aims: Ensure all issues/concerns raised by stakeholders during the assessment process have been addressed; as many additional stakeholders as possible have been identified; all stakeholders are aware of the final decision and opportunities to further engage with Santos. Key activities: + Engage with DEPWS and stakeholders on additional issues/concerns raised during public comment period. + Continued engagement with NT Government agencies and private organisations on technical issues, secondary project approvals and/or collaborative opportunities. + Notification to all stakeholders re assessment outcome and conditions placed on Project; progress on approved activities and required associated approvals; stakeholder communication and consultation process going forward. + Continued engagement with NT Government agencies and other relevant stakeholders for all secondary project approvals that are required prior to activities commencing + Engage with indigenous organisations on outcomes from AAPA investigation and Clearance Certificate conditions + Continued engagement with community and indigenous organisations on opportunities to support/collaborate associated directly with project activities (e.g. Larrakia Rangers) or community-based activities + Engage with key contractors to be undertaking activities on Santos' behalf and owners of land upon which activities will occur (e.g. Darwin Port, DIPL- East Arm, DLNG, Wickham Point Deed Reference Group, Mount Bundey) + Ongoing engagement with potential suppliers via ICN NT + Ongoing engagement with the following stakeholders on specific issues raised:	+ Stakeholder meetings + Presentations at stakeholder events (see potential list below) + Email, phone communication + Distribution of project update via email + Publication of SER documentation on NT EPA website + Notification via email of SER public comment period + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statements

Stage	Aims and Activities	Deliverables
	– Opportunities for collaboration on dredging-related activities – NT DIPL, INPEX, Department of Defence – Pipelay activities within Reef Fish Protection Area – NT DITT – Fisheries, AFANT, NTSC – Indigenous consultation resulting from AAPA Clearance Certification – AAPA, NLC, Wickham Point Deed Reference Group, other identified Larrakia stakeholders – Opportunities for collaboration on environmental studies and modelling – NT DPEWS, INPEX, Darwin Harbour Advisory Group, Larrakia Rangers – Road traffic management – NT DIPL – Darwin Harbour impacts management – NT DIPL, Darwin Port, DHAC, Tourism NT, Top End Tourism, AFANT, NTGFIA	
Lead-up to execution of activities	Aims: Ensure all identified stakeholders are aware of pending activities, timeframes, how issues/concerns have been mitigated/are being managed, how complaints will be handled and ongoing communications process and contact points. Key activities: + Continued engagement with NT Government agencies and private organisations on technical issues and/or collaborative opportunities. + Continued engagement with NT Government agencies and other relevant stakeholders for all secondary approvals associated with the Project and required prior to activities commencing + Notification to all stakeholders re proposed activities, schedule stakeholder communication and consultation process going forward. + Ongoing engagement with potential suppliers via ICN NT + Engage with key contractors who will be undertaking activities on Santos’ behalf and the owners of land upon which activities will occur (e.g. Darwin Port, DIPL- East Arm, DLNG Management, Wickham Point Deed Reference Group)	+ Stakeholder meetings + Presentations at stakeholder events (e.g. Darwin Port Users Group, Darwin Harbour Advisory Committee, Top End Tourism, Tourism NT, NT Chamber of Commerce, NT Energy Club) + Email, phone communication + Distribution of project update via email + Distribution of project fact sheets via email and stakeholder meetings + Distribution of project information via third parties

Stage	Aims and Activities	Deliverables
	+ Ongoing engagement with the following stakeholders on specific issues raised: – Opportunities for collaboration on dredging-related activities – NT DIPL, INPEX, Department of Defence – Pipelay activities within Reef Fish Protection Area – NT DITT – Fisheries, AFANT, NTSC – Indigenous consultation resulting from AAPA Clearance Certification – AAPA, NLC, Wickham Point Deed Reference Group, other identified Larrakia stakeholders – Opportunities for collaboration on environmental studies and modelling – NT DPEWS, INPEX, Darwin Harbour Advisory Group, Larrakia Rangers – Road traffic management – NT DIPL, other stakeholders identified – Darwin Harbour impacts management – NT DIPL, Darwin Port, DHAC, Tourism NT, Top End Tourism, AFANT, NTGFIA	(e.g. Darwin Port, Tourism NT) to their membership + Distribution of project information via paid advertorial in NT News + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statements
Execution of activities in NT Waters	Aims: To help ensure safe use by all users of locations where project activities are occurring. Ensure all identified stakeholders are kept regularly informed of aware of progress on current activities, pending activities, timeframes, how issues/concerns have been mitigated/are being managed, how complaints are being handled and ongoing communications process and contact points. Key activities: + Continued engagement with NT Government agencies and private organisations on technical issues and/or collaborative activities. + Continued engagement with NT Government agencies and other relevant stakeholders for the safe and efficient compliance of all secondary approvals (e.g. road traffic management, waste discharges, licence conditions) associated with the Project + Notification to all stakeholders re proposed activities, schedule stakeholder communication and consultation process going forward. + Ongoing engagement with potential suppliers via ICN NT	+ Stakeholder meetings + Presentations at stakeholder events (e.g. Darwin Port, Top End Tourism, Tourism NT, Chamber of Commerce, Energy Club) + Email, phone communication + Distribution of project update via email + Distribution of project fact sheets via email and stakeholder meetings + Project fact sheets posted to Santos external website

Stage	Aims and Activities	Deliverables
	+ Ongoing engagement with key contractors undertaking activities on Santos' behalf and the owners of land upon which activities will occur (e.g. Darwin Port, DIPL- East Arm, DLNG Management, Wickham Point Deed Reference Group) to ensure efficient communications and help maintain safe operations. + Ongoing engagement with the following stakeholders on specific issues raised: – Opportunities for collaboration on dredging-related activities – NT DIPL, INPEX, Department of Defence – Pipelay activities within Reef Fish Protection Area – NT DITT – Fisheries, AFANT, NTSC – Indigenous consultation resulting from AAPA Clearance Certification – AAPA, NLC, Wickham Point Deed Reference Group, other identified Larrakia stakeholders – Opportunities for collaboration on environmental studies and modelling – NT DPEWS, INPEX, Darwin Harbour Advisory Group, Larrakia Rangers – Road traffic management – NT DIPL – Darwin Harbour impacts management – NT DIPL, Darwin Port, DHAC, Tourism NT, Top End Tourism, AFANT, NTGFIA	+ Distribution of project information via third parties (e.g. Darwin Port, Tourism NT) to their membership + Distribution of project information via paid advertorial in NT News + Physical location on Darwin Harbour for distribution of project information and discussion of issues/concerns + Santos ASX and media statements

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Appendix 1: Santos Environment, Health and Safety Policies

Environment, Health & Safety

Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Jodie Hatherly, General Counsel and VP Legal, Risk and Governance		
Approved by:	The Board	Version:	3

20 August 2019 Page 1 of 1

Appendix 2: Summary of Management Actions

MA reference	Management Action
DPD-MA04	Activity vessels equipped and crewed in accordance with Australian maritime requirements
DPD-MA05	Ongoing stakeholder consultation with relevant stakeholders (including applicable notifications) to minimise adverse impacts on other marine users
DPD-MA06	Implementation of precautionary zones around DPD Project vessel to mitigate against adverse interactions
DPD-MA07	Vessels supporting the trenching operations will act as surveillance vessels when operating adjacent to the trenching vessels
DPD-MA08	The proposed pipeline route will be marked on marine charts, in the same way that the existing pipelines are gazetted and marked on marine charts
DPD-MA12	Pipeline route was surveyed (geophysical and geotechnical) to evaluate seabed, trenching, stabilisation and freespan correction/ prevention will only be undertaken at identified areas (using standard positional accuracy measures used in the industry)
DPD-MA13	Overflow from the TSHD will be undertaken through the adaptive management processes. There will be 'environmental valve', 'green valve' where available (attached to O/F to reduce air entrained, to reduce billowing and facilitates sediment sinking) as standard which will be used as a first step.
DPD-MA14	Standard operating procedure for spoil disposal will be used.
DPD-MA15	Spoil will not be disposed of in a single location, to avoid developing a single large mound.
DPD-MA16	Spoil will only be placed *in situ* within a short section of trenching within intertidal zones and will be removed subsequently where accessible by BHD and SHB for offshore disposal
DPD-MA18	Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, trenching and other support activities in the vicinity of sensitive habitats and nearshore heritage or sacred sites
DPD-MA19	Trained and competent anchor handling operators will be used
DPD-MA20	Anchors exclusion areas will be implemented to avoid sensitive habitats and heritage sites
DPD-MA21	Independent cultural heritage and habitat assessment have been undertaken to identify potential important heritage sites and habitat along the pipeline route and to avoid sensitive benthic habitats and cultural objects where practicable. Maritime cultural heritage objects that cannot be avoided will be managed as per NT Heritage Branch requirements
DPD-MA28	Adaptive management process as defined in Section 8.6.2.4 which includes environmental monitoring of water quality with management measures applied if water quality exceeds trigger levels
DPD-MA49	Observation and shut-down zones for marine fauna have been developed based on noise modelling results and standard protocols
DPD-MA50	Vessel inductions for all crew will address marine fauna risks and the required management controls
DPD-MA51	Vessel and helicopter contractor procedures will comply with Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA52	Personnel trained in marine fauna observation (MFO) will be present on trenching and spoil disposal vessels during daylight hours, including one crew member with MFO training on the bridge at all times
DPD-MA53	All marine fauna interactions and observations will be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW
DPD-MA55	Vessels will adhere to Port of Darwin vessel speed limits
DPD-MA56	Maintenance of vessel, vehicle and equipment combustions engines and vessel incinerators as per planned maintenance system
DPD-MA57	Observation and shut-down zones for marine fauna have been developed based on noise modelling results for trenching and standard protocols and include: + Observation (150 m) and exclusion (50 m) zones for marine mammals and turtles. + Observation zone monitored for 10 minutes prior to commencing trenching and sheet piling. A Marine Megafauna Observation and Adaptive Management Protocol will be included within the MMNMP (BAS-210 0022)

MA reference	Management Action
DPD-MA58	+ Soft start (ramp-up) of hydraulic tools (rock breaking) by BHD + Soft start (ramp-up) of trenching equipment, where practicable, will apply to the CSD and TSHD
DPD-MA60	Shielding, where practicable, and/or orienting operational lights (excluding navigational lighting) on vessels to limit light spill to the environment
DPD-MA61	Housekeeping measures will be adopted, including requiring all crew to keep shutters on windows closed at night, to limit light emissions from vessels
DPD-MA62	Vessel searchlights will only be operated in an emergency situation.
DPD-MA63	Santos will document vessel light spill on Darwin Harbour turtle nesting beaches as part of the DPD Project's environmental monitoring program
DPD-MA64	Vessels will comply with relevant Marine Orders with respect to planned discharges, including: + Marine Order 91 – Marine Pollution Prevention: Oil, which implements Annex I of the MARPOL + Marine Order 95 – Marine Pollution Prevention: Garbage + Marine Order 96 – Marine Pollution Prevention: Sewage, which implements Annex IV of the MARPOL
DPD-MA65	Santos Marine Assurance Process
DPD-MA69	Atmospheric emissions from combustion, incinerators and ODS managed in accordance with standard maritime practice (MARPOL)
DPD-MA70	Monitoring and reporting of fuel consumption and calculated GHG emissions
DPD-MA71	Use of low sulphur diesel
DPD-MA78	Implementation of Santos approved standards and procedures for outboard lifts
DPD-MA79	All lifting and winching equipment will undergo inspection, testing and certification as per Applicable Laws and Applicable Codes and Standards
DPD-MA80	Dropped object recovered where safe and practicable to do so
DPD-MA81	Identification of no lift zones or additional controls, where relevant, in proximity to subsea pipelines as documented in relevant lifting and operational procedure/s
DPD-MA84	Pipeline route design selected where practicable to avoid the potential for impact to habitat / cultural seabed features or assets from a dropped object
DPD-MA85	Vessels equipped with effective anti-fouling coatings as required for class
DPD-MA86	Ballast water management will comply with MARPOL requirements (as applicable to class), Australian Ballast Water Management Requirements and *Biosecurity Act 2015*
DPD-MA87	Apply risk-based IMS management for vessels and immersible equipment – vessel and immersible equipment must be assessed as having a low risk of IMS prior to coming onto activity
DPD-MA88	Vessels having suitable anti-fouling coating (marine growth prevention system) in accordance with the *Protection of the Sea Act 2006*
DPD-MA89	– Inductions to include observing marine fauna (e.g., dolphins and turtles)
DPD-MA90	The TSHD shall be fitted with pre-sweeping mechanisms / chain curtains to mitigate turtle entrapment (fauna strike – unplanned)
DPD-MA91	Inspection and maintenance for all equipment using chemicals
DPD-MA92	Santos chemical selection procedure applied for chemicals planned to be discharged to the environment
DPD-MA93	ROV operations undertaken in accordance with good industry practise (in relation to hydraulic fluid control)
DPD-MA96	Chemical storage areas designed to contain leaks and spills and inspected routinely
DPD-MA97	Chemicals will be managed in accordance with standard maritime practices as per vessel shipboard oil pollution emergency plan (SOPEP)
DPD-MA98	Spill clean-up kits available in high-risk areas
DPD-MA99	Bunding/secondary containment

MA reference	Management Action
DPD-MA100	Vessel-specific bunkering procedures and equipment consistent with Santos marine vessel vetting requirements including: + Use of bulk hoses that have quick connect 'dry break' couplings + Correct valve line-up + Defined roles and responsibilities, and the specific requirement for bunkering to be completed by trained personnel only + Visual inspection of hoses prior to bunkering to confirm they are in good condition + Testing of the emergency shutdown mechanism on the transfer pumps + Assessment of weather/sea state + Maintenance of radio contact with Vessel during bunkering operations + Bunkering checklist Visual monitoring during bunkering Marine Order 91 – Marine Pollution Prevention: Oil
DPD-MA101	Vessel equipped and crewed in accordance with Australian maritime requirements
DPD-MA102	Safety exclusion zone around DPD Project vessels and Notice to Mariners will be issued for offshore works advising all major shipping traffic formally.
DPD-MA103	No intermediate fuel oil (IFO) or heavy fuel oil (HFO) will be used in activity vessels working inside the Project Area
DPD-MA104	Implement tiered spill response as per DPD Project specific OPEP in the event of an MDO spill
DPD-MA105	Santos to make oil spill tracking buoys available on primary project vessel/s with Santos CSR/s and/or at local supply base for immediate deployment to assist with tracking of an oil spill
DPD-MA106	Trenching will only occur within pre-programmed areas (using standard positional accuracy measures used in the industry)
DPD-MA107	Exclusion zones programmed on all primary vessels associated with the works to clearly indicate no entry zones and nearby pipelines – this will clearly identify areas for spud placement, anchor positioning and trenching activities

Appendix 5: Treated Seawater Discharge Modelling Report

SANTOS DARWIN PIPELINE DUPLICATION (DPD) PROJECT

Treated Seawater Modelling

MAQ1077J.002
Darwin DPD Treated Water Modelling
Rev0
2 August 2022

rpsgroup.com

Document status					
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Contents

Executive Summary 1
Background 1
Methodology 1
Key Findings 2
1 INTRODUCTION 3
1.1 Background 3
2 SCOPE OF WORK 6
3 CURRENTS 7
3.1 Development of Regional Current Data 7
3.2 Boundary Conditions 8
3.2.1 Overview 8
3.3 Near-Seabed Currents 9
4 WATER TEMPERATURE AND SALINITY 11
5 ENVIRONMENTAL REPORTING CRITERIA 12
6 NEAR-FIELD MODEL 13
7 NEAR-FIELD RESULTS 15
8 FAR-FIELD MODELLING 16
8.1 Description of the Near-Field Model: MUDMAP 16
8.2 Far-Field Model Setup 16
9 FAR-FIELD RESULTS 18
9.1 General Observations 18
9.2 Combined Analysis Over 12- Hour Period 22
9.3 Combined analysis over 24 and 48-hour period 27
10 REFERENCES 29

Tables

Table 1.1 Coordinates of the Barossa DPD treated seawater release locations. 3
Table 1.2 Volumes of treated seawater and corresponding release durations during overflow and dewatering. 3
Table 4.1 Average water temperature and salinity near the seabed at the treated seater release locations. 11
Table 9.1 Summary of the maximum distances and areas of exposure by the preservation chemical during dewatering for each NOEC value at the three locations. Results are derived from 25 simulations, each simulation was individually assessed based over a 12-hour continuous exposure period for the NOEC values. 23

Figures

Figure 1.1 Barossa DPD treated seawater release locations. 5
Figure 3.1 Detail of the hydrodynamic model grid 8
Figure 3.2 Annual near-seabed current rose plots near KP84 (Left), KP102 (Middle) and KP114 (Right). derived from the 2019 – 2020 water level dataset. 10
Figure 9.1 Predicted preservation chemical concentrations during dewatering for simulation 1 at KP84 between 11 am to 11 pm 15th October 2019 for KP84. 19

Figure 9.2 Predicted preservation chemical concentrations during dewatering for simulation 1 at KP102 between 3 pm 21st April to 3 am 22nd April 2020. 20
Figure 9.3 Predicted preservation chemical concentrations during dewatering for simulation 1 at KP114 between 7 am to 7 pm 16th October 2020. 21
Figure 9.4 Predicted concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP84. The results were calculated from 25 simulations with different metocean conditions. 24
Figure 9.5 Predicted concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP102. The results were calculated from 25 simulations with different metocean conditions. 25
Figure 9.6 Predicted concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP114. The results were calculated from 25 simulations with different metocean conditions. 26
Figure 9.7 Predicted concentrations of the preservation chemical over a 24-hour exposure period during dewatering from KP102. The results were calculated from 25 simulations with different metocean conditions. 28

EXECUTIVE SUMMARY

Background

Santos is assessing environmental impacts and risks associated with the Darwin Pipeline Duplication (DPD) Project. The DPD Project involves the installation of a gas export pipeline (GEP) from a point (kilometre point (KP) 0) in Commonwealth waters (25 km from the Commonwealth/ NT waters boundary) to the Darwin LNG (DLNG) Facility on Wickham Point in Darwin Harbour (KP122.2). The pipeline will transfer dry gas from the offshore Barossa field to the DLNG facility. The new pipeline (nearshore Barossa GEP) would run alongside the existing Bayu-Undan (BU) to Darwin GEP, typically within 50 – 100 m thereby effectively duplicating that pipeline.

While highly unlikely, an unplanned 'wet buckle' event may occur during installation of the nearshore Barossa GEP, thereby causing flooding of the pipeline with seawater. In the event of a 'wet buckle' the raw seawater will need to be displaced from the pipeline with seawater treated with a preservation chemical consisting of a biocide, corrosion inhibitor and oxygen scavenger. The treated seawater would then be dewatered to facilitate continued installation of the pipeline. To support the impact assessment for contingency pipeline filling and dewatering of treated seawater, Santos has commissioned a dispersion modelling study. Given the 'wet buckle' may occur anywhere along the proposed pipeline between KP0 and KP122.2, the study examined discharges at three locations (KP84, KP102 and KP114), specifically selected due the proximity of pipeline to areas of importance (i.e. reefs, coral, etc).

Both pipeline over filling (overflow) and dewatering scenarios were considered. The volume of treated seawater released as overflow (600 m^3) with a corresponding release duration (38 minutes) has been estimated to be the same at all three locations. However, during dewatering the volume and release duration was varied due to the length of the pipe at the given location (KP84 – 19,958 m^3 over 21.4 hours; KP102 – 10,623 m^3 over 11.4 hours; and KP114 – 4,400 m^3 over 4.7 hours). The concentration of the preservation chemical was assumed to be 550 mg/L with the discharge of treated water during overflow and dewatering via a single 4" diameter outlet 0.5 m above the seafloor.

The main objective of the study was to determine the area of exposure of the preservation chemical at different concentrations and compare this to different No Observable Effect Concentration (NOEC) thresholds.

Methodology

The physical mixing of the treated seawater was assessed for two distinct zones: near-field and far-field. The near-field zone is defined by the region where the levels of mixing and dilution are purely controlled by the plume's initial jet momentum and the static current. The buoyancy in this instance is negligible given that the treated seawater has the same density as the surrounding seawater. Once the near-field assessment was complete, the far-field phase examined the transported and mixing of the preservation chemical by the ambient currents.

The extent and area of predicted exposure of the discharge were reported against established No Observable Effect Concentrations (NOECs) and calculated species protection levels for Hydrosure, the preferred preservation chemical to be used to treat the seawater. As a conservative approach, the 99% of species protection level (PC99%) NOEC of 0.06 mg/L; (which is a dilution of 1:9,167 based on initial concentration of 550 mg/L) was used as the minimum reporting threshold. Additional reporting thresholds based on the species protection limits of PC95% (NOEC of 0.10 mg/L), PC90% (NOEC of 0.15 mg/L) and PC80% (NOEC of 0.23 mg/L), were also used to assess plume extents and areas of coverage.

While the NOEC values are typically derived from long term tests whereby organisms are exposed to the preservation chemical between 48 and 96 hrs, due to the short-term release duration (<22 hours) and in turn, short exposure times, as an additional level of conservatism, the values of each modelled cell were examined over a 12-hour duration. Consequently, the extent of the mixing zone was based on a NOEC threshold of 0.06 mg/L (PC99%) over a 12-hour continuous duration.

For completeness, the areas of exposure from the preservation chemical during the overflow and dewatering releases were also assessed over 24 and 48-hour exposure period.

Key Findings

The key findings are:

- The near-field results showed that treated seawater would initially project horizontally approximately 1 – 2 m due to the orientation of the outlet and the fast exit velocities. Once the plume had lost its momentum, it mixed laterally due to the currents as it is neutrally buoyant. The near identical current speeds at the three locations and water depths meant the dilutions achieved were similar in each scenario. The lowest dilutions predicted at the three locations at 10 m and 30 m were 1:13.6–1:13.8 and 1:39.9, equating to concentrations of 39.8–40.6 mg/L (or ppm) and 13.8 mg/L (or ppm).

- There was no predicted exposure above the lowest NOEC threshold (PC99%) of 0.06 mg/L (or 0.06 ppm) over a 12-hour period from the preservation chemical during overflow at all three locations.

- For treated seawater dewatering there was no exceedance of the PC99% threshold over a 24-hour period at KP84 and KP114. Whereas the area of exposure from the dewatering at KP102 had significantly reduced to 0.16 km^2 and limited to the PC99% threshold.

- There was no exceedance of the PC99% threshold over a 48-hour period at all three locations for treated seawater dewatering.

- For a conservative 12-hour exposure time the dewatering discharge at KP84 resulted in a preservation chemical plume (PC99%; NOEC of 0.06 mg/L) that was generally continuous up to ~1.4 km from the release location, with small isolated patches predicted up to 9.61 km. Isolated patches beyond 2 km were predicted to occur during 2 of the 25 simulations and the plume was predicted to travel a maximum distance of 9.61 km in only 1 simulation. The isolated patches were due to an accumulation of the treated seawater, which had occurred during a current reversal, causing it to concentrate. The predicted maximum distances from the release location to the PC95% and PC90% were significantly smaller: 1.02 km and 0.75 km, respectively. The potential areas of exposure based on the PC99%, PC95% and PC90% thresholds 0.40 km^2, 0.17 km^2 and 0.08 km^2, respectively.

- Similarly, for a dewatering discharge KP102 over a conservative 12-hour exposure period, there were isolated patches of the preservation chemical above PC99% (NOEC of 0.06 mg/L) up to 6.78 km from the dewatering release location due to the plume drifting into the shallow intertidal areas, reducing the potential for mixing and dilution. The modelling also predicted a continuous area of exposure up to ~4 km west offset from the release location due to the plume migrating into the shallower waters, mixing less, resulting in the concentration accumulating. The area of exposure for the PC99% threshold was 4.14 km^2. The maximum distances from the release location based on the PC95% and PC90% thresholds were 2.18 km and 1.59 km, respectively.

- For the dewatering discharge at KP114, the maximum distance from the release location and area of exposure based on the PC99% threshold was 2.40 km and 1.45 km^2, respectively. The preservation chemical concentrations did not trigger any other threshold over a conservative 12-hour continuous duration.

1 INTRODUCTION

1.1 Background

Santos is assessing environmental impacts and risks associated with the Darwin Pipeline Duplication (DPD) Project. The DPD Project involves the installation of a gas export pipeline (GEP) from a point (kilometre point (KP) 0) in Commonwealth waters (25 km from the Commonwealth/ NT waters boundary) to the Darwin LNG (DLNG) Facility on Wickham Point in Darwin Harbour (KP122.2). The pipeline will transfer dry gas from the offshore Barossa field to the DLNG facility. The new pipeline (nearshore Barossa GEP) would run alongside the existing Bayu-Undan (BU) to Darwin GEP, typically within 50 – 100 m thereby effectively duplicating that pipeline.

While highly unlikely, an unplanned ‘wet buckle’ event may occur during installation of the nearshore Barossa GEP, thereby causing flooding of the pipeline with seawater. In the event of a ‘wet buckle’ the raw seawater will need to be displaced from the pipeline with seawater treated with a preservation chemical consisting of a biocide, corrosion inhibitor and oxygen scavenger. The treated seawater would then be dewatered to facilitate continued installation of the pipeline. To support the impact assessment of pipeline filling and dewatering of treated seawater, Santos has commissioned a dispersion modelling study. Given the 'wet buckle' may occur anywhere along the proposed pipeline between KP0 and KP122.2, the study examined discharges at three locations (KP84, KP102 and KP114), specifically selected due the proximity of pipeline to areas of importance (i.e. reefs, coral, etc). Table 1.1 presents the coordinates of each location and Figure 1.1 is the location map.

Both pipeline over filling (overflow) and dewatering scenarios were considered. The volume of treated seawater released as overflow (600 m^3) with a corresponding release duration (38 minutes) has been estimated to be the same at all three locations. However, during dewatering the volume and release durations varied due to the length of the pipe at the given location (see Table 1.2) and modelled as a separate discharge. The assumed concentration of the preservation chemical was 550 mg/L during overflow and dewatering, and the discharge via a single 4” diameter outlet 0.5 m above the seafloor.

The main objective of the study was to determine the area of exposure of the preservation chemical over a 12-hour continuous duration and compare this to different No Observable Effect Concentration (NOEC) thresholds.

Table 1.1 Coordinates of the Barossa DPD treated seawater release locations.

Identifier	Latitude	Longitude	Water Depth (m)
KP84	8,639,681.22	675,450.46	23.65
KP102	8,629,189.96	689,902.26	23.30
KP114	8,619,537.48	696,972.89	19.44

Table 1.2 Volumes of treated seawater and corresponding release durations during overflow and dewatering.

Scenario	Identifier	KP84	KP102	KP114
Scenario 1 – overflow	Volume of treated seawater released as overflow (m^3)		600	
	Release duration during overflow (hours)		0.63	

Scenario 2 – dewatering	Volume of treated seawater released during dewatering (m^3)	19,958	10,623	4,400
	Release duration during dewatering (hours)	21.37	11.37	4.7

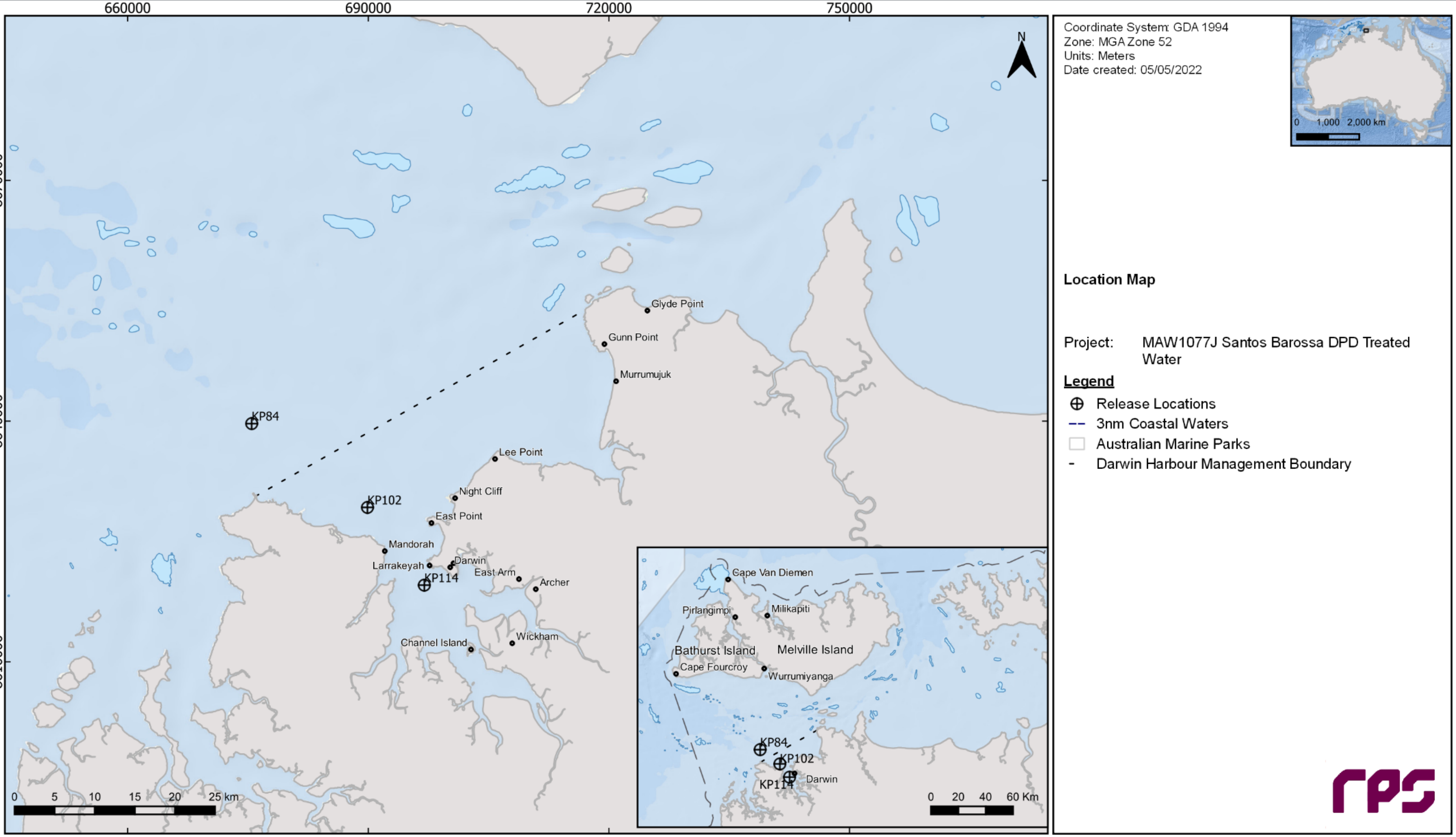

Figure 1.1 Barossa DPD treated seawater release locations.

2 SCOPE OF WORK

The physical mixing of the treated seawater discharge can be separated into two distinct zones: near-field and far-field. The near-field zone focusses on the mixing of the treated seawater. The near-field zone is defined by the region that is controlled by the plume's initial jet momentum and the static current. Normally, the buoyancy difference is considered in the near-field, however, it is negligible because the treated seawater has the same density as the surrounding seawater. Once the near-field assessment was complete, the far-field phase examined the transport and mixing of the preservation chemical by the ambient currents.

The scope of work included the following components:

1. Model the near-field plume dynamics (or initial dilution) based on the release rate, outfall configuration and treated water characteristics under weak, moderate and strong current speeds;

2. Simulate the far-field mixing and dispersion of the release of the preservation chemical at the three locations for the overflow and dewatering as separate discharges. Due to the short release duration, 25 simulations were run at each location per discharge, each having randomly selected start times to ensure that a range of current conditions are examined;

3. Examine the concentrations of the preservation chemical during overflow and dewatering over a continuous 12-hour exposure period in each grid cell for each simulation separately; and

4. Combine the results for all 25 simulations representing the overflow and dewatering discharges and determine the potential area of exposure at all three locations.

For completeness, the areas of exposure from the preservation chemical during the overflow and dewatering releases were also assessed over 24 and 48-hour exposure period.

3 CURRENTS

3.1 Development of Regional Current Data

To simulate the hydrodynamics within Darwin Harbour and Beagle Gulf, a three-dimensional model was setup which accounted for tidal and oceanic currents, bathymetry, bottom roughness and wind stress. The model framework was developed through the combination of a large-scale regional model with smaller refined regions, or sub-domains. The D-FLOW model is ideally suited to represent the hydrodynamics of complex coastal waters, including regions where the tidal range creates large intertidal zones.

The three-dimensional simulations were generated using a rectangular grid in the horizontal with a series of interconnected (two-way, dynamically-nested) grids of varying resolution; a technique referred to as “domain decomposition”. This allows for the generation of a series of grids with progressively increasing spatial resolution, down to an appropriate scale for accurate resolution of the hydrodynamics to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. The main advantage of domain decomposition over traditional one-way, or static, nesting systems is that the model domains interact seamlessly, allowing transport and feedback between the regions of different scales. The ability to dynamically couple multiple model domains offer a flexible framework for hydrodynamic model development. In the vertical, a sigma-coordinate approach was employed to divide the water column into a series of layers.

D-FLOW allows for the establishment of a:

- Detailed bathymetry of the study area with wetting and drying of the intertidal zones simulated in applicable areas;
- Boundary elevation forcing data in the form of water levels representing the tides was sourced from the TPXO8.0 database, which is derived from sea-surface topography measurement by the TOPEX/Poseidon satellite-borne radar altimeters; TOPEX). While elevation data representing the ocean currents sourced from Hybrid Coordinate Ocean Model (HYCOM); and
- Spatially-varying surface wind data.

To optimise the computational effort required for a large, multi-layered model domain, and to achieve adequate horizontal and temporal resolution, a multiple-grid (domain-decomposition) strategy was applied using five sub-domains of varying horizontal grid cell size (Figure 3.1). The horizontal resolution within Darwin Harbour was 80 m (sub-grid 4), 240 m for the intermediate region (sub-grid 3), 720 m, 2.2 km and 6.5 km for the outer domains (sub-grids 2, 1 and 0, respectively).

A combination of datasets was used and merged to describe the shape of the seabed within Darwin Harbour and the intermediate area, including spot depths and contours which were digitised from nautical charts released by the hydrographic offices. For the outer domains, depths extracted from the General Bathymetric Chart of the Oceans (GEBCO) dataset on a 15 arc-second interval grid was used.

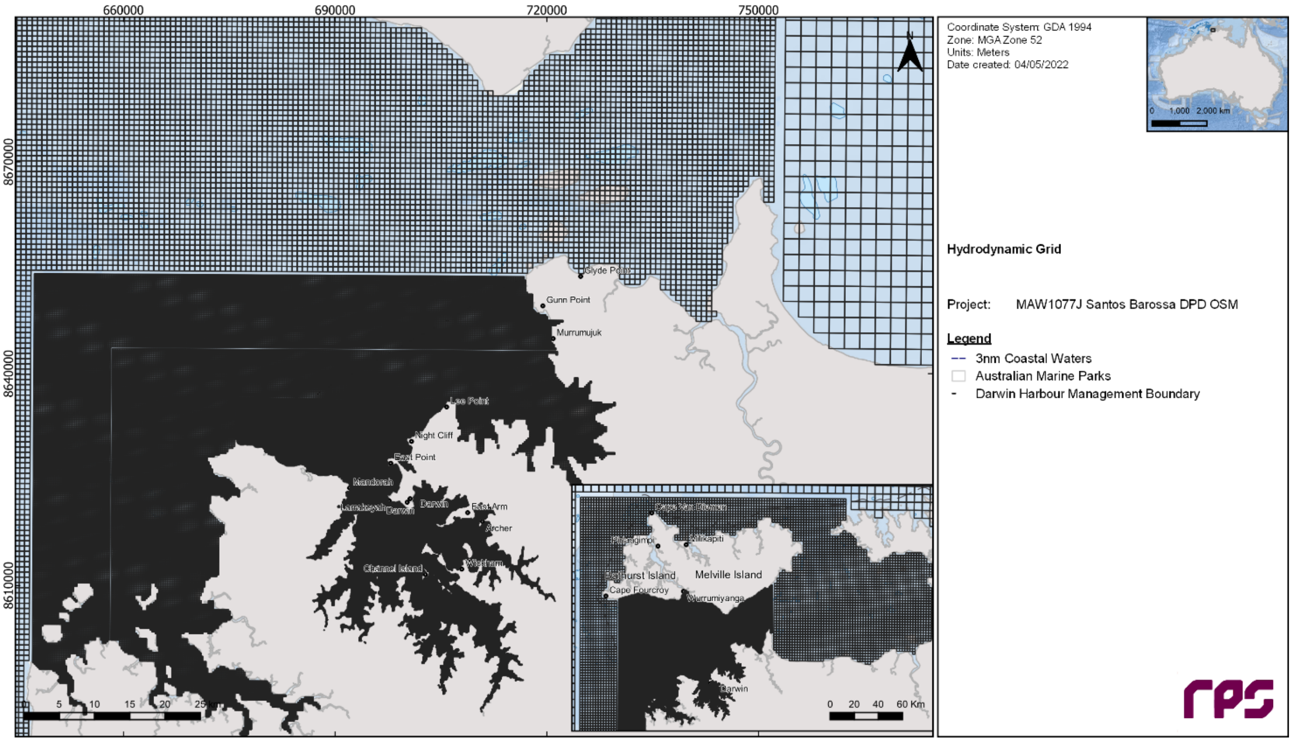

Figure 3.1 Detail of the hydrodynamic model grid.

3.2 Boundary Conditions

3.2.1 Overview

While the hydrodynamics in Darwin Harbour are controlled primarily by tidal flows, oceanic and wind forcing were explicitly included to account for the conditions beyond the port limits.

The model was forced on the open boundaries of the outer sub-domain with time series of water elevation obtained for the chosen simulation period. Spatial and temporal variation in wind forcing across the entire domain was accounted for by applying spatially-varying wind speed and wind direction data that varied over time.

3.2.1.1 Water Elevation

Water elevations at hourly intervals were obtained from the TPXO8.0 database, which is derived from measurements of sea-surface topography by the TOPEX/Poseidon satellite-borne radar altimeters. Tides are provided as complex amplitudes of earth-relative sea-surface elevation for eight primary (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1), two long-period (M_f, M_m) and three non-linear (M_4, MS_4, MN_4) harmonic constituents at a spatial resolution of 0.25°.

The tidal sea level data was augmented with non-tidal (or oceanic) sea level elevation data from the global Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet *et al.*, 2007, 2009; Halliwell, 2004), created by the USA's National Ocean Partnership Program (NOPP) as part of the Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite instrumentation, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density, sea height variations and the rotation of the Earth. The model has a global coverage with a horizontal resolution of 1/12th of a degree (~7 km at mid-latitudes) and a temporal resolution of 24 hours.

3.2.1.2 Wind Forcing

Wind forcing was included in the hydrodynamic model as a boundary condition to capture its effect on water currents. For this model, wind data was sourced from the National Center for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha *et al.*, 2010). The CFSR wind model includes observations from many data sources: surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at a horizontal resolution of 0.25° (~33 km) and a temporal resolution of 1 hour.

3.3 Near-Seabed Currents

Figure 3.2 shows the predicted annual near-seabed current rose distributions at treated seawater release Locations 1, 2 and 3. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are predominantly used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

The predicted near-seabed currents predominantly flowed along the east-west axis at KP84 and southeast-northwest axis at KP102 and KP114. Average monthly speeds ranged from 0.38 to 0.43 m/s, 0.52 to 0.60 m/s and 0.43 to 0.50 m/s at KP84, KP102 and KP114, respectively. Additionally, the maximum current speeds ranged between 1.04 and 1.22 m/s, 1.37 and 1.62 m/s and 1.16 and 1.31 m/s at the respective sites.

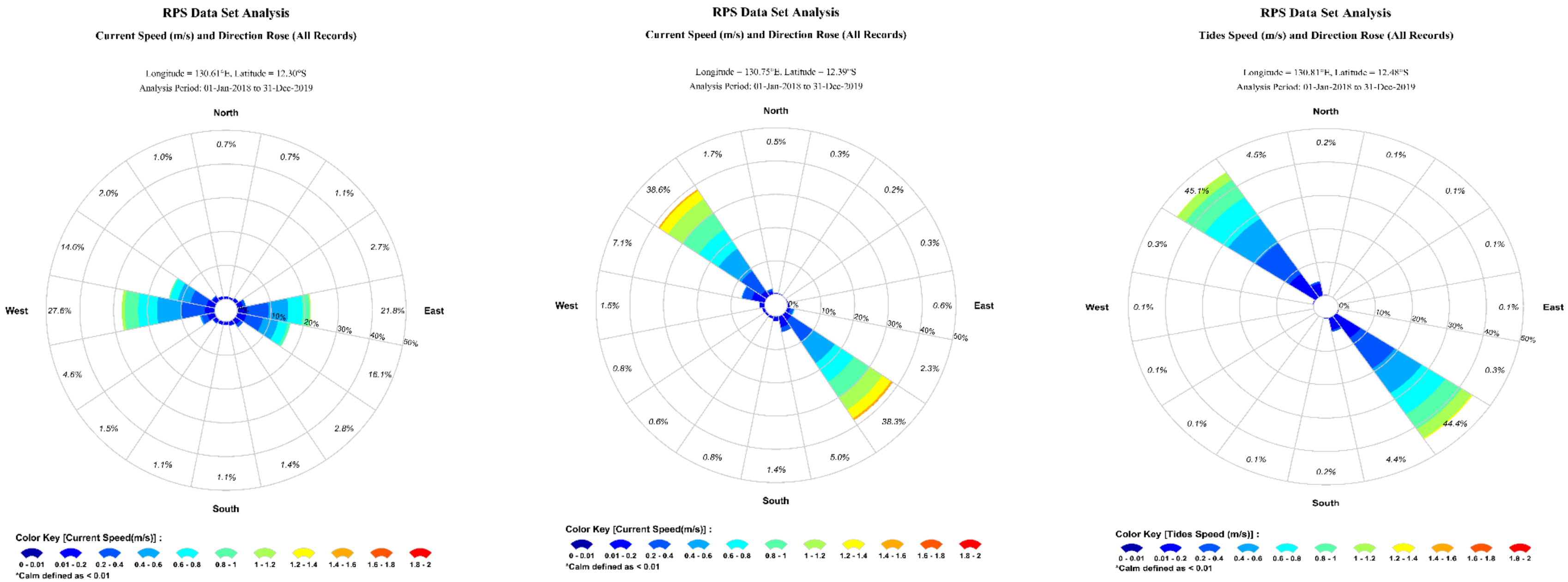

Figure 3.2 Annual near-seabed current rose plots near KP84 (Left), KP102 (Middle) and KP114 (Right). derived from the 2019 – 2020 water level dataset.

4 WATER TEMPERATURE AND SALINITY

Table 4.1. provides a summary of the annual average water temperature and salinity values near the seabed at the release locations. The temperature and salinity data throughout the water column was obtained from the World Ocean Atlas 2018 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration, NOAA) and its co-located World Data Centre for Oceanography (Levitus *et al.*, 2013).

The water temperature and salinity values are relatively similar between the three locations (28.4 to 28.8 C and 34.0 to 34.4 psu). The data aligns with the Darwin Harbour water quality monitoring program (https://depws.nt.gov.au/water/water-management/darwin-harbour/darwin-harbour-region-report-cards/2018-report-cards).

Table 4.1 Average water temperature and salinity near the seabed at the treated seater release locations.

	KP84	KP102	KP114
Temperature (°C)	28.4	28.4	28.8
Salinity (psu)	34.4	34.4	34.0

5 ENVIRONMENTAL REPORTING CRITERIA

Santos plan to use a preservation chemical such as Hydrosure 0-3670R to treat the seawater to be pumped into the pipeline. Table 5.1 presents a summary of the No Observable Effects Concentrations (NOEC) that were derived from the whole of effluent toxicity (WET) testing results for Hydrosure (Chevron 2015). During WET testing, a suite of relevant local species were exposed under a range of concentrations using the recommended protocols from ANZECC and ARMCANZ (2000). The NOEC values for varying species protection levels and the dilutions to achieve the concentration based on a dosage of 550 mg/L are presented in Table 5.1.

While the NOEC values are derived from long term ecological tests typically between 48 and 96 hrs, due to the short-term release periods (< 22.0 hrs) and with the tides altering direction, the dose that environmental receptors shall receive will be less than those exposed in the toxicological tests. Hence, as an additional level of conservatism, the concentrations in each model cell was examined over a 12-hour continuous duration. Consequently, the extent of the mixing zone was based on a NOEC threshold of 0.06 mg/L (PC99%) over a 12-hour continuous duration.

Table 5.1 NOEC values for varying species protection levels for Hydrosure 0-3670R based on WET testing (from Chevron, 2015).

Species protection level	NOEC threshold (mg/L)	Dilution to achieve the NOEC threshold based on an inhibitor dosing concentration of 550 mg/L (or ppm)
NOEC PC99%	0.06	1:9,167
NOEC PC95%	0.10	1:5,500
NOEC PC90%	0.15	1:3,667
NOEC PC80%	0.23	1:2,391

6 NEAR-FIELD MODEL

6.1 Description of the Near-Field Model: CORMIX

The near-field mixing and dispersion was simulated using the three-dimensional flow model, CORMIX. CORMIX is a mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones. CORMIX contains a series of elements for the analysis and design of single or multi-port discharges. Discharges may be submerged or above surface, buoyant or denser than receiving water and the receiving water may be stratified or unstratified. The emphasis of the model is the influence of the geometry and dilution characteristics on the initial mixing zone (Doneker & Jirka, 1990; Jirka *et al.*, 1991). CORMIX is widely applied worldwide and has been validated in many independent studies (http://www.cormix.info/validations.php).

CORMIX specifies the average dilution or bulk dilution (flux averaged) as 1.7 times the centreline dilution. The centreline is defined by the points of maximum concentration (maximum temperature, minimum dilution etc.) at each vertical section along the longitudinal axis. Accordingly, centreline depth is defined as the depth of the maximum concentration point (maximum temperature, minimum dilution) along the longitudinal axis.

6.2 Near-Field Model Setup

Table 6.1 is a summary of the treated seawater discharge characteristic for the near-field model setup with the flow rate and outlet configuration at all three treated seawater release locations.

Table 6.1 Summary of the near-field modelling inputs.

Parameter	KP84	KP102	KP114
Flow rate (m^3/s)	0.26		
Outlet configuration	Single 4” outlet orientated horizontally with pipeline		
Discharge height (m) above the seabed	0.5		
Discharge temperature (same as ambient seawater)	28.4 °C		28.8 °C
Discharge salinity (same as ambient seawater)	34.4 psu		34.0 psu

Along with the ambient water temperature and salinity (see Section 4), a range of current speeds were included in the near-field model. The yearlong seabed current data was analysed and the 5th, 50th and 95th percentile current speeds were chosen to reflect the potentially contrasting dilution and advection cases:

- 5th percentile (or 5 percent of the time the currents will be below the identified speed): weak currents, low dilution and slow advection;
- 50th percentile (or 50 percent of the time the currents will be below the identified speed): moderate currents, average dilution and advection; and
- 95th percentile current speed (or 95 percent of the time the currents will be below the identified speed): strong currents, high dilution and rapid advection to nearby areas.

The 5th, 50th and 95th percentile values are referenced as weak, moderate and strong current speeds, respectively.

Table 6.2 Static current speeds for each location.

Identifier	5th Percentile (Weak) Current Speed (m/s)	50th Percentile (Moderate) Current Speed (m/s)	95th Percentile (Strong) Current Speed (m/s)
KP84	0.08	0.35	0.79
KP102	0.05	0.34	0.83
KP114	0.04	0.30	0.82

7 NEAR-FIELD RESULTS

Due to the fast exit velocities, the treated seawater would initially project horizontally at a rapid speed approximately 1–2 m from the outlet. Once the plume had lost its momentum, it mixed laterally due to the currents as it is neutrally buoyant.

Table 7.1 presents the predicted dilutions and preservation chemical concentrations at 10 m and 30 m (horizontally) from each location with varying static current speeds. Due to the near identical current speeds at the three locations, the predicted dilutions achieved and in turn the preservation chemical concentrations at the designated distances are very similar.

For KP84, within 30 m of discharge the predicted concentration reduced from 550 mg/L to 9.4 and 13.8 mg/L (or ppm) under strong and weak current conditions, respectively. Meaning that within 30 m the minimum dilution was 1:58.4 and 1:39.9 for the strong and weak currents, respectively.

For KP102 within 30 m the predicted concentration was 10.2 and 13.8 mg/L (or ppm) under strong and weak currents, respectively. The corresponding minimum dilutions were 1:54.1 and 1:39.9, respectively.

For KP114 within 30 m, the predicted concentration had reduced from 550 mg/L to 9.2 and 13.5 mg/L (or ppm) under strong and weak current conditions, respectively. Meaning that within 30 m the minimum dilution was 1:60.0 and 1:40.7 for the strong and weak currents, respectively.

Note that these predictions rely on the persistence of current speed and direction over time and does not account for the build-up of the plume.

Table 7.1 Predicted near-field plume characteristics at 10 m and 30 m from the release location for each case.

Location	Current speed (m/s)	Distance from the release location (m)	Plume centre (minimum) dilution (1:x)	Plume centre concentration (mg/L or ppm) based on an initial concentration of 550 mg/L	Plume diameter (m)
KP84	Weak (0.08)	10.0	13.8	39.8	1.2
		30.0	39.9	13.8	3.2
	Moderate (0.35)	10.0	14.3	38.4	1.2
		30.0	40.4	13.6	3.1
	Strong (0.79)	10.0	14.1	39.0	1.0
		30.0	58.4	9.4	4.7
KP102	Weak (0.05)	10.0	13.8	39.8	1.1
		30.0	39.9	13.8	3.8
	Moderate (0.34)	10.0	14.2	38.6	0.9
		30.0	57.2	9.6	2.1
	Strong (0.83)	10.0	14.2	38.6	0.9
		30.0	54.1	10.2	2.1
KP114	Weak (0.04)	10.0	13.8	39.8	1.2
		30.0	40.7	13.5	3.3
	Moderate (0.30)	10.0	13.6	40.6	1.1
		30.0	39.9	13.8	3.3
	Strong (0.82)	10.0	14.0	39.4	1.0
		30.0	60.0	9.2	4.8

8 FAR-FIELD MODELLING

As previously mentioned, the far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, and the potential for recirculation of the plume back to the discharge location to be assessed. In this case, preservation chemical concentrations near the release location can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

8.1 Description of the Near-Field Model: MUDMAP

The mixing and dispersion of the treated water discharge was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP. The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. Any chemicals (constituents) within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes actually do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters (e.g. Burns *et al.*, 1999; King & McAllister, 1997, 1998).

8.2 Far-Field Model Setup

Table 8.1 presents a summary of the far-field model inputs used to calculate the transport and mixing of the preservation chemical by the ambient currents for the overflow and dewatering. As previously mentioned, 25 simulations were run (for each location and discharge type) and each simulation had randomly chosen start times from the historical dataset to ensure a range of current conditions were sampled.

MUDMAP uses a three-dimensional grid to represent the water depth and bathymetric profiles of the study area. For this modelling assessment, a 30 m grid in the horizontal and 2 m grid in the vertical was used to track the movement and fate of the treated seawater plume to adequately replicate the mixing and near-field dilutions achieved under similar current conditions in the immediate vicinity of the release location. Similarly, horizontal and vertical dispersion coefficients (used to control the exchange of the plume in the horizontal and vertical directions respectively) of 0.5 m^2/s and 0.001 m^2/s were carefully selected through sensitivity testing to recreate the concentrations as predicted during the near-field modelling.

Table 8.1 Summary of far-field modelling inputs.

<table>
<tr><th>Parameter</th><th colspan="4">KP84</th><th colspan="4">KP102</th><th colspan="4">KP114</th></tr>
<tr><td>Volume of treated seawater released as overflow (m^3)</td><td colspan="12">600</td></tr>
<tr><td>Release duration during overflow (hours)</td><td colspan="12">0.63</td></tr>
<tr><td>Model simulation length (days) for the overflow</td><td colspan="12">1</td></tr>
<tr><td>Volume of treated seawater released during dewatering (m^3)</td><td colspan="4">19,958</td><td colspan="4">10,623</td><td colspan="4">4,400</td></tr>
<tr><td>Release duration during dewatering (hours)</td><td colspan="4">21.37</td><td colspan="4">11.37</td><td colspan="4">4.7</td></tr>
<tr><td>Model simulation length (days)</td><td colspan="4">2.2</td><td colspan="4">2.00</td><td colspan="4">1.6</td></tr>
<tr><td>Initial preservation chemical concentration (ppm or mg/L)</td><td colspan="12">550</td></tr>
<tr><td rowspan="2">Preservation chemical threshold concentrations (ppm or mg/L) based on a continuous exposure over 12 hours</td><td colspan="3">NOEC PC99%</td><td colspan="3">NOEC PC95%</td><td colspan="3">NOEC PC90%</td><td colspan="3">NOEC PC80%</td></tr>
<tr><td colspan="3">0.06</td><td colspan="3">0.10</td><td colspan="3">0.15</td><td colspan="3">0.23</td></tr>
</table>

9 FAR-FIELD RESULTS

9.1 General Observations

Figure 9.1 to Figure 9.3 show the maximum predicted preservation chemical concentrations during dewatering over a 12-hour period (2-hour intervals) as an aerial plan view for the first simulation at each location. The images have been included to illustrate the predicted movement and concentrations of the preservation chemical as a result of the time-varying current directions and speeds. It can be seen how the tides dominate the local currents and cause the plume to bend and change direction from the northwest to the southeast under the influence of the flood tide currents. The predicted preservation chemical concentrations during this period demonstrate decreasing concentrations with increasing distance from the release location.

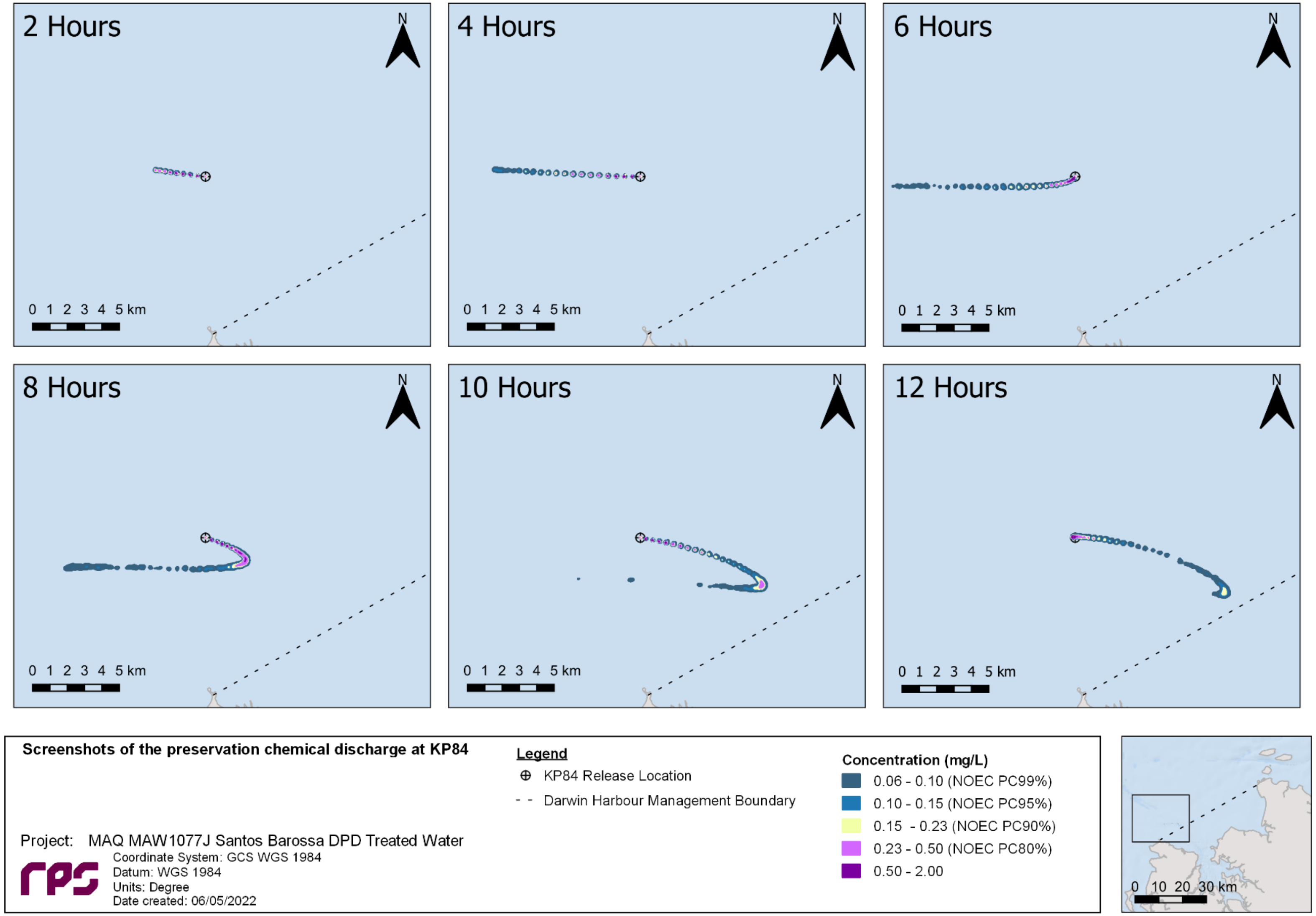

Figure 9.1 Predicted preservation chemical concentrations during dewatering for simulation 1 at KP84 between 11 am to 11 pm 15th October 2019 for KP84.

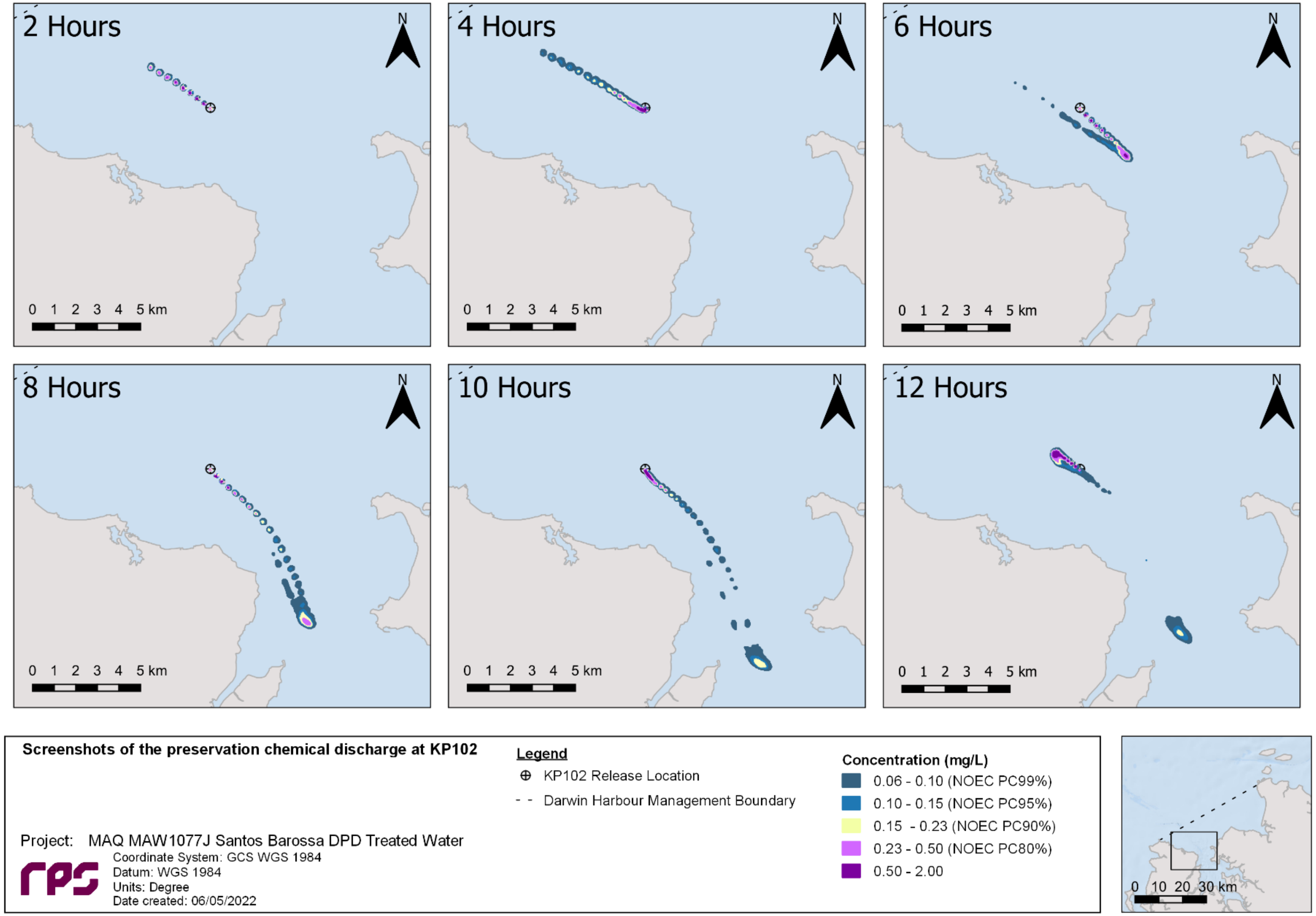

Figure 9.2 Predicted preservation chemical concentrations during dewatering for simulation 1 at KP102 between 3 pm 21st April to 3 am 22nd April 2020.

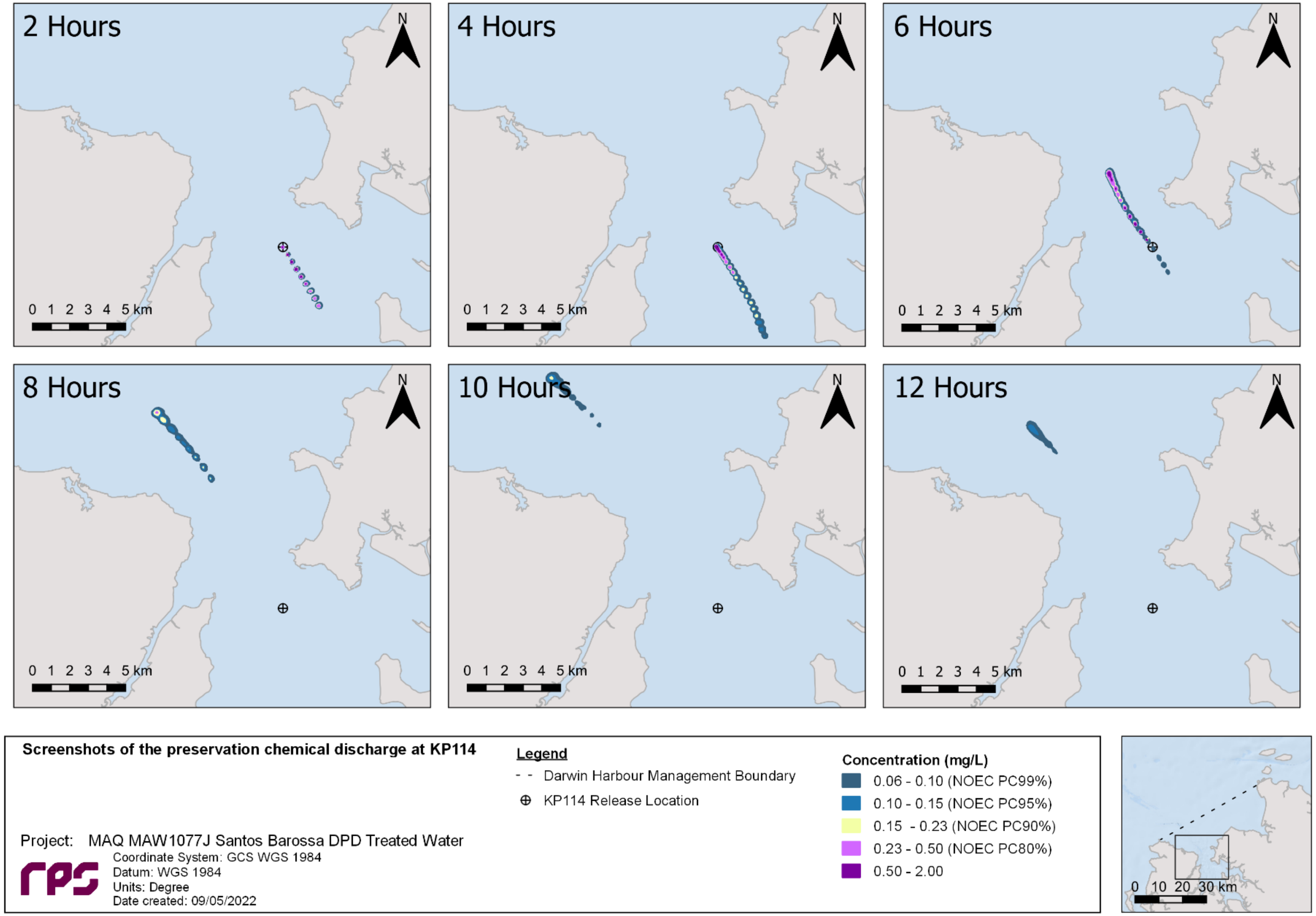

Figure 9.3 Predicted preservation chemical concentrations during dewatering for simulation 1 at KP114 between 7 am to 7 pm 16th October 2020.

9.2 Combined Analysis Over 12- Hour Period

There was no predicted exposure above 0.06 mg/L (or 0.06 ppm) over a 12-hour period from the preservation chemical during overflow at all three locations.

Figure 9.4 to Figure 9.6 illustrate the predicted maximum distances and area of exposure by the preservation chemical at the three locations during dewatering. It should be noted that area presented is created by overlaying the results of the 25 individual simulations and therefore does not represent the area of effect from a discharge, rather represents the area within which the effects of a discharge could potentially occur dependant on environmental conditions Table 9.1 summarises the maximum distances from the release locations and area of exposure for each NOEC value.

At KP84, the preservation chemical plume was generally continuous up to ~1.4 km from the release location based on the PC99% threshold (NOEC of 0.06 mg/L), with small isolated patches predicted up to 9.61 km. The isolated patches more than ~2 km away were predicted to occur during 2 of the 25 simulations and the plume was predicted to travel a maximum distance of 9.61 km for only 1 simulation. The isolated patches were due to an accumulation, which had occurred further away during a current reversal, causing it to concentrate. The predicted maximum distances from the release location to the PC95% (NOEC of 0.10 mg/L) and PC90% (NOEC of 0.15 mg/L) were significantly smaller: 1.02 km and 0.75 km, respectively. The potential areas of exposure based on the PC99%, PC95% and PC90% thresholds were 0.40 km^2, 0.17 km^2 and 0.08 km^2, respectively.

Likewise for KP102, there were isolated patches of the preservation chemical above PC99% (NOEC of 0.06 mg/L) up to 6.78 km from the release location due to the plume drifting into the shallow intertidal areas and reducing the potential for mixing and dilution. The modelling also predicted a continuous area of exposure up to ~4 km west offset from the release location due to the plume migrating into the shallower waters, mixing less and the concentration accumulating. The area of exposure for the PC99% threshold was 4.14 km^2. The maximum distances from the release location based on the PC95% and PC90% thresholds were 2.18 km and 1.59 km, respectively.

For the discharge at KP114, the maximum distance from the release location and the area of exposure of the preservation chemical based on the PC99% threshold was 2.40 km and 1.45 km^2, respectively. The preservation chemical concentrations did not trigger any other threshold over a 12-hour continuous duration.

Table 9.1 Summary of the maximum distances and areas of exposure by the preservation chemical during dewatering for each NOEC value at the three locations. Results are derived from 25 simulations, each simulation was individually assessed based over a 12-hour continuous exposure period for the NOEC values.

Location	Initial chemical dosing (ppm or mg/L)	Species protection level	NOEC value (mg/L)	Area of exposure (km^2)	Maximum horizontal distance from the release location (km)
1 – KP84	550	NOEC PC99%	0.06	0.40	9.61
		NOEC PC95%	0.10	0.17	1.02
		NOEC PC90%	0.15	0.08	0.75
		NOEC PC80%	0.23	0.04	0.36
2 – KP102	550	NOEC PC99%	0.06	4.14	6.78
		NOEC PC95%	0.10	2.18	4.33
		NOEC PC90%	0.15	1.59	4.13
		NOEC PC80%	0.23	0.96	3.84
3 – KP114	550	NOEC PC99%	0.06	1.45	2.40
		NOEC PC95%	0.10	-	-
		NOEC PC90%	0.15	-	-
		NOEC PC80%	0.23	-	-

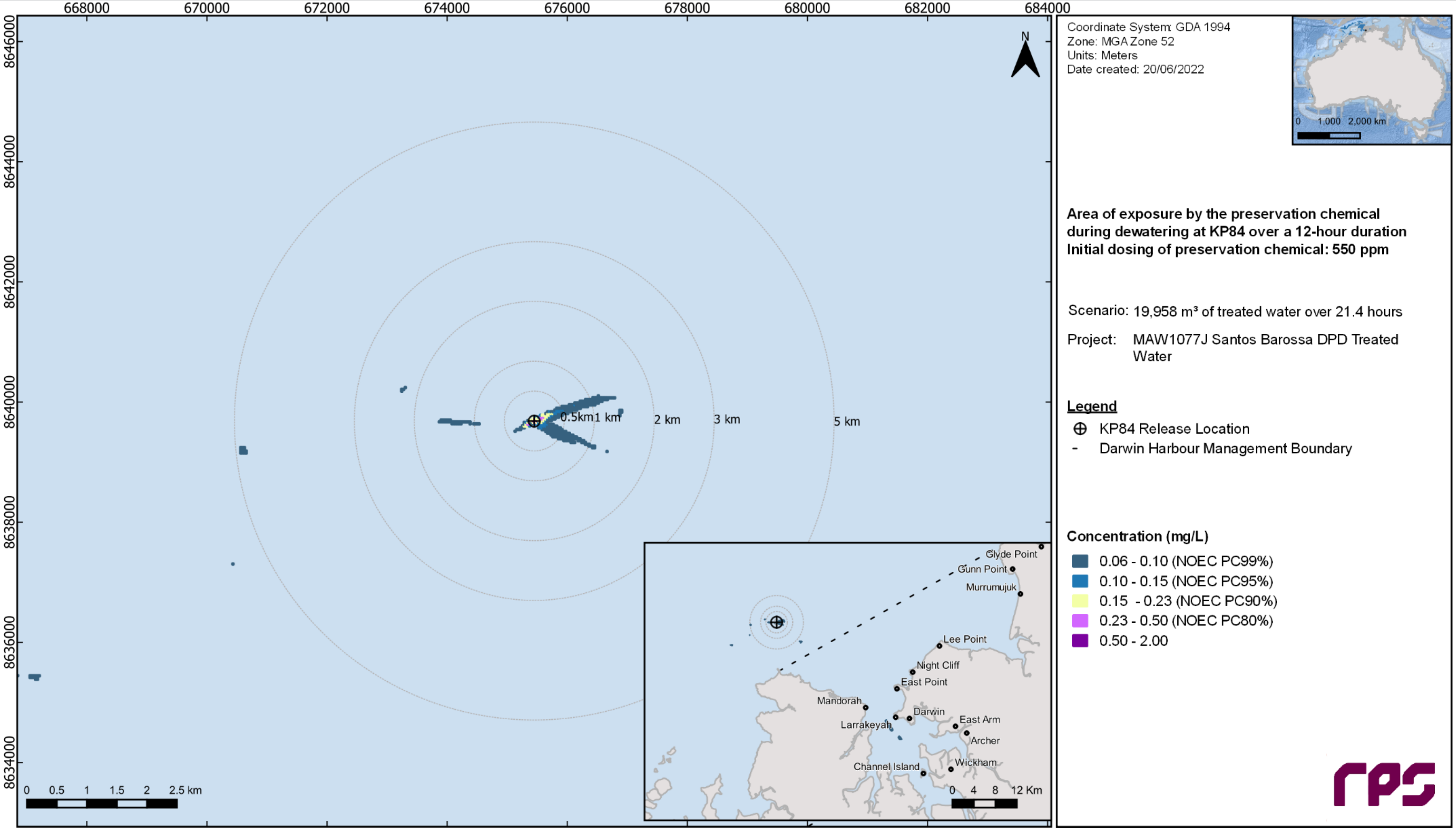

Figure 9.4 Predicted concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP84. The results were calculated from 25 simulations with different metocean conditions.

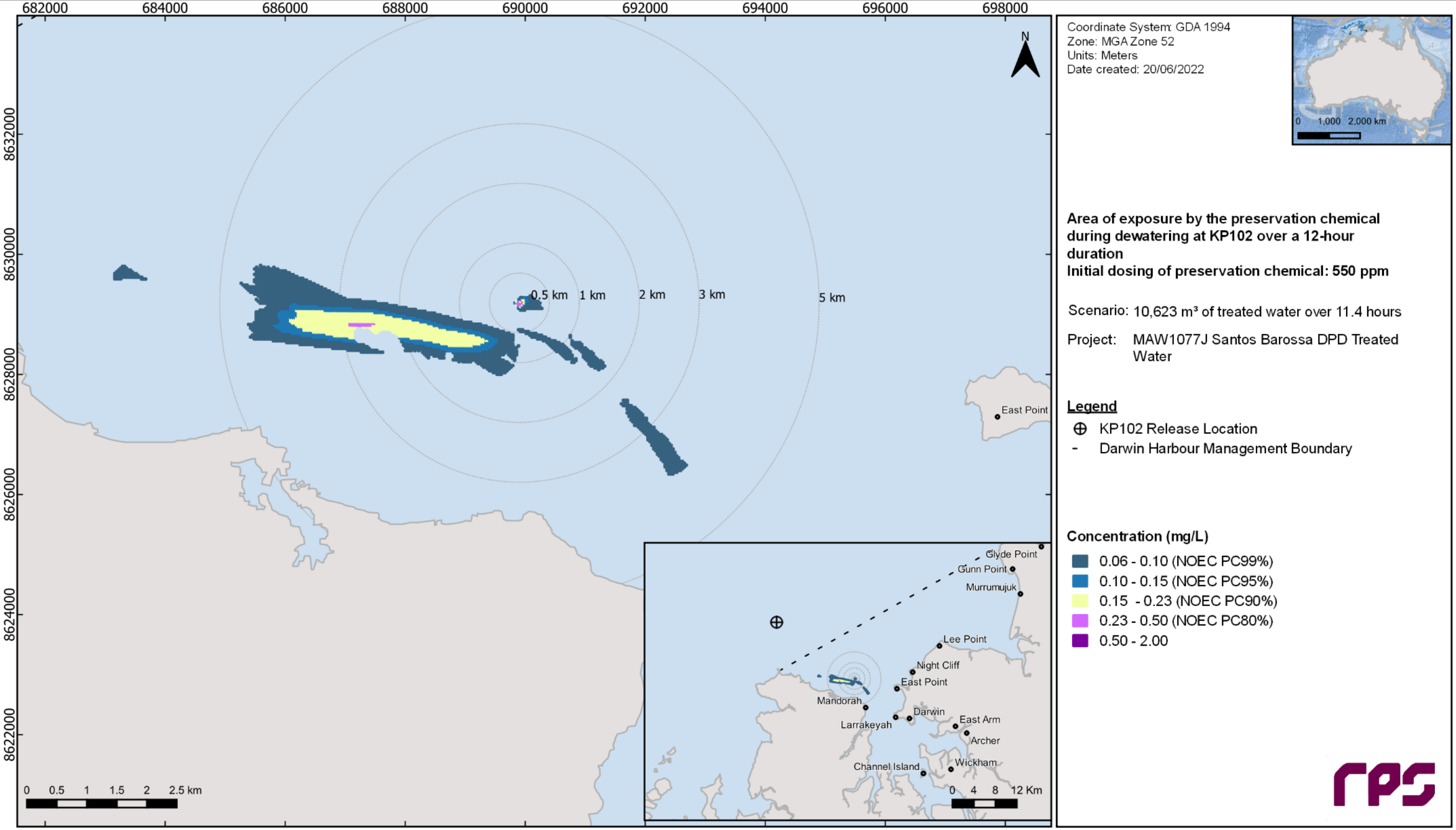

Figure 9.5 Predicted concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP102. The results were calculated from 25 simulations with different metocean conditions.

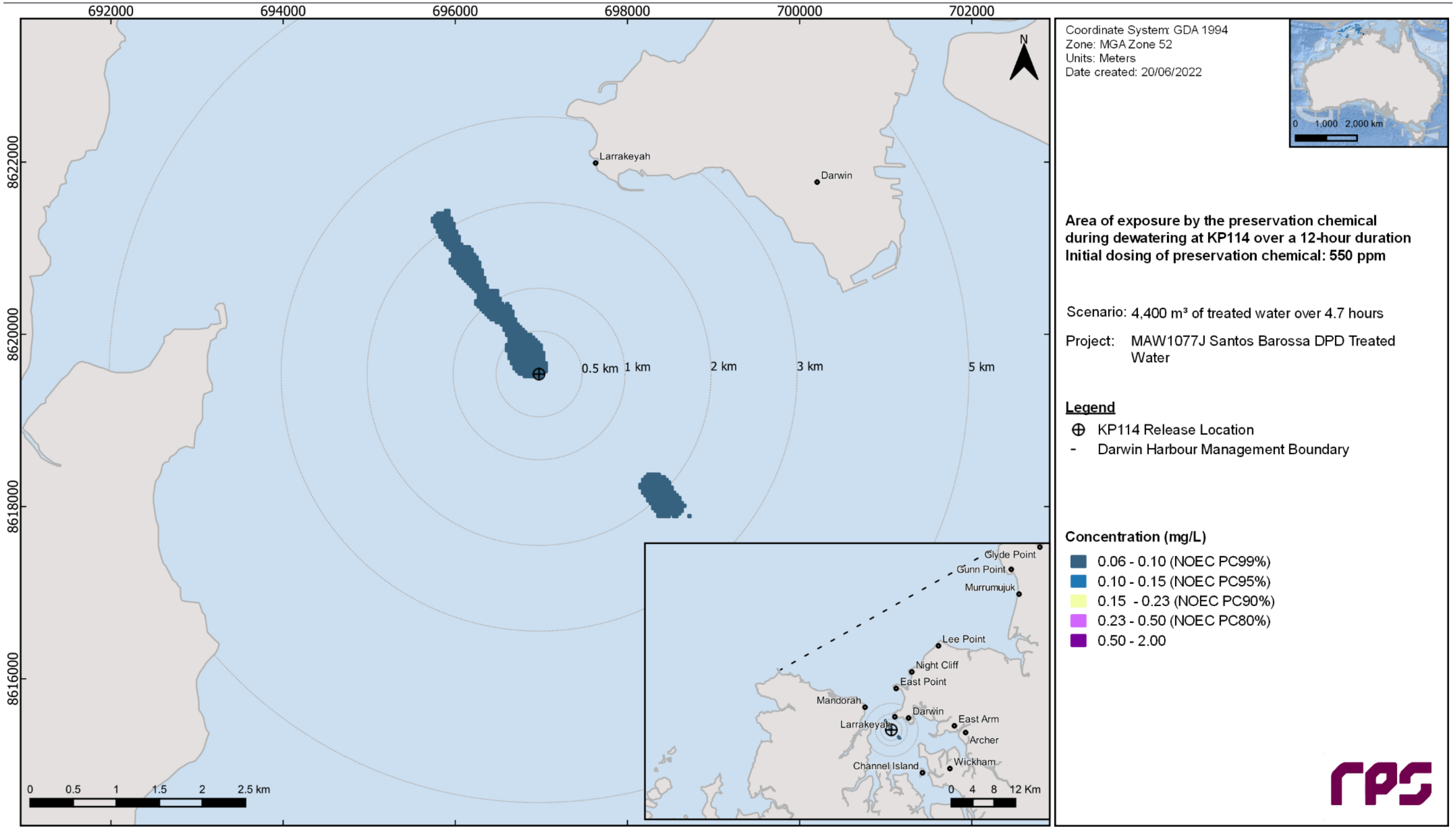

Figure 9.6 Predicted concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP114. The results were calculated from 25 simulations with different metocean conditions.

9.3 Combined analysis over 24 and 48-hour period

There was no exceedance of the PC99% threshold predicted over a 24-hour period at KP84 and KP114. The area of exposure from the dewatering at KP102 had significantly reduced to 0.16 km^2 and limited to the PC99% threshold (see Figure 9.7).

There was no exceedance of the PC99% threshold over a 48-hour period at all three locations.

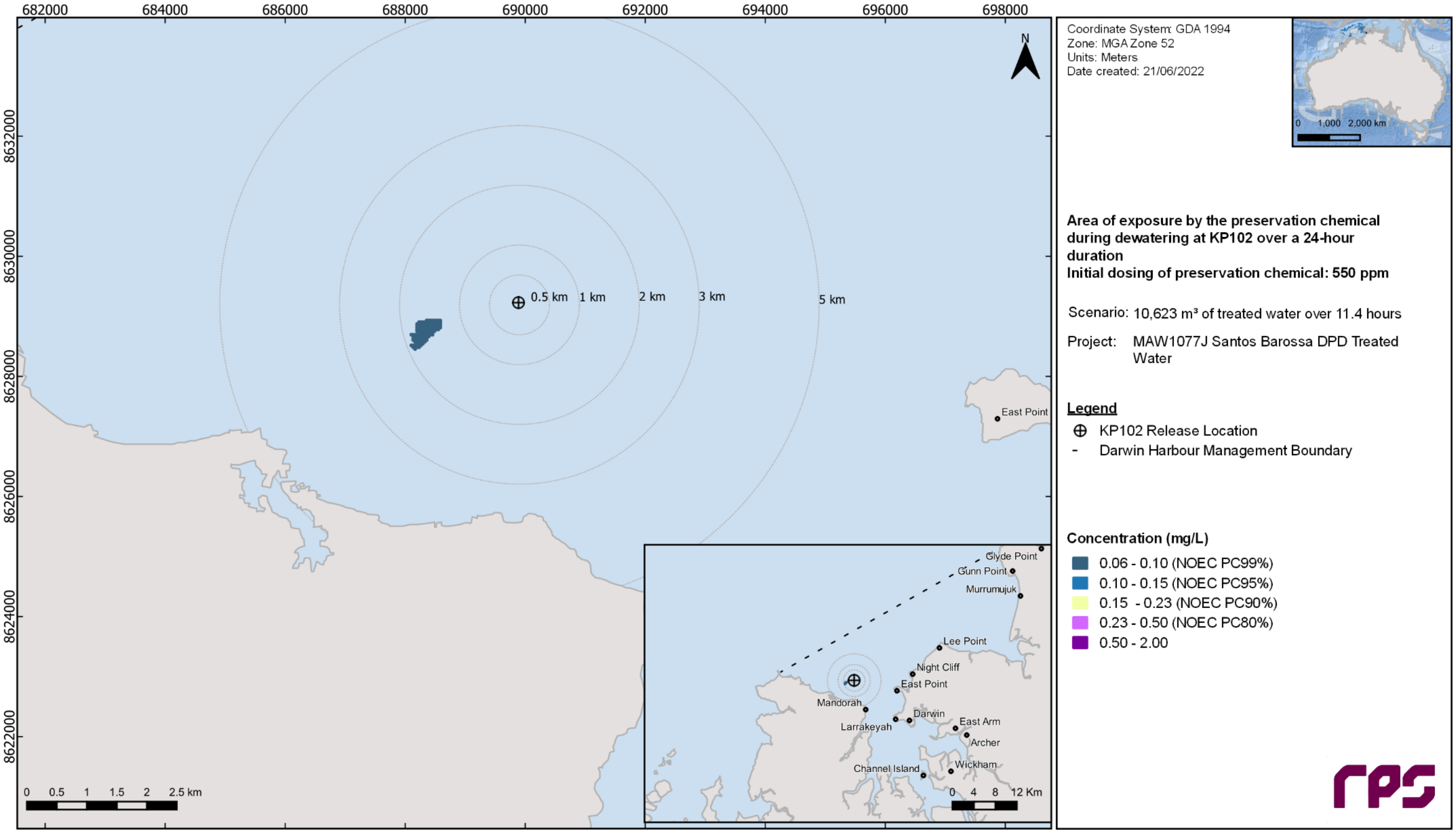

Figure 9.7 Predicted concentrations of the preservation chemical over a 24-hour exposure period during dewatering from KP102. The results were calculated from 25 simulations with different metocean conditions.

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Appendix 6: Pipeline Benthic Survey Report

PIPELINE BENTHIC SURVEY REPORT

Barossa DPD

AU213002038.001
Rev 1
18 January 2023

rpsgroup.com

Document status

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Draft B	Draft for client review	NatRob	GarHoo	NA	02/12/2021
Draft C	Draft for client review	GarHoo/NatRob	KatTho	NA	16/05/2022
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Contents

EXECUTIVE SUMMARY ... 1

1 INTRODUCTION ... 3
- 1.1 Objectives ... 3
- 1.2 Purpose ... 3

2 METHODS ... 4
- 2.1 Surveys ... 4
  - 2.1.1 October 2021 survey ... 4
  - 2.1.2 January 2022 sediment survey ... 4
  - 2.1.3 Sediment sampling and analysis ... 4
  - 2.1.4 June 2022 survey ... 9
- 2.2 Subsea video ... 11
- 2.3 Sediment quality ... 11
  - 2.3.1 Sample collection ... 11
  - 2.3.2 Offshore pipeline and spoil ground ... 13
  - 2.3.3 Darwin Harbour pipeline ... 14
  - 2.3.4 Darwin Harbour pipeline sediment survey ... 15
- 2.4 Water quality ... 16
- 2.5 Quality assurance and quality control ... 18
  - 2.5.1 Triplicates/duplicates ... 18
  - 2.5.2 Trip blanks ... 18
  - 2.5.3 Field blanks ... 18
  - 2.5.4 Equipment blanks ... 18
  - 2.5.5 Sample preservation and storage ... 18

3 RESULTS ... 19
- 3.1 Benthic habitat ... 19
  - 3.1.1 October 2021 survey ... 19
  - 3.1.2 June 2022 survey ... 33
- 3.2 Sediment quality ... 40
  - 3.2.1 Offshore pipeline ... 40
  - 3.2.2 Darwin Harbour pipeline ... 48
  - 3.2.3 Spoil ground ... 57
  - 3.2.4 Darwin Harbour sediment survey ... 62
  - 3.2.5 Soft substrate benthic habitats across the study area ... 68
- 3.3 Water quality ... 72
  - 3.3.1 Offshore pipeline ... 72
  - 3.3.2 Spoil ground ... 80
- 3.4 Quality control ... 88
  - 3.4.1 Field quality control samples ... 88
  - 3.4.2 Laboratory quality control compliance assessment ... 88

4 DISCUSSION ... 89
- 4.1 Benthic habitats ... 89
  - 4.1.1 October 2021 survey ... 89
  - 4.1.2 June 2022 survey ... 89
  - 4.1.3 Video transect surveys compared to AIMS 2021 habitat mapping ... 90
- 4.2 Infauna assemblages ... 96
- 4.3 Sediment characteristics ... 96
- 4.4 Water quality ... 98

5 REFERENCES ... 100

Tables

Table 2-1: Sample naming conventions for the Barossa DPD survey 4
Table 2-2: Sediment quality sampling summary for offshore pipeline and spoil ground sites 14
Table 2-3: Sediment quality sampling summary for Darwin Harbour pipeline sites....14
Table 2-4: Sediment quality sampling summary for Darwin Harbour DPD sediment core samples....15
Table 2-5: Water quality sampling summary for offshore pipeline and spoil ground sites....17
Table 3-1: Transects conducted in June 2022 survey, describing substrate and predominate biota and the mapping habitat classification 34
Table 3-2: Sediment particle size characteristics along the offshore pipeline route (from west (OP1) to Darwin Harbour limits (OP30) 40
Table 3-3: Descriptive statistics of offshore pipeline (OP) infaunal data....42
Table 3-4: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations along the offshore pipeline route....47
Table 3-5: Sediment particle size characteristics along the Darwin Harbour pipeline route (from south (HS01) to north (HS49) 48
Table 3-6: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations in Darwin Harbour 53
Table 3-7: Total recoverable hydrocarbons detected above the LOR in Darwin Harbour sediments, normalised to 1% TOC 55
Table 3-8: Sediment particle size characteristics at the spoil ground 57
Table 3-9: Descriptive statistics of spoil ground infaunal data 58
Table 3-10: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations at the spoil ground....61
Table 3-11: Sediment particle size characteristics from the sediment survey 63
Table 3-12: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations in Darwin Harbour 67
Table 3-13: Total recoverable hydrocarbons detected above the LOR, normalised to 1% TOC....68
Table 3-14: Summary of acid sulfate soil results 68
Table 4-1: Comparison of habitat classifications of towed video surveys (October 2021 and June 2022) and AIMS habitat mapping (2021)....91

Plates

Plate 2-1: SeaSpyder camera system....11
Plate 2-2: Infauna filtering table and puddling bin set up on the *Lauri-J* 13
Plate 2-3: Water quality filtering station set up on the *Lauri-J*....16
Plate 3-1: Grab sample from site OP1, showing silty shelly sand with clumps of clay 25
Plate 3-2: Silty, shelly sand with very sparse soft corals (Alcyoniidae) at site OP1 26
Plate 3-3: Silty/clay sand with a motile crinoid at site V12 26
Plate 3-4: Small sand wave at site V11, with coarse, shelly sand at the crest....27
Plate 3-5: Silty/clay sediment with soft corals, Bryozoa (lace coral) and a motile crinoid at site SG10....28
Plate 3-6: Coarse shelly sand waves with very sparse epibiota at site HS78....29
Plate 3-7: Coarse shelly sand from site HS34, inside the potential sand wave dredging zone at the outer edge of Darwin Harbour....29
Plate 3-8: Hermit crabs from site HS33....30
Plate 3-9: Silty shelly sand, with very sparse to no conspicuous epibiota at site HS73....30
Plate 3-10: Silty shelly sand and part of a bombora supporting assemblages of sponges, anemones and soft corals at site HS51 31
Plate 3-11: Hard bottom (consolidated granite rocks) with a shelly sediment veneer supporting gorgonians and bryozoans (lace corals) at site HS68 32
Plate 3-12: Low-profile reef with medium density gorgonians and sponges at site HSN2....32
Plate 3-13: Silty shelly sand with sparse soft corals at RFPA3....37

Plate 3-14: Rippled course shelly sand with no to very sparse epibiota at Hab3 38
Plate 3-15: Rocky reef with medium to high density epibiota, including large soft corals (gorgonian fans and sea whips), hydroids, sponges (multiple morphotypes) and occasional hard coral at INPHCMAN 38
Plate 3-16: Coarse shelly sand with sparse epibiota and moderate bioturbation at Hab10 39
Plate 3-17: Rocky reef with diverse sponges, soft and hard corals, macroalgae and fish at INPHCCHI 39

Figures

Figure 2-1: Sediment and water quality sampling sites (November 2021) and sediment core sampling sites collected during geotechnical sampling sites (January 2022) along the proposed Barossa pipeline route and at the proposed spoil ground (SG) 5
Figure 2-2: Sediment and water quality sampling sites from outer Darwin Harbour to sand wave area, showing with 2021 multi-beam bathymetric data 6
Figure 2-3: Sediment quality sampling sites in inner Darwin Harbour, with 2021 multi-beam bathymetric data 7
Figure 2-4: Darwin Harbour sediment quality sampling sites near the shore crossing, with 2021 multi-beam bathymetric data 8
Figure 2-5: Darwin Harbour benthic habitat survey video transect sites (June 2022) 10
Figure 3-1: Benthic habitat types identified along the furthest offshore pipeline route (October 2021) 20
Figure 3-2: Benthic habitat types identified along the offshore pipeline route (October 2021), including the Reef Fish Protection Area 21
Figure 3-3: Benthic habitat types identified within the spoil ground (October 2021) 22
Figure 3-4: Benthic habitat types along the pipeline route in northern Darwin Harbour (October 2021), including the Reef Fish Protection Area 23
Figure 3-5: Benthic habitats along the southernmost section of the pipeline route in Darwin Harbour (October 2021) 24
Figure 3-6: Benthic habitats along the proposed Barossa GEP pipeline, including outer pipeline, outer Darwin Harbour and inner Darwin Harbour survey sites (June 2022), including the Reef Fish Protection Area 36
Figure 3-7: Sediment sample particle size characteristics along the offshore pipeline route 41
Figure 3-8: Offshore pipeline infaunal SIMPROF cluster groups 43
Figure 3-9: Metal concentrations along the offshore pipeline route (from west (OP1) to east (OP30)) 45
Figure 3-10: Correlation between iron and arsenic concentrations along the offshore pipeline route 46
Figure 3-11: NORMs concentrations along the offshore pipeline route (from west (OP1) to east (OP30)) 48
Figure 3-12: Sediment sample particle size characteristics inside Darwin Harbour (from south (HS01) to north (HS49)) 50
Figure 3-13: Metal concentrations along the offshore pipeline route (from south (HS1) to north (HS49)) 52
Figure 3-14: Correlation between iron and arsenic concentrations along the Darwin Harbour pipeline route (HS1 to HS49) 53
Figure 3-15: Total recoverable hydrocarbons (normalised to 1% TOC) in Darwin Harbour (from south (HS01) to north (HS49) 56
Figure 3-16: NORMs concentrations along the Darwin Harbour section of the pipeline route (from South (HS01) to North (HS49)) 57
Figure 3-17: Sediment sample particle size characteristics at the spoil ground 58
Figure 3-18: Metal concentrations at the spoil ground 60
Figure 3-19: Correlation between iron and arsenic concentrations inside the spoil ground 61
Figure 3-20: NORMs concentrations at the spoil ground 62
Figure 3-21: Sediment sample particle size characteristics at the sediment sampling sites (from north to south) 63

Figure 3-22: Metal concentrations along the Darwin Harbour sediment cores (L = lower (0 to 50 cm core depth), U = upper (>50 cm))....65
Figure 3-23: Correlation between iron and arsenic concentrations in Darwin Harbour sediment core samples....66
Figure 3-24: Principal coordinates ordination (PCO) plot showing particle size distribution samples by study area....69
Figure 3-25: Cluster analysis of average distance between/within study area groups....70
Figure 3-26: Principal coordinates ordination (PCO) of offshore pipeline (OP) and spoil ground (SG) infaunal data....71
Figure 3-27: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP1....73
Figure 3-28: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP2....73
Figure 3-29: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP3....74
Figure 3-30: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP4....74
Figure 3-31: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP5....75
Figure 3-32: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP6....75
Figure 3-33: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP7....76
Figure 3-34: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP8....76
Figure 3-35: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP9....77
Figure 3-36: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP10....77
Figure 3-37: Filtered and unfiltered metal concentrations above LoRs from the offshore pipeline route (from south to north)....78
Figure 3-38: Surface and bottom chlorophyll-a and phaeophytin-a concentrations along the offshore pipeline route....80
Figure 3-39: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG1....82
Figure 3-40: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG4....82
Figure 3-41: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG7....83
Figure 3-42: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG8....83
Figure 3-43: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG11....84
Figure 3-44: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG12....84
Figure 3-45: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG13....85
Figure 3-46: Filtered and unfiltered metal concentrations from the spoil ground....85
Figure 3-47: Surface and bottom chlorophyll-a concentrations at the spoil ground....87
Figure 4-1: Benthic habitat types identified along the offshore pipeline route overlayed on AIMS 2021 habitat map, including the Reef Fish Protection Area....93

Figure 4-2: Benthic habitat types identified along the pipeline route and outer Darwin Harbour overlayed on AIMS 2021 habitat map 94
Figure 4-3: Benthic habitat types identified along the pipeline route and inner Darwin Harbour overlayed on AIMS 2021 habitat map 95

Appendices

Appendix A: Survey sites
Appendix B: Sediment survey log
Appendix C: Sediment sample photographs
Appendix D: Laboratory sediment particle size data
Appendix E: Laboratory sediment infauna data
Appendix F: Laboratory sediment and water naturally occurring radioactive materials data
Appendix G: Laboratory sediment and water metals, nutrients, chlorophyll-a and total suspended solids data
Appendix H: Laboratory sediment and water hydrocarbon, pesticides, tributyl tin and acid sulfate soils data

EXECUTIVE SUMMARY

Santos is exploring options for the Darwin Pipeline Duplication (DPD) Project associated with development of the Barossa gas field in northern Australia. The pipeline would run from the point where the Barossa gas export pipeline (GEP) intersects the existing Bayu-Undan (BU) pipeline (kilometre point (KP) 0), running alongside the existing BU GEP into Darwin LNG plant at Wickham Point in Darwin Harbour (KP122.5). The pipeline would be trenched using a dredge in areas within the harbour and then laid on the seabed offshore outside of the harbour. Dredge spoil will be placed at an offshore dredge spoil disposal site adjacent the existing INPEX spoil ground outside the harbour in Northern Territory waters. As such, baseline information on the benthic habitats, sediment composition (including contaminant concentrations), macroinvertebrate (infaunal) assemblages, and water quality was required along the pipeline route and in the proposed spoil ground. The surveys were undertaken between 14–22 October 2022, 6–10 January 2022 and 6–10 June 2022.

During the surveys, 99 × 0.1 m^2 van Veen grab samples (in October 2021), 111 subsea video deployments (69 in October 2021 and 42 in June 2022), 34 water samples (in October 2021) and 27 core samples (in January 2022) were collected. The pipeline survey area extended from approximately 3 km west of KP0 to KP120.6 (near the KP122.5 Darwin Harbour shore crossing) and included a potential spoil ground outside of Darwin Harbour port limits.

Key conclusions from the surveys are:

- Eight overarching benthic habitat types were identified from subsea video surveys of the offshore pipeline route, spoil ground and pipeline route in Darwin Harbour. Benthic habitats comprised soft sediment habitat types outside of Darwin Harbour, and a mosaic of hard and soft substrate habitats within the harbour. Highest densities of epibiota were associated with hard substrates (consolidated rocky seabed and low-profile reef).
- Sediments in the survey area were represented by slightly gravelly muddy sands to gravelly sands.
- Infaunal analysis indicated that the number of species (S), abundance (N), species richness (d) and diversity (H') indices varied between different sampled areas. Comparison with historic data (INPEX Browse Ltd, 2010) indicated that the lowest values of these indices were likely to be within Darwin Harbour, with highest values recorded for the offshore pipeline section (~KP-3 to KP90). Infaunal assemblages were characteristic of soft sediment habitat.
- Macroinvertebrate assemblages were dominated by crustaceans (mainly amphipods, tanaids and isopods) and annelid polychaetes (mainly deposit-feeding tube worms and free-living taxa), with crustacea (mainly amphipods). Characteristic taxa included Anthuridae (elongate isopods), polychaetes (*Lumbrineris* sp., spionids, *Nephthys* sp., *Axiothella* sp. and *Eunice* sp.), brittlestars (Ophiuroidea) and other echinoderms, sipunculids, molluscs and chordates were also represented.
- Multivariate analysis identified that the sampled areas (offshore pipeline and spoil ground) were significantly different.
- The silt/clay and gravel components indicated a transition in benthic sediments from the tie-in point at KP0 to the shore crossing at KP122.5. Sampled areas (the offshore pipeline, the spoil ground, the sand wave dredge area in the northern part of Darwin Harbour and the pipeline route in southern Darwin Harbour (near the shore crossing)) were all significantly different in terms of particle size distribution, with clay/silt and gravel per cent contributions highest in Darwin Harbour. Similar transitional patterns were observed for infaunal biological assemblage composition along the offshore pipeline route and at the spoil ground. It is likely that other unmeasured factors, e.g. current speeds/site energy, riverine input into Darwin Harbour (e.g. freshwater, silt), salinity profiles up the river and sediment chemistry, also contribute, and that there is likely to be seasonal variability in the distribution and composition of benthic faunal assemblages.

- Sediment sampling and analysis was conducted in line with the National Assessment Guidelines for Dredging. Analysis of metals and metalloids in sediments along the pipeline route and at the spoil ground indicated elevated concentrations of arsenic greater than the relevant National Assessment Guidelines for Dredging screening levels. Elevated levels of arsenic were found both along the pipeline route and at the proposed dredge spoil disposal ground indicating a naturally high background concentration and have been previously recorded in Darwin Harbour sediments. This is expected as arsenic is considered to have become concentrated in sedimentary rocks through sedimentation processes in this region. The fine-grained clastic sediments have higher arsenic concentrations than the coarse-grained sediments.
- Total petroleum hydrocarbons (TPH), total recoverable hydrocarbons (TRH) and benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) were detected at 35 of the Darwin Harbour sites, at low levels. Normalised TPH and TRH concentrations met the relevant guidelines across all sites. PAH concentrations at these 35 sites were below the laboratory limit of reporting.
- Concentrations of naturally occurring radioactive materials, pesticides and tributyl tin (TBT) were all below limits of detection in harbour sediments. There is low potential for acid sulfate soils as, although inorganic sulfur is present in the sediments, there is significant acid neutralising capacity kinetically available to neutralise the oxidation products from the inorganic sulfur.
- No contaminants of concern were found in the sediments along the pipeline route or at the potential spoil disposal ground, with elevated levels of arsenic considered to be naturally occurring. Therefore the sediments along the pipeline route are considered to be suitable for unconfined ocean disposal, as per the National Assessment Guidelines for Dredging and Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory.
- Water column profiles at sites along the offshore pipeline and at the spoil ground showed no indications of stratification of the water column.
- Analysis of contaminants in water quality samples identified several exceedances of the relevant guideline values:
  - Three copper samples from the surface waters
  - One lead sample from surface waters
  - A total of 35 total nitrogen and total phosphorous samples.

In summary, the results of the Barossa DPD surveys contributed to the understanding of seabed habitat chemico-physical and biological composition in the study area. The Barossa DPD pipeline route is a transitional environment, with soft sediment habitats along the offshore pipeline route and spoil ground, and with areas of both soft and hard substrate habitat within Darwin Harbour.

1 INTRODUCTION

Santos is exploring options for the Darwin Pipeline Duplication (DPD) Project associated with development of the Barossa gas field in northern Australia. The pipeline would run from the point where the existing approved Barossa gas export pipeline (GEP) reaches the existing approved Bayu-Undan pipeline (kilometre point (KP) 0), running alongside the existing Bayu-Undan GEP into Darwin LNG plant at Wickham Point in Darwin Harbour (KP122.5). The pipeline will be trenched using a dredge in areas within the harbour, where required, and then laid on the seabed further offshore outside of the harbour. Dredge spoil will be placed at an offshore dredge spoil disposal site adjacent the existing INPEX spoil ground outside the harbour in Northern Territory waters. Rock sourced from a local quarry will be used to backfill the trench once the pipeline has been laid. These activities have potential to cause environmental impacts that must be identified, quantified, mitigated, and managed to acceptable levels.

In support of environmental approvals for the DPD project, Santos has engaged RPS to conduct a baseline environmental survey for the project, designed to fill gaps in the existing dataset. Sampling sites have been selected to ensure representation of the different sections of the pipeline route and to investigate features identified from interpretation of geophysical data, stakeholder consultation and existing marine habitat mapping.

The baseline survey included the following areas:

- The pipeline route from KP0 (equivalent to Bayu-Undan pipeline kilometre point (KP) 380) to ~KP91 (Darwin Harbour port boundary)
- The proposed spoil ground
- The pipeline route within Darwin Harbour (KP91 to KP122.5)
- The proposed pipeline trenching areas within Darwin Harbour
- Habitat areas identified from existing Darwin Harbour habitat mapping
- The Charles Point Wide Reef Fish Protection Area.

1.1 Objectives

The Barossa DPD offshore survey objectives were to:

- Undertake water quality, sediment quality and benthic habitat and communities assessments along the proposed pipeline route and at the spoil ground.
- Identify any areas of higher environmental value or sensitivity to inform the Environmental Impact Assessment (EIA) for the project.
- Collect additional samples and benthic habitat imagery during other surveys to augment the benthic dataset.

1.2 Purpose

- The purpose of this field survey report is to provide a summary of the field survey activities and results from the field surveys, including a brief description of the key features and benthic habitats along the pipeline route and at the spoil ground area.

2 METHODS

2.1 Surveys

2.1.1 October 2021 survey

2.1.1.1 Sampling sites

The sediment grab and video surveys were carried out between 14 and 22 October 2021. The survey design was supplemented in the field with additional sites based on any potential features identified during the Fugro geophysical scope. The survey was divided into three sampling areas and the samples coded accordingly; the offshore pipeline (OP; KP0 to ~KP91), Darwin Harbour pipeline (HS; ~KP91 to KP122, including the sand wave dredge areas), and the spoil ground (SG; Figure 2-1). The sampling sites were based on historical geophysical data (see Figure 2-1, Figure 2-2, Figure 2-3 and Figure 2-4) and therefore considered representative of the full pipeline corridor, including the anchoring areas either side of the proposed pipeline route. The sampling was conducted as per requirements of NAGD and NT EPA dredging guidelines, ensuring sufficient sites were sampled in a standard method. Further details about the survey sites, including the relative KP Points are in Appendix A.

Table 2-1: Sample naming conventions for the Barossa DPD survey

Sample location	Sample type	Sample ID	Number of sites
Offshore pipeline	Sediment (grabs)	OP	33
	Drop video	OP	9
	Video transect	V	17
	Surface water	OP S	10
	Bottom water	OP B	10
Spoil ground	Sediment (grabs)	SG	13
	Drop video	SG	13
	Surface water	SG S	7
	Bottom water	SG B	7
Darwin Harbour	Sediment (grabs)	HS	53
	Sediment (cores)	KP	17
	Video transect	HS	30

2.1.2 January 2022 sediment survey

A sediment survey was undertaken between 6–10 January 2022. The sediment survey was undertaken during a geotechnical survey conducted by Fugro, which collected the cores and positional data, and CDM Smith, which processed the core samples aboard the survey vessel.

2.1.3 Sediment sampling and analysis

The sampling and analysis was conducted as per requirements of National Assessment Guidelines for Dredging (NAGD; CoA, 2009) and Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA, 2013). This ensured sufficient sites were sampled and appropriate analytes were identified. Further details about the survey sites, including the relative KP locations are in Appendix A.

2.1.3.1 Sampling sites

Sediment cores were collected at pre-determined sites, with samples separated into 0–50 cm and >50 cm core depth intervals (below sediment surface) for processing and laboratory analysis. A total of 29 sediment core samples were collected from 17 sampling locations inside Darwin Harbour (Figure 2-1).

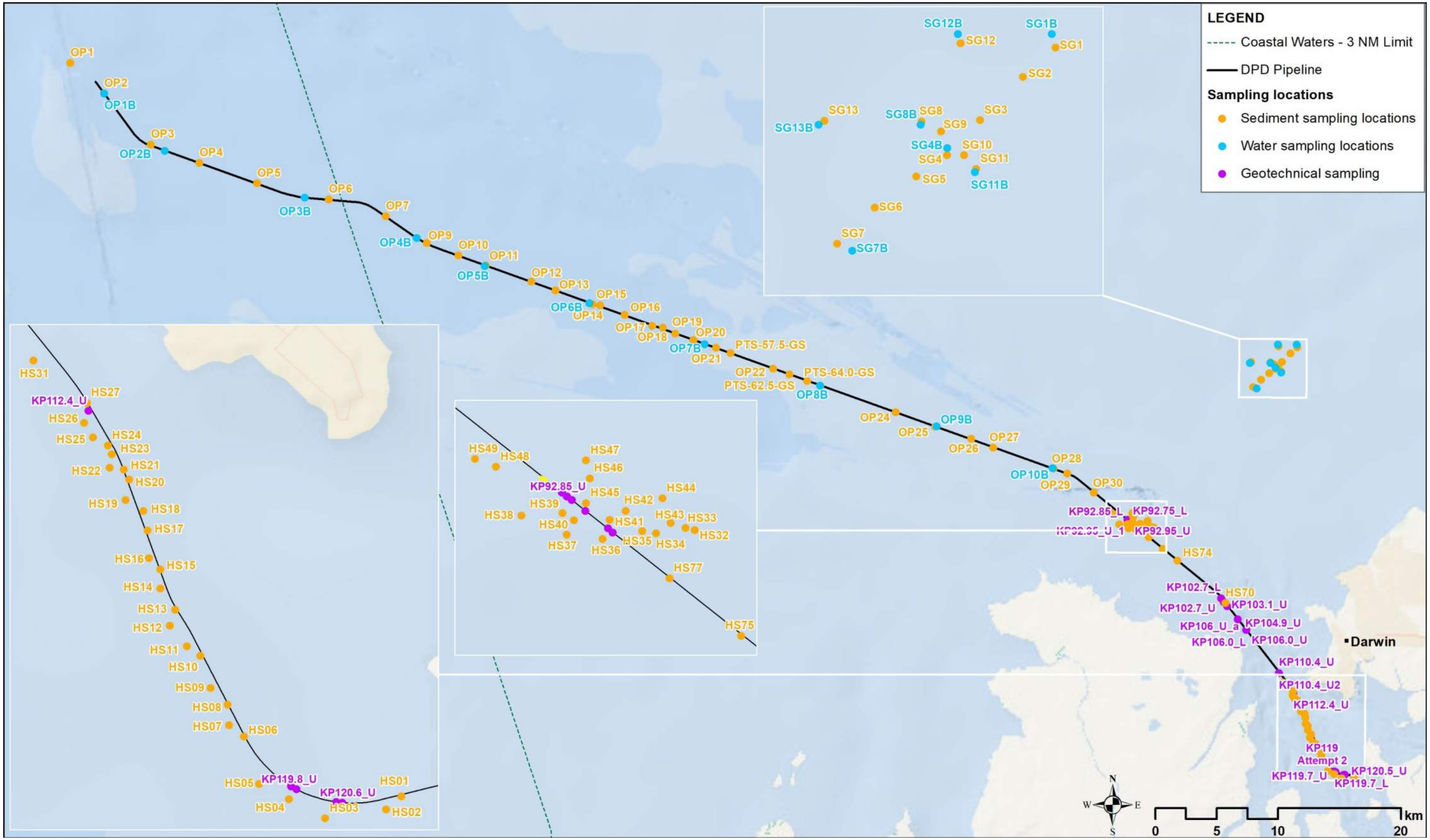


Figure 2-1: Sediment and water quality sampling sites (November 2021) and sediment core sampling sites collected during geotechnical sampling sites (January 2022) along the proposed Barossa pipeline route and at the proposed spoil ground (SG)

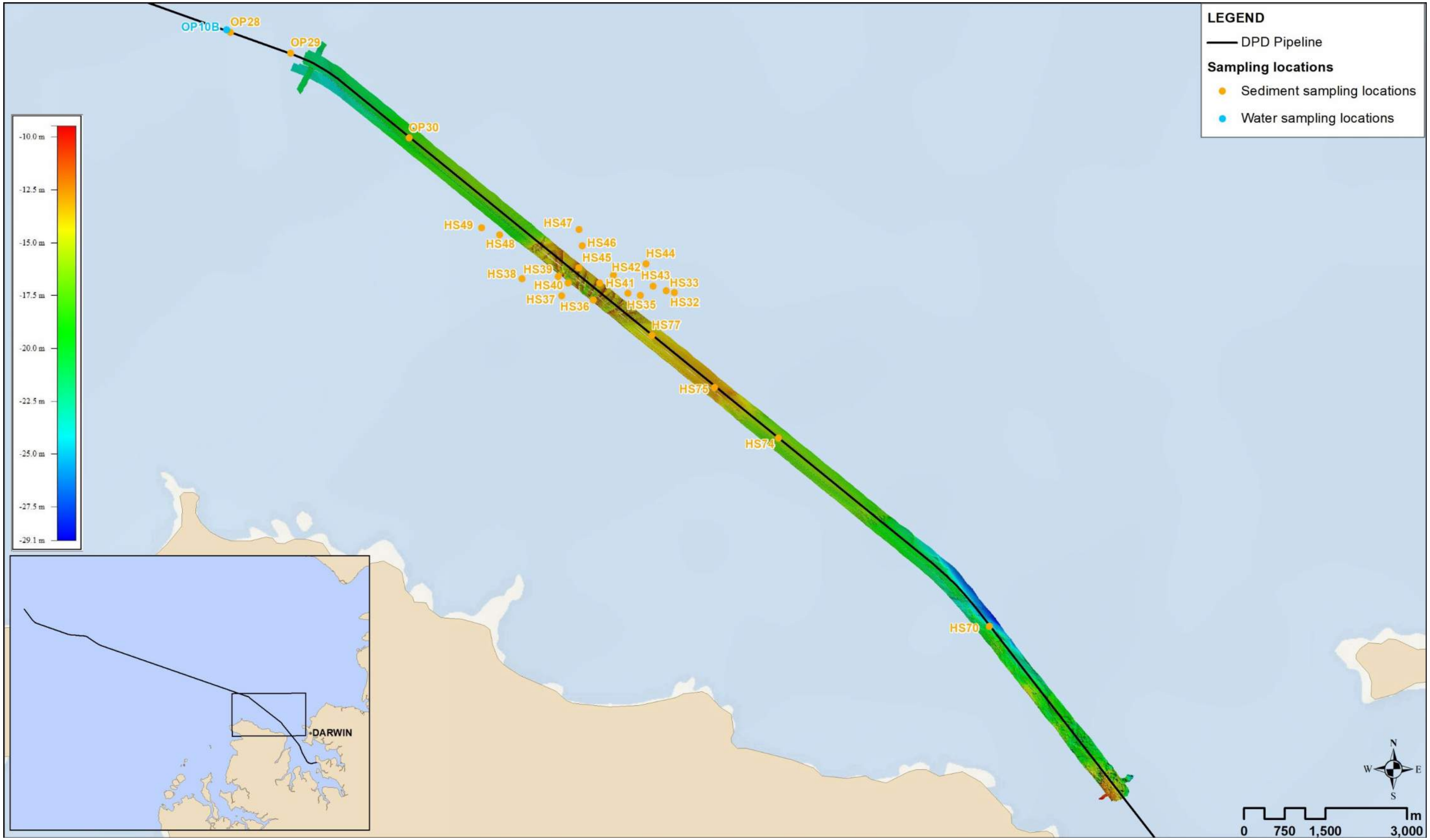


Figure 2-2: Sediment and water quality sampling sites from outer Darwin Harbour to sand wave area, showing with 2021 multi-beam bathymetric data

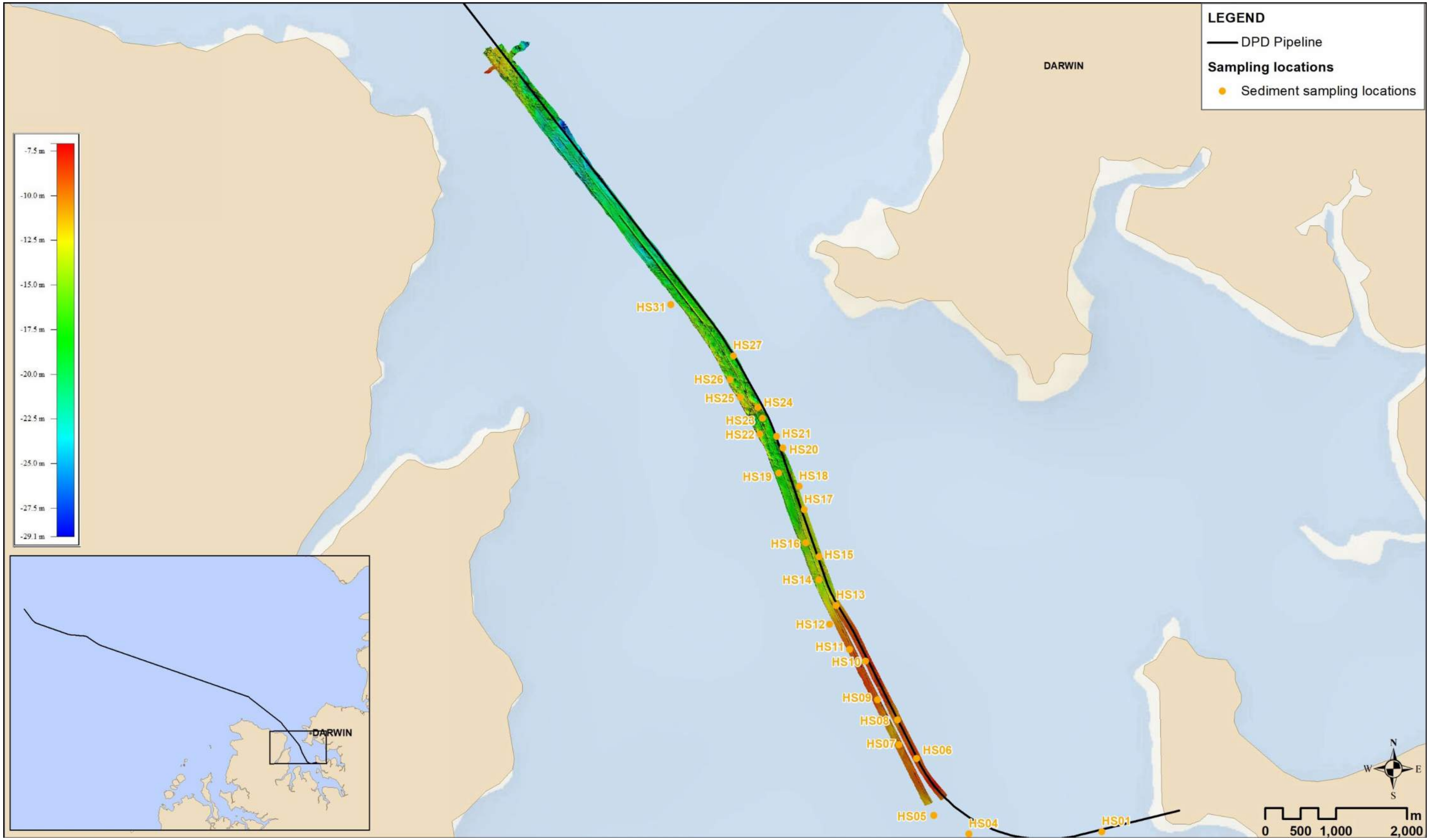


Figure 2-3: Sediment quality sampling sites in inner Darwin Harbour, with 2021 multi-beam bathymetric data

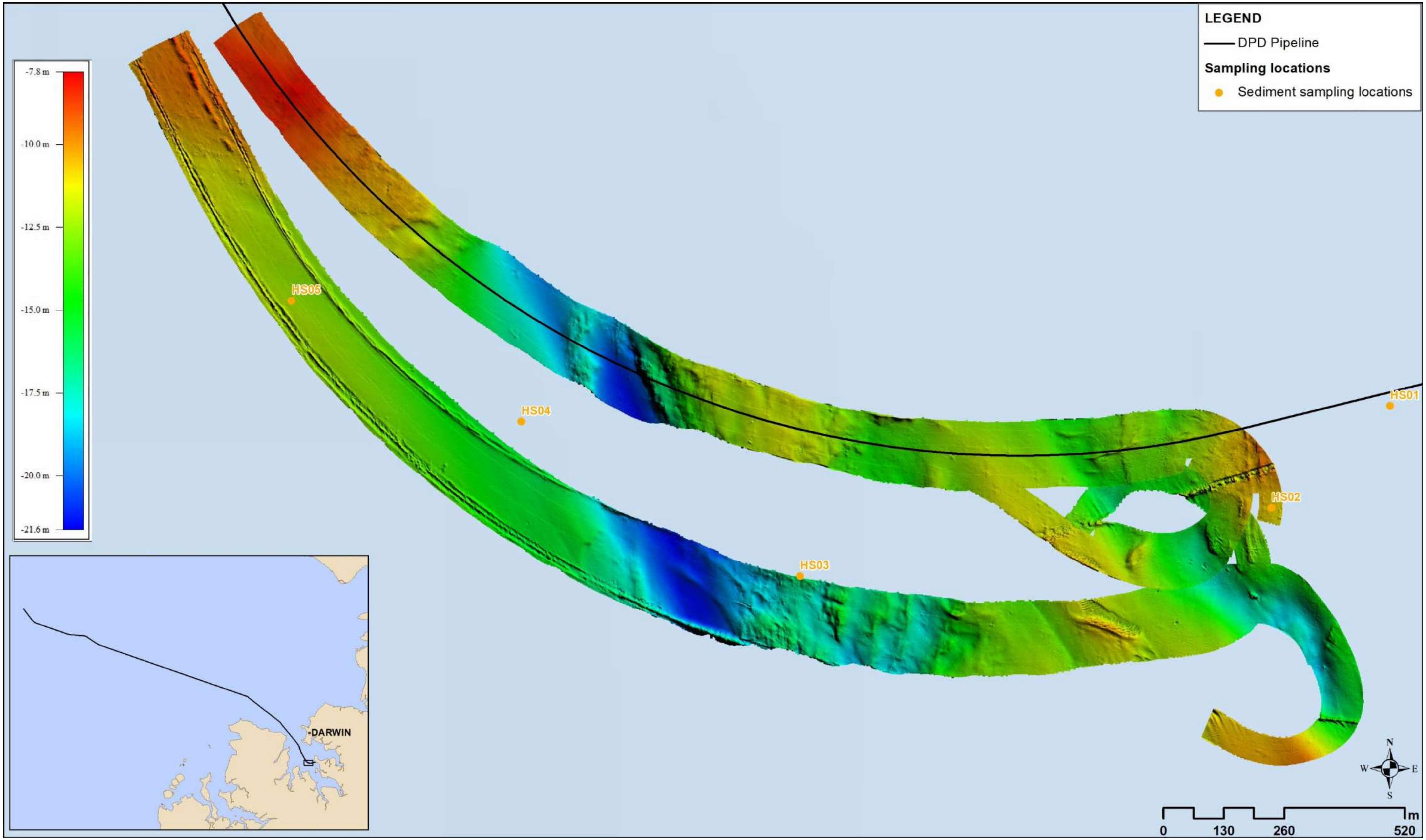


Figure 2-4: Darwin Harbour sediment quality sampling sites near the shore crossing, with 2021 multi-beam bathymetric data

2.1.4 June 2022 survey

An additional video transect survey was conducted between 6 and 10 June 2022. RPS designed and conducted the remote operated vehicle (ROV) benthic imagery. The objective for this survey was to further ground truth the 2019 and 2021 AIMS benthic habitat data around the pipeline route offshore and in Darwin Harbour (including the sand wave dredge areas). The survey was undertaken in conjunction with a marine archaeological survey.

2.1.4.1 Sampling sites

The video transect survey was divided into three general sampling areas: the offshore pipeline, outer Darwin Harbour pipeline and inner Darwin Harbour (Figure 2-5). The sampling sites were based on historical AIMS 2019 and 2021 benthic surveys and the proposed location of the DPD, including key ecological and historical locations. A total of 42 transects were analysed during the survey; 12 at the offshore pipeline, 15 near at outer Darwin Harbour and the remaining 15 at inner Darwin Harbour. Further details about the survey sites are included in Appendix A.

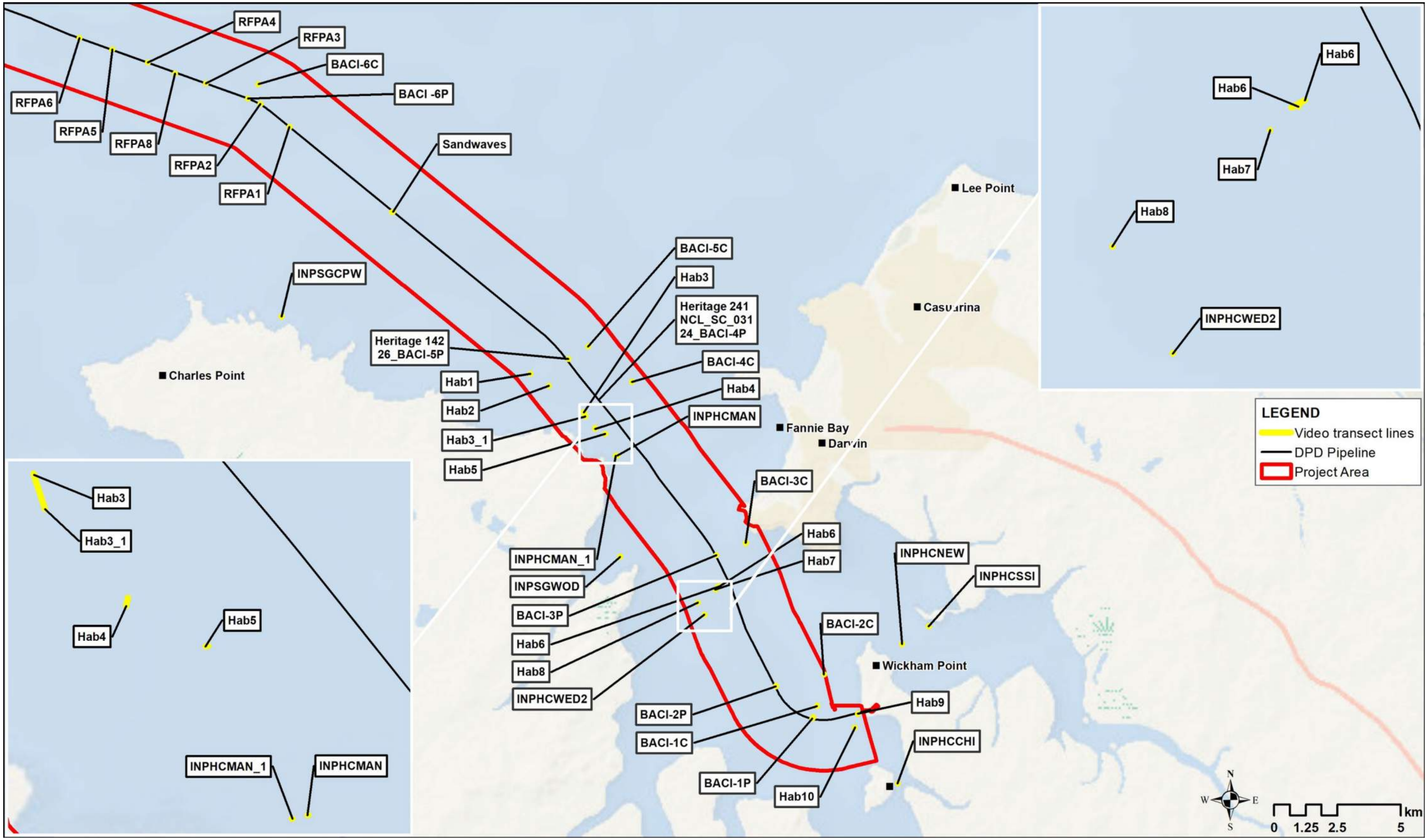


Figure 2-5: Darwin Harbour benthic habitat survey video transect sites (June 2022)

2.2 Subsea video

A SeaSpyder subsea video system mounted on a drop camera frame was used to collect digital video and stills imagery (Plate 2-1). The colour video camera was fitted with a zoom lens controllable from the surface control unit and live imagery was transmitted to the control room on the vessel via a load-bearing umbilical. Imagery was also recorded for subsequent analysis. The system also comprised a stills camera, lighting system and lasers (spaced 20 cm apart).

The benthic habitats observed and recorded during each camera drop were described by RPS' marine scientists during the survey. ESRI's ArcPad software was used to record the positional data for the tracklog of the towed video transect and the spot-point positions for each still image taken. During the video deployments, vessel speed did not exceed ~1.5 knots. The imagery collected was subsequently analysed in detail by RPS' marine scientists to characterise topographic features, benthic habitats and macrofaunal communities.

The video system was deployed at sites across the pipeline route and spoil ground (October 2021 and June 2022). Video site locations were initially based on positions of seabed features derived from the original Bayu-Undan geophysical survey data. Areas of interest were then identified in the field, using the 2021 Fugro geophysical survey data, and the video site locations and transects were adjusted accordingly.

Plate 2-1: SeaSpyder camera system

2.3 Sediment quality

2.3.1 Sample collection

During the October 2021 survey, sediments were sampled via van Veen grab sampler at 30 offshore pipeline locations, an additional three offshore pipeline locations for particle size distribution only (at the request of Santos), 13 spoil ground locations and 53 Darwin Harbour locations. During the January 2022 survey, sediment cores were collected from 17 Darwin Harbour core sample locations. The sampling and analysis sediments was conducted as per the NAGD (CoA, 2009) and NT EPA (2013) dredging guidelines.

Grab samples were collected using a double van Veen grab mounted in a single frame (with a sampled surface area of each grab of 0.1 m^2), which was deployed and retrieved by Fugro's personnel. An optimal sample processing area was identified as part of strict contamination risk management protocols. GPS position, depth, time and date were recorded every time the grab reached the seabed. Upon retrieval to deck, each sample was photographed with a video slate showing the project name, site, sample number and date (see Appendix B and Appendix C). Each sample was then characterised to document any conspicuous biota, sediment type, presence of visible anoxic layers, hydrocarbons or anthropogenic material. If samples could not be obtained at the site (after three attempts), then the site was moved and sampled nearby (within 50 m).

Core samples were collected using a gravity piston corer with plastic liners. The level of sediment penetration was estimated from sediment smears on the outside of the liner. Where no smear was present, the depth of recovery was given as the penetration depth.

Samples were taken for laboratory analysis of the following:

- Particle size distribution (PSD)
- Infauna (offshore pipeline and spoil ground only)
- total Organic Carbon (TOC)
- Metals and metalloids (Al, Sb, As, Ca, Cr, Co, Cu, Fe, Pb, Mn, Hg, Ni, Ag, Zn)
- Nutrients (total phosphorous (TP), total Kjeldahl nitrogen (TKN))
- Total recoverable hydrocarbons (TRH) and benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN)
- Polycyclic aromatic hydrocarbons (PAH), where TRHs are above limits of detection)
- Naturally occurring radioactive materials (NORMs; radium^{226}, radium^{228} and thorium^{228}).

The following additional analytes were included in laboratory analysis for Darwin Harbour grab and core samples:

- Tributyltin (TBT)
- Acid sulphate soils (ASS)
- Organochlorine pesticides
- Polychlorinated biphenyls (PCBs).

2.3.1.1 Subsampling – sediment contaminants

Subsamples for contaminants were taken from the top 2–5 cm of grab samples, excluding the surficial sediments within 5–10 mm of the sides of the grab (to reduce the risk of contamination). Cores were separated into 0–50 cm and (where at least 1 m of sediment was collected) >50 cm horizons. The entire sediment sample for one horizon was processed for laboratory analysis.

Sediment was removed from the grab or core sleeve using a stainless-steel scoop and placed in a glass bowl for mixing. All implements had been pre-cleaned with Decon-90 prior to each site.

Once homogenised, samples were placed in the appropriate laboratory-supplied sample containers. The PSD sample was also taken from surficial sediments / relevant core horizons to allow direct comparison between contaminants and sediment grain sizes.

For all samples:

- Sterile gloves were always worn when collecting and processing samples. These were changed between samples.
- The insides of sample lids did not come into contact with anything potentially contaminated.
- Jars and bags were sealed, correct labelling confirmed, and then stored in an esky with ice blocks.

At the end of each shift, samples were stored as identified in Table 2-2.

2.3.1.2 Sampling – infauna

A full 0.1 m^2 van Veen grab sample was collected for infaunal assessment at offshore pipeline (OP) and spoil ground (SG) sites. The infauna sample was carefully emptied into a fish tray and then placed into the infauna processing table (Plate 2-2). The sample was carefully washed using sea water from the deck hose, with the washings flowing out through the sluice gate and draining through a 1 mm mesh sieve. The rate of flow through the sluice was managed by controlling the volume of water within the table and by using the sluice door to control the amount of water flowing through the sluice gate. The sieve was rotated and shuffled to prevent clogging. When the sieve was almost full, the sluice gate was shut to stop the flow, and the full sieve swapped out for a replacement empty sieve. A puddling bin was used to remove as much remaining sediment as possible through the sieve. Samples were then carefully washed out into a plastic Ziplock bag and preserved with 100% ethanol (to a final concentration of ~80% in seawater).

Infauna were picked from the sediment retained on the sieves by Benthic Australia. They were then analysed to the lowest practicable taxonomic level, with the abundance of each taxa recorded from each sample.

Plate 2-2: Infauna filtering table and puddling bin set up on the *Lauri-J*

2.3.2 Offshore pipeline and spoil ground

Sediment samples for contaminants, particle size distribution and infauna were collected from 29 offshore pipeline sites (with an additional three PSD sites were added during the survey) and 13 spoil ground sites (Table 2-2).

Table 2-2: Sediment quality sampling summary for offshore pipeline and spoil ground sites

Sample	Total samples (spoil ground)*	Total samples (offshore pipeline)*	Total samples	Laboratory	Lab LOR†	Container	Volume	Storage method	Holding time
PSD	13	29	42	MAFRL	NA	Ziplock bag	250 ml	Freeze	Five years
Infauna	13	29	42	Benthic Australia	NA	Bucket	0.1 m^2	Ethanol	
TOC	13	29	42	MAFRL	<0.1%	2 × plastic jars	70 ml	Freeze	One month
Metals and metalloids (Ag, Al, As, Ca, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Zn)	13	29	42	MAFRL	Depends on metal, 0.01–2				
Nutrients TP	13	29	42	MAFRL	<0.05				
Nutrients TKN	13	29	42	MAFRL	<0.1				
TRH and BTEXN	13	29	42	ALS	0.2–5 mg/kg, 1%	Glass jar	150 ml	Cold	Fourteen days
PAHs (where TRHs are above LoRs)	0	0	0	ALS	4–5 µg/kg			Cold	Fourteen days
NORMS (Ra^{226}, Ra^{228}, Th^{228})	13	29	42	SGS	3, 5, 3 Bq/kg	Ziplock	250 ml	Freeze	One month

*Sample numbers do not include quality assurance/quality control samples

†LoR = limit of reporting.

2.3.3 Darwin Harbour pipeline

Sediment samples for contaminants and PSD were collected from 50 sites along the pipeline route in Darwin Harbour (Table 2-3). Of these, TRHs were at or above limits of detection in 35 sites, and so PAH analysis was undertaken on these samples.

Table 2-3: Sediment quality sampling summary for Darwin Harbour pipeline sites

Sample	Total samples*	Laboratory	Lab LOR†	Container	Volume	Storage method	Holding time
PSD	50	MAFRL	NA	Ziplock bag	250 ml	Freeze	Five years
TBT	50	ALS	NA	Glass jar	250 ml	Cold	Fourteen days
TOC	50	ALS	0.02%	Glass jar	250 ml	Cold	Fourteen days
Metals and metalloids (Ag, Al, As, Ca, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Zn)			Depends on metal, 0.01–50				
Nutrients (TP)			2 mg/kg				
Nutrients (TKN)			20 mg/kg				

Sample	Total samples*	Laboratory	Lab LOR†	Container	Volume	Storage method	Holding time
TRH and BTEXN			0.2–5 mg/kg, 1%				
PAHs (where TRH is above limits of reporting)	35		4–5 µg/k				
Acid Sulphate Soils (ASS)	50	ALS	0.1 pH Unit	Zip-lock	250 ml	Freeze	Fourteen days
Organochlorine pesticides	50	ALS	0.25–0.5 µg/kg	Glass jar	250 ml	Cold	Fourteen days
Polychlorinated biphenyls	50	ALS	5 µg/kg				
NORMS (Ra226, Ra228, Th228)	50	SGS	3, 5, 3 Bq/kg	Ziplock	250 ml	Freeze	1 month

*Sample numbers do not include quality assurance/quality control samples

†LoR = limit of reporting.

2.3.4 Darwin Harbour pipeline sediment survey

A total of 24 sediment core samples were collected from 17 sites along the Darwin Harbour pipeline route (Table 2-4).

Table 2-4: Sediment quality sampling summary for Darwin Harbour DPD sediment core samples

Sample	Total samples*	Laboratory	Lab LOR†	Container	Volume	Storage method	Holding time
PSD	24	MAFRL	NA	Ziplock bag	250 ml	Freeze	Five years
TBT	24	ALS	NA	Glass jar	250 ml	Cold	Fourteen days
TOC	24	ALS	0.02%	Glass jar	250 ml	Cold	Fourteen days
Metals and metalloids (Ag, Al, As, Ca, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Zn)			Depends on metal; 0.01–50 mg/kg				
Nutrients (TP)			2 mg/kg				
Nutrients (TKN)			20 mg/kg				
TRH and BTEXN			0.2–5 mg/kg, 1%				
PAH (where TRHs are above LORs)	18		4–5 µg/kg				
ASS	24	ALS	0.1 pH Uni	Zip-lock	250 ml	Freeze	Fourteen days
Organochlorine pesticides	24	ALS	0.25–0.5 µg/kg	Glass jar	250 ml	Cold	Fourteen days
Polychlorinated biphenyls	24	ALS	5 µg/kg				

*Sample numbers do not include quality assurance/quality control samples

†LoR = limit of reporting.

2.4 Water quality

2.4.1.1 Water column profiling

Water column profiling was undertaken using a calibrated SeaBird SBE19plusV2 conductivity, temperature depth (CTD) profiler lowered through the water column at a rate of half a metre per second at each of the 17 water quality sampling locations. The maximum deployment depth (the position of the profiler above the seabed) was determined from the vessel echosounder prior to deployment. The following parameters were recorded in each profile:

- Pressure (to derive depth)
- Conductivity (to derive salinity)
- Temperature
- pH
- Dissolved oxygen
- Turbidity
- The data was downloaded off the SeaBird after each profile.

2.4.1.2 Sample collection

Water samples were collected at the sea surface (1–5 m below sea level (BSL)) and near the seabed (5 m above seabed (ASB)) using ten-litre Niskin bottles.

Phytoplankton and total suspended solids (TSS) samples were collected by filtering a 3 L sample of water through a filter tower (Plate 2-3). Phytoplankton samples were collected through a 0.8–1.2 µm filter, whilst TSS samples were filtered through a pre-weighed filter (stored in an envelope until used). Each filter paper was folded into quarters and wrapped in a dry piece of filter paper and placed back in the envelope for storage. Filtered metal samples were drawn through filter using a syringe. These samples were then transferred to a small pre-labelled sample jar. All other samples were placed in pre-labelled containers.

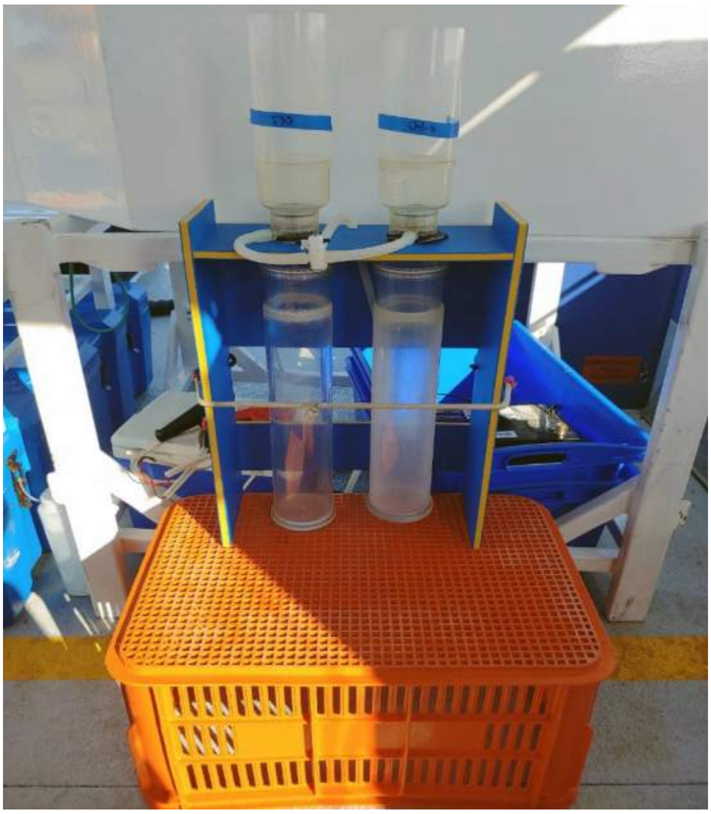


Plate 2-3: Water quality filtering station set up on the *Lauri-J*

Table 2-5: Water quality sampling summary for offshore pipeline and spoil ground sites

Analyte	Total samples (spoil ground)	Total samples (offshore pipeline)	Total samples	Laboratory	Lab LOR	Container	Volume	Storage method	Holding time
TSS	14	20	34	MAFRL	1 mg/L	Filter paper placed in Ziplock bag	NA	Cold	Seven days
Nutrients (TP and TN)	14	20	34	MAFRL	5 µg.P/L/50 µg.N/L	PP container	125 ml	Freeze	One month
Orthophosphate	14	20	34	MAFRL	2 µg.P/L	PP tubes	10 ml		
Nitrite and nitrate (NO_2 and NO_3)	14	20	34		2 µg.N/L				
Ammonium (NH_4+)	14	20	34		3 µg.N/L				
Phytoplankton pigments (Chlorophyll-a and Phaeophytin-a)	14	20	34	MAFRL	0.1 mg/L	Filter paper placed in Ziplock bag	NA	Freeze (in dark)	One month
Unfiltered metals and metalloids (As, Ca, Cr, Co, Cu, Pb, Ni, Zn)	14	20	34	MAFRL	0.05–1 µg/L	PP tube	10 ml	Cold	Two weeks
Unfiltered Hg	14	20	34	MAFRL	0.1 µg/L	Dark bottles	125 ml	Cold	Two weeks
Filtered metals and metalloids (As, Ca, Cr, Co, Cu, Hg, Pb, Ni, Zn)	14	20	34	MAFRL	0.05–1 µg/L	PP container	125 ml	Cold	Two weeks
Filtered Hg	14	20	34	MAFRL	0.1 µg/L	Dark bottles	125 ml	Cold	Two weeks
TRH and BTEXN	14	20	34	ALS	1–100 µg/L	Purple glass vials (sulfuric acid)	2 × 40 ml	Cold	One week
PAH (where TRH above LORs)	0	0	0	ALS	0.5–1 µg/L	Orange glass bottle	100 ml	Cold	One week
NORMS (Ra^{226}, Ra^{228}, Th^{228})	7	10	17	SGS	0.05, 0.1, 0.03 Bq/L	Plastic container	1000 ml	Nitric acid	Six months

2.5 Quality assurance and quality control

Prior to sampling, the deck area was assessed for potential sources of contamination. Where there had been clear wash-out of the surficial sediments in grab samples (e.g. due to a shell or rock caught in the jaws of the grab) the sample was discarded and classed as a failed attempt. Similarly, if water from the winch wire was observed dripping into the sample, the sample was discarded as it was potentially contaminated by hydrocarbons from the winch.

RPS requires that laboratories use NATA-accredited methods and have a Quality Assurance and Quality Control (QA/QC) program, where possible. Pre-cleaned sample containers for chemical analyses were provided by the laboratories for this survey. The following control process were undertaken to quantify potential within-laboratory variability in analysis and any potential sample contamination that could have occurred during sample collection, handling, storage or transport. All samples were transported with relevant and fully completed Chain of Custody (CoC) documentation.

2.5.1 Triplicates/duplicates

Triplicate sediment and water samples were collected at the offshore pipeline and spoil ground sites, while duplicates were collected within the Darwin Harbour sites, to determine potential within-laboratory variability in analyses. At least one triplicate or duplicate sample was collected for every 20 primary samples. Triplicates and duplicates were collected from the same bulk sediment sample as the primary sample and were labelled appropriately. The labelling code for triplicates allowed RPS to identify the collection site but it was not apparent to the laboratories.

2.5.2 Trip blanks

Trip blanks, or transport blanks, are used to assess potential contamination of samples during transport and storage. Trip blanks were supplied by the laboratory and consisted of plastic jars pre-filled with deionised water. They remained unopened during sampling. Rinsate water was used rather than inert sediment as it is considered to be a more sensitive test.

2.5.3 Field blanks

Field blanks detect contamination from sample handling, dust and other atmospheric fallout during the sampling process. Laboratory-supplied deionised water was decanted and stored in the same containers and in the same way as for the sediment samples and left open during sediment sampling. Water was used rather than inert sediment as it is considered to be a more sensitive test.

2.5.4 Equipment blanks

Equipment blanks measure contamination introduced through contact with sampling equipment. The samples were taken after the grab sampler had been decontaminated with Decon-90. After decontamination, the operator thoroughly rinsed the grab with seawater, then rinsed it again with the laboratory-supplied deionised water, which was captured in a laboratory-supplied sample container. This will detect potential contamination from the stainless-steel grab sampler.

2.5.5 Sample preservation and storage

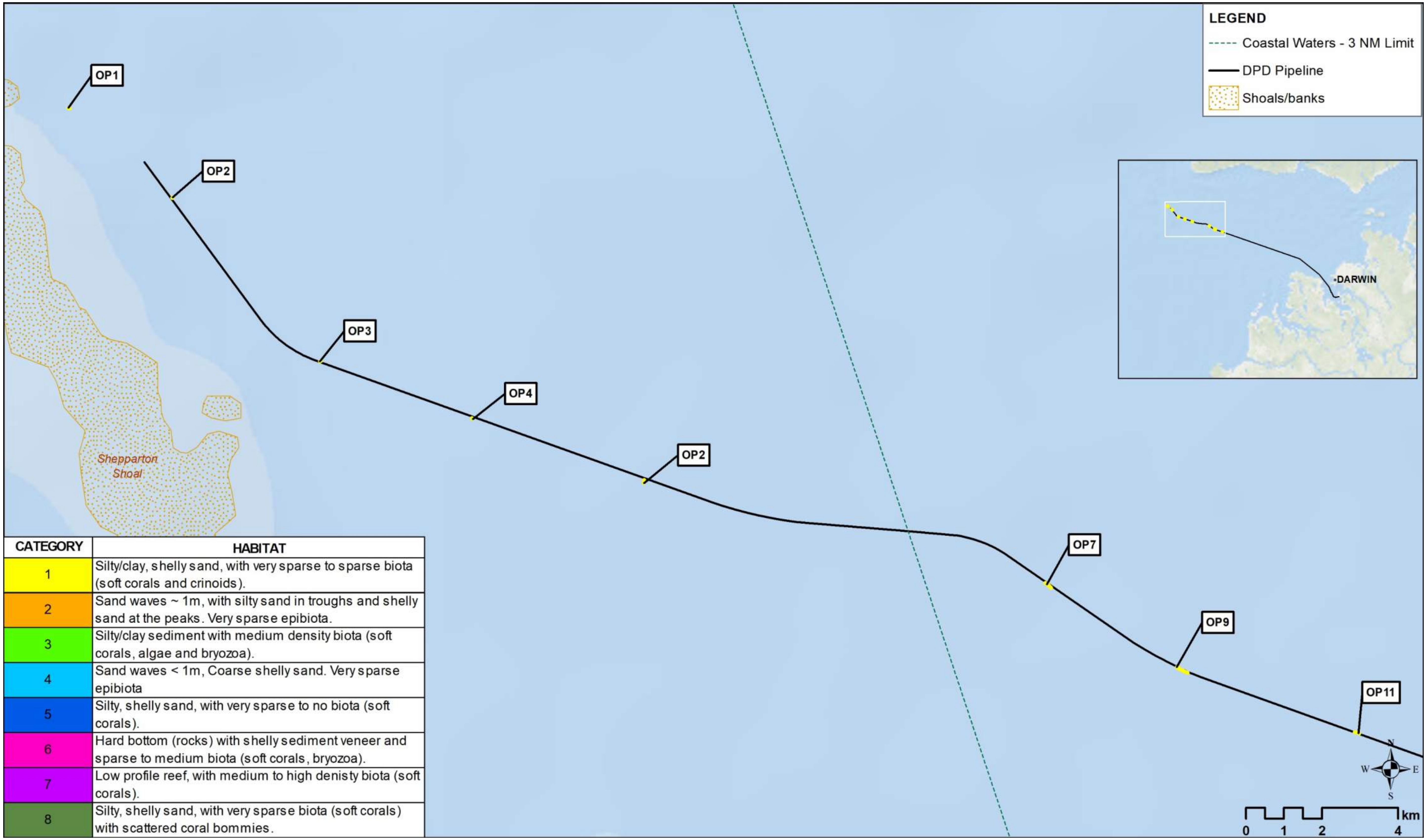
Water containers were filled to ~80% to leave a head-space sufficient to allow for expansion of the sample during freezing. Samples were stored during each of the surveys as required in Table 2-2–Table 2-5. During vessel demobilisation, samples were separated based on the laboratory they were being shipped to and transferred to clean eskies containing ice blocks for delivery to the laboratory. CoCs were filled out for each laboratory and sent with the relevant eskies.

3 RESULTS

3.1 Benthic habitat

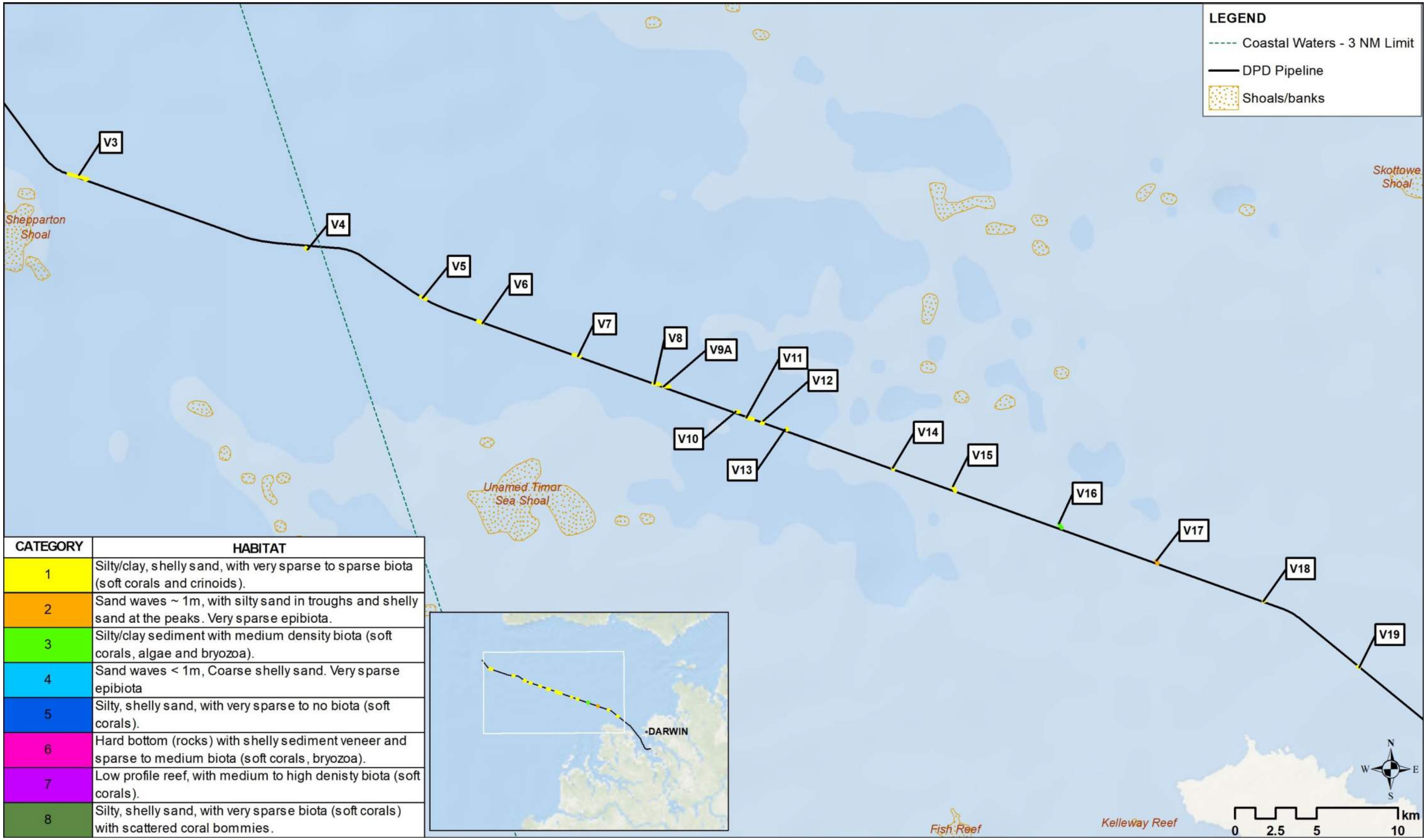
3.1.1 October 2021 survey

Eight high-level habitat types were identified along the Barossa DPD pipeline route and in the spoil ground area. This comprised six soft substrate habitats and two hard substrate habitats, with the offshore pipeline route and spoil ground dominated by particulate sediments with sparse to medium-density epibiota (Figure 3-1, Figure 3-2 and Figure 3-3). The hard substrate habitats were limited to the Darwin Harbour section of the pipeline route (Figure 3-4 and Figure 3-5). Offshore fishing sites were commonly identified with known shoals and were not identified along the pipeline route (Figure 3-1 and Figure 3-2). Inside Darwin Harbour, higher densities of fishing sites were located in close proximity to areas identified as hard substrate (Figure 3-4 and Figure 3-5).



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high denisty biota (soft corals).
8	Silty, shelly sand, with very sparse biota (soft corals) with scattered coral bommies.

Figure 3-1: Benthic habitat types identified along the furthest offshore pipeline route (October 2021)



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high denisty biota (soft corals).
8	Silty, shelly sand, with very sparse biota (soft corals) with scattered coral bommies.

Figure 3-2: Benthic habitat types identified along the offshore pipeline route (October 2021), including the Reef Fish Protection Area

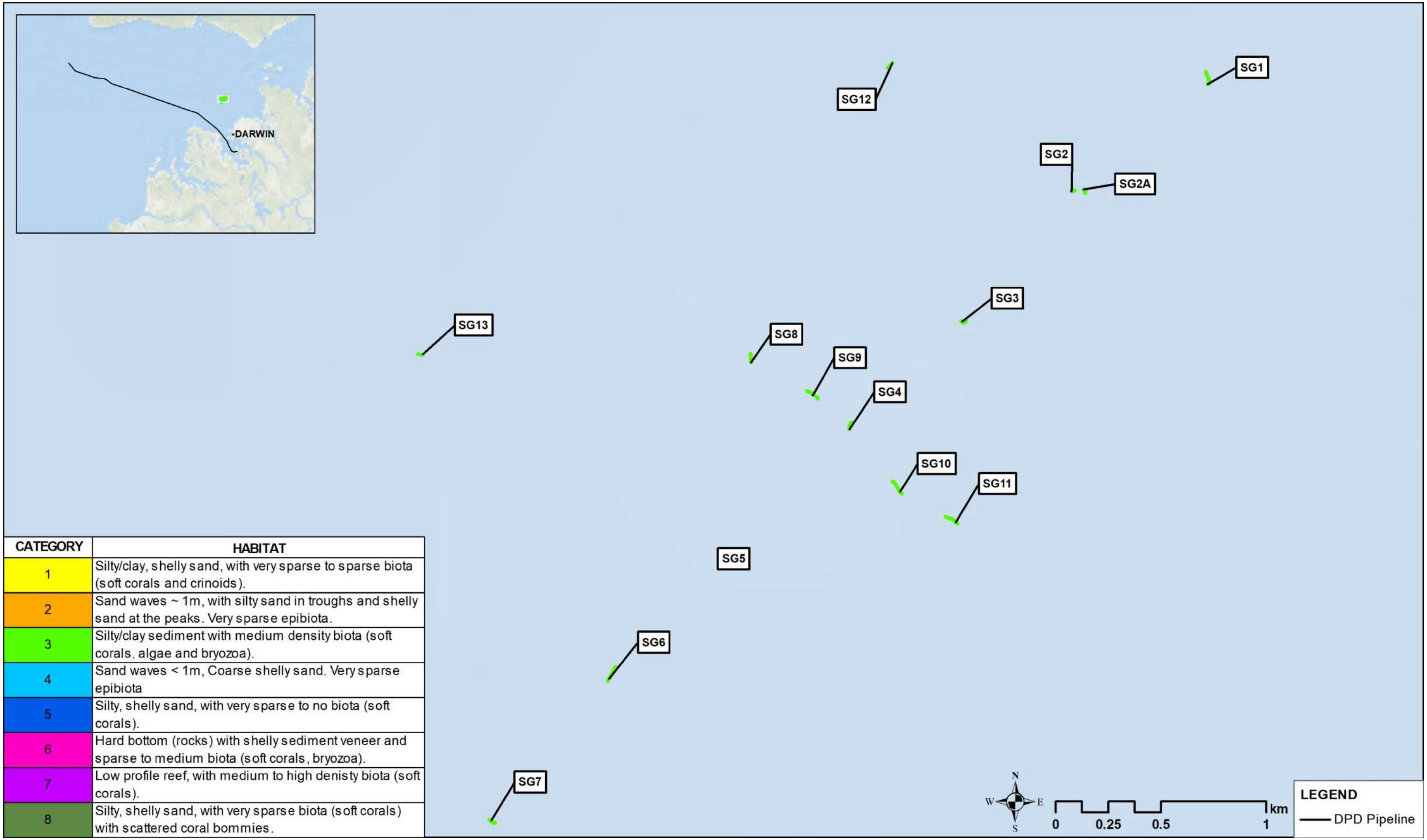


Figure 3-3: Benthic habitat types identified within the spoil ground (October 2021)

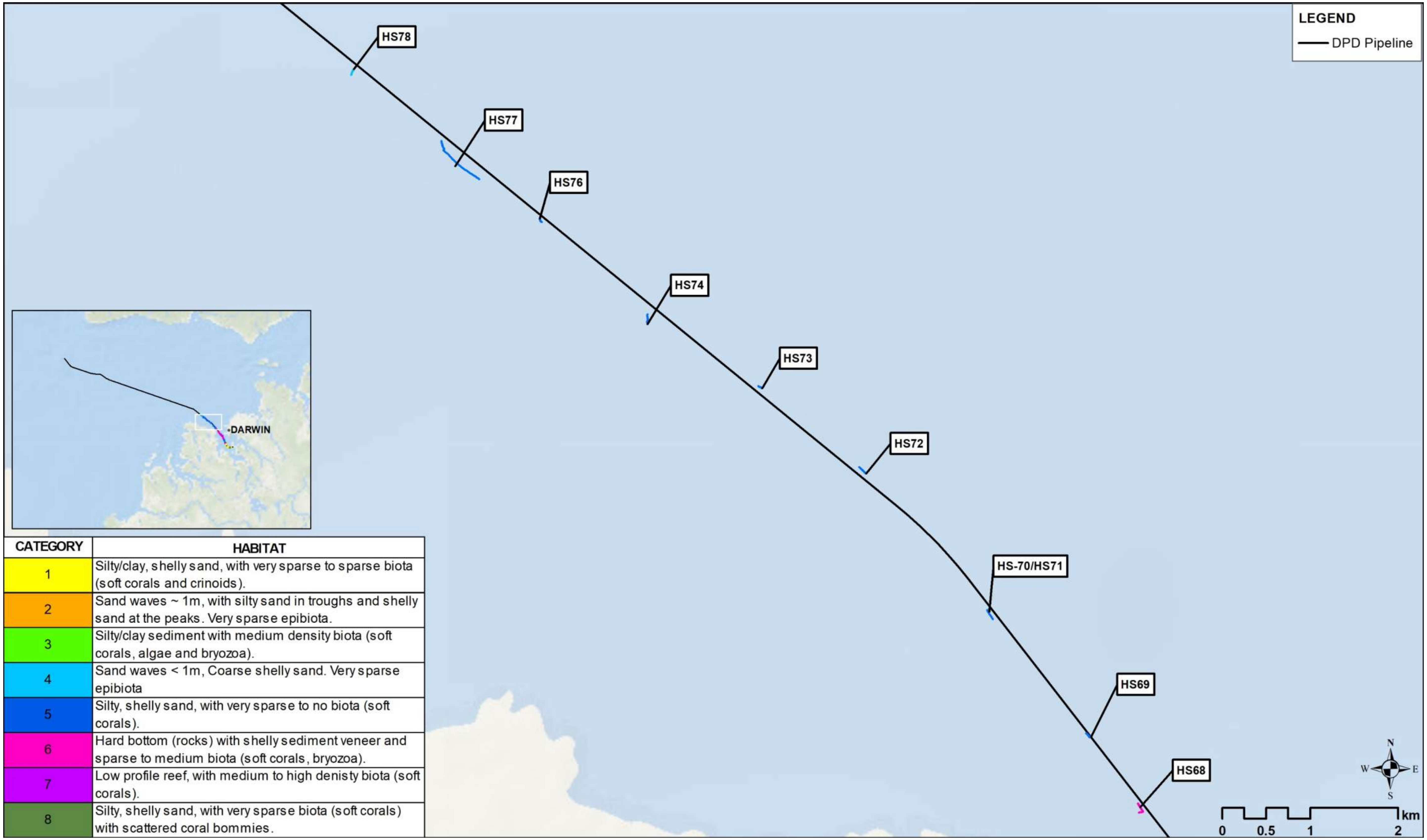
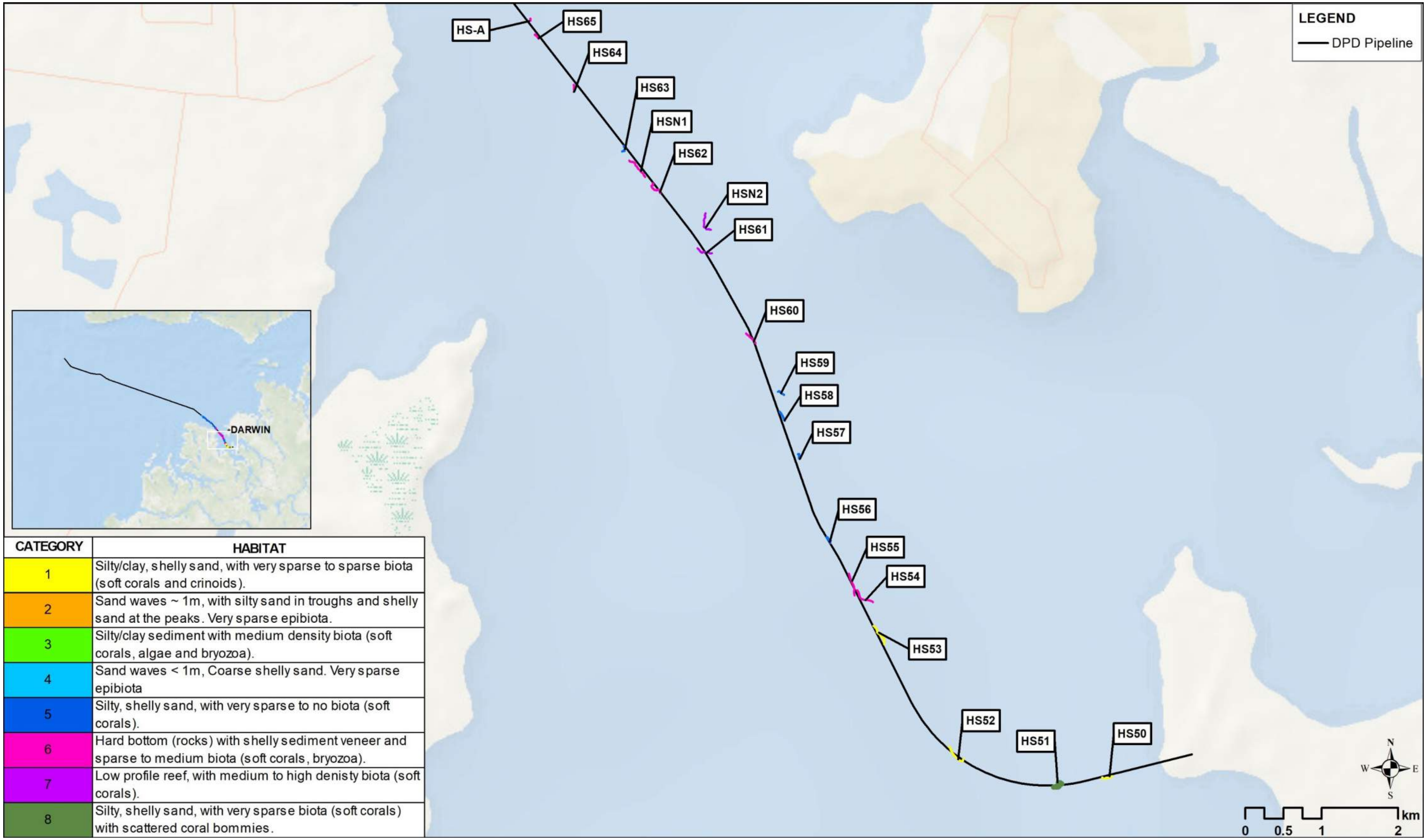


Figure 3-4: Benthic habitat types along the pipeline route in northern Darwin Harbour (October 2021), including the Reef Fish Protection Area



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high denisty biota (soft corals).
8	Silty, shelly sand, with very sparse biota (soft corals) with scattered coral bommies.

Figure 3-5: Benthic habitats along the southernmost section of the pipeline route in Darwin Harbour (October 2021)

3.1.1.1 Soft substrate habitats

3.1.1.1.1 Offshore pipeline

Offshore seabed habitats were characterised by silty/clay shelly sand from KP0 to KP65 (Plate 3-1), with very sparse to sparse conspicuous epibiota (mainly soft corals and crinoids). This soft sediment habitat was identified again at the shoreward end of the pipeline route (near the shore crossing). Biota commonly associated with this habitat type included:

- Soft corals, including gorgonians, sea whips (*Junceella* spp.), Neptheidae and Alcyoniidae (Plate 3-2)
- Echinoderms including sea urchins, sea stars, sea cucumbers and crinoids (Plate 3-3)
- Molluscs, including squid
- Crustaceans including shrimp and the painted pebble crab (*Leucosia anatum*)
- Burrows and polychaete tubes.

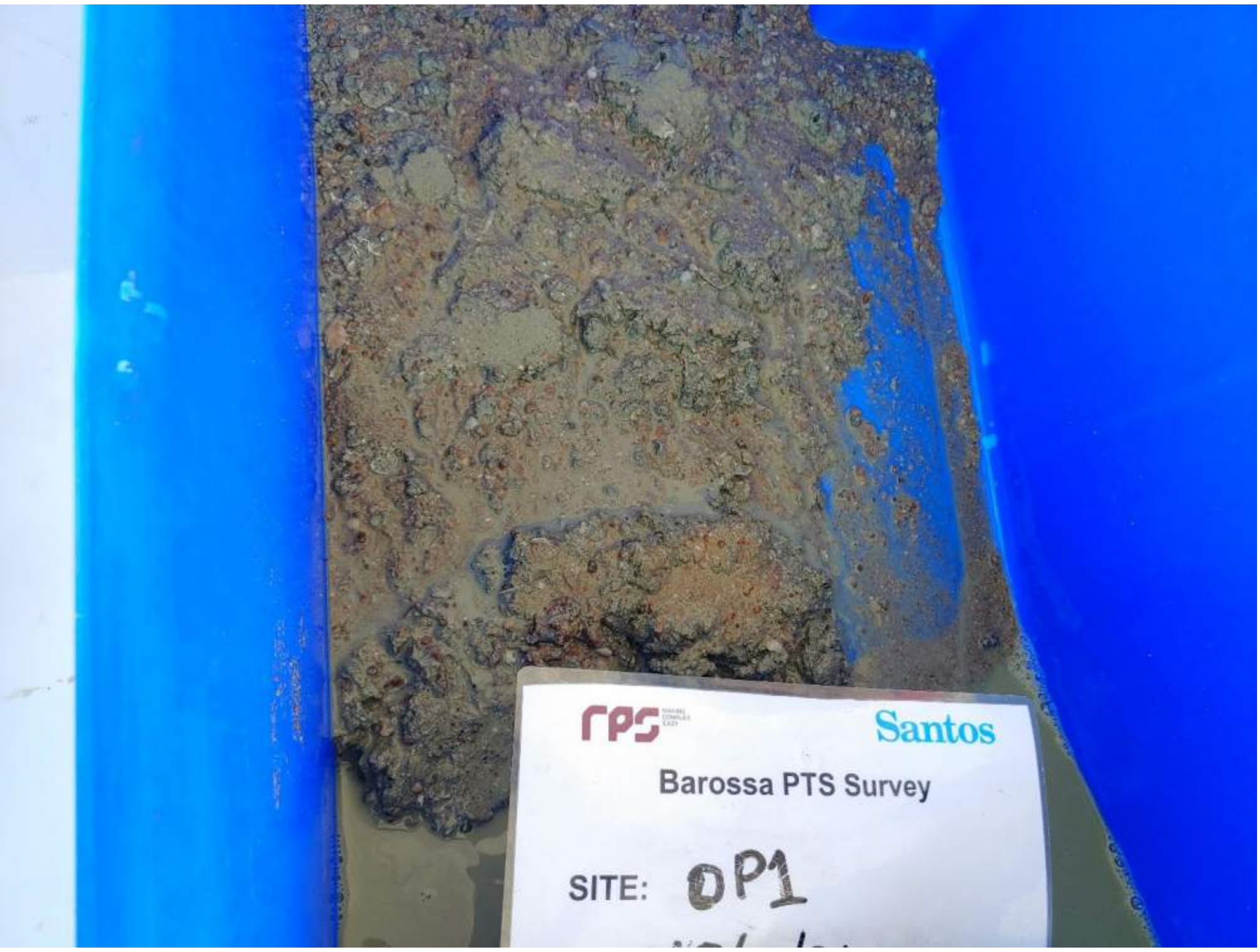


Plate 3-1: Grab sample from site OP1, showing silty shelly sand with clumps of clay

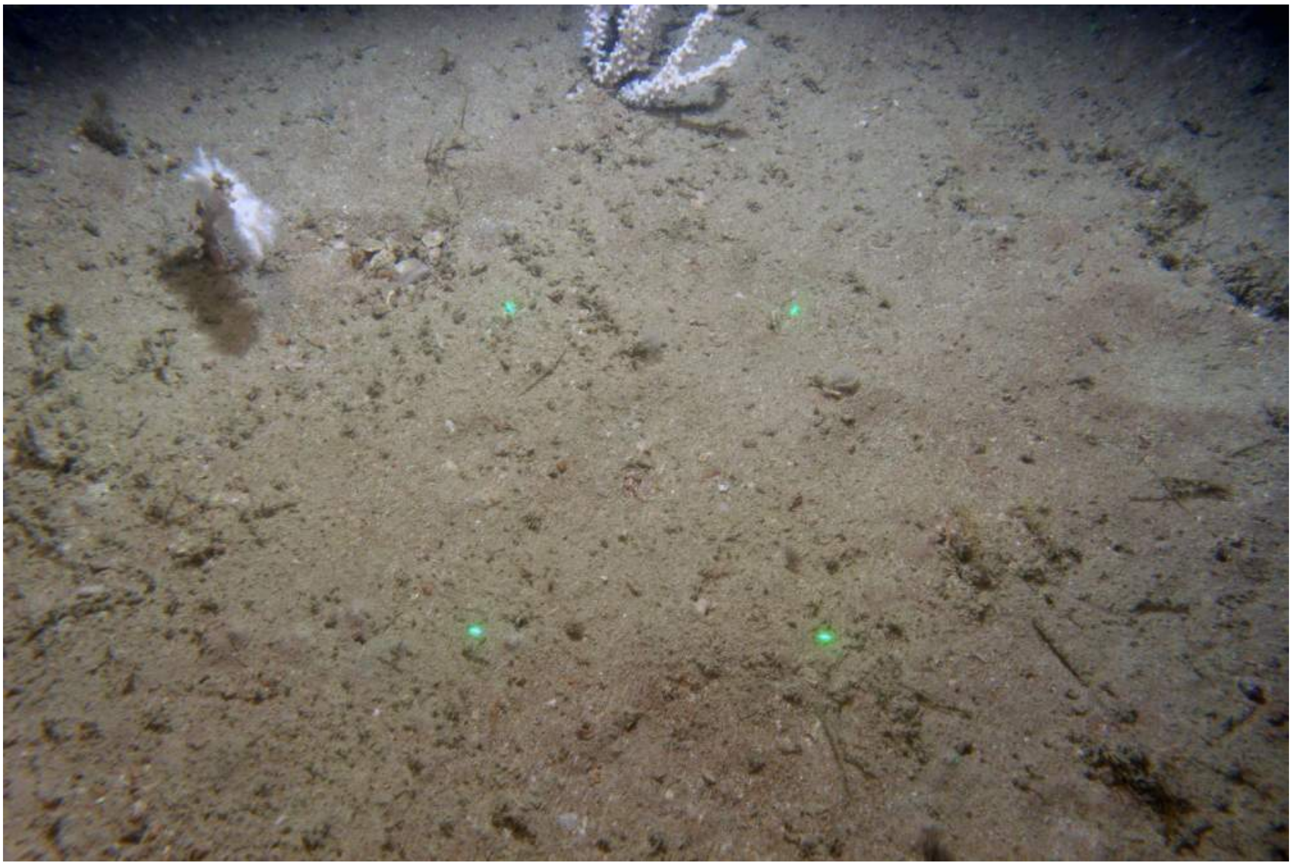


Plate 3-2: Silty, shelly sand with very sparse soft corals (Alcyoniidae) at site OP1

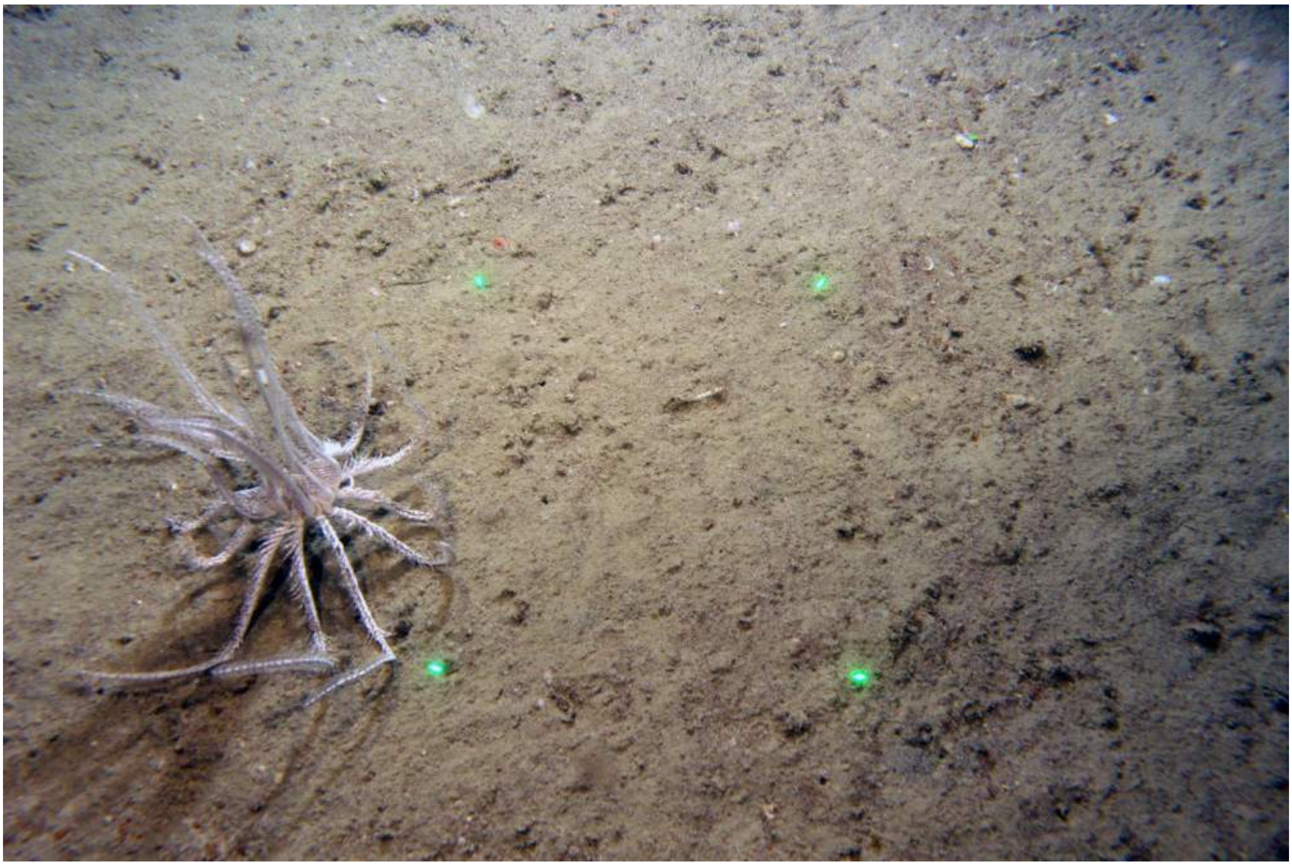


Plate 3-3: Silty/clay sand with a motile crinoid at site V12

Sand waves were recorded at three offshore silty/clay shelly sand sites (V10, V11 and V12), roughly 1 m in height, with silty sand in the troughs and coarse shelly sand at the crests (Plate 3-4). This substrate was associated with very sparse epibiota.

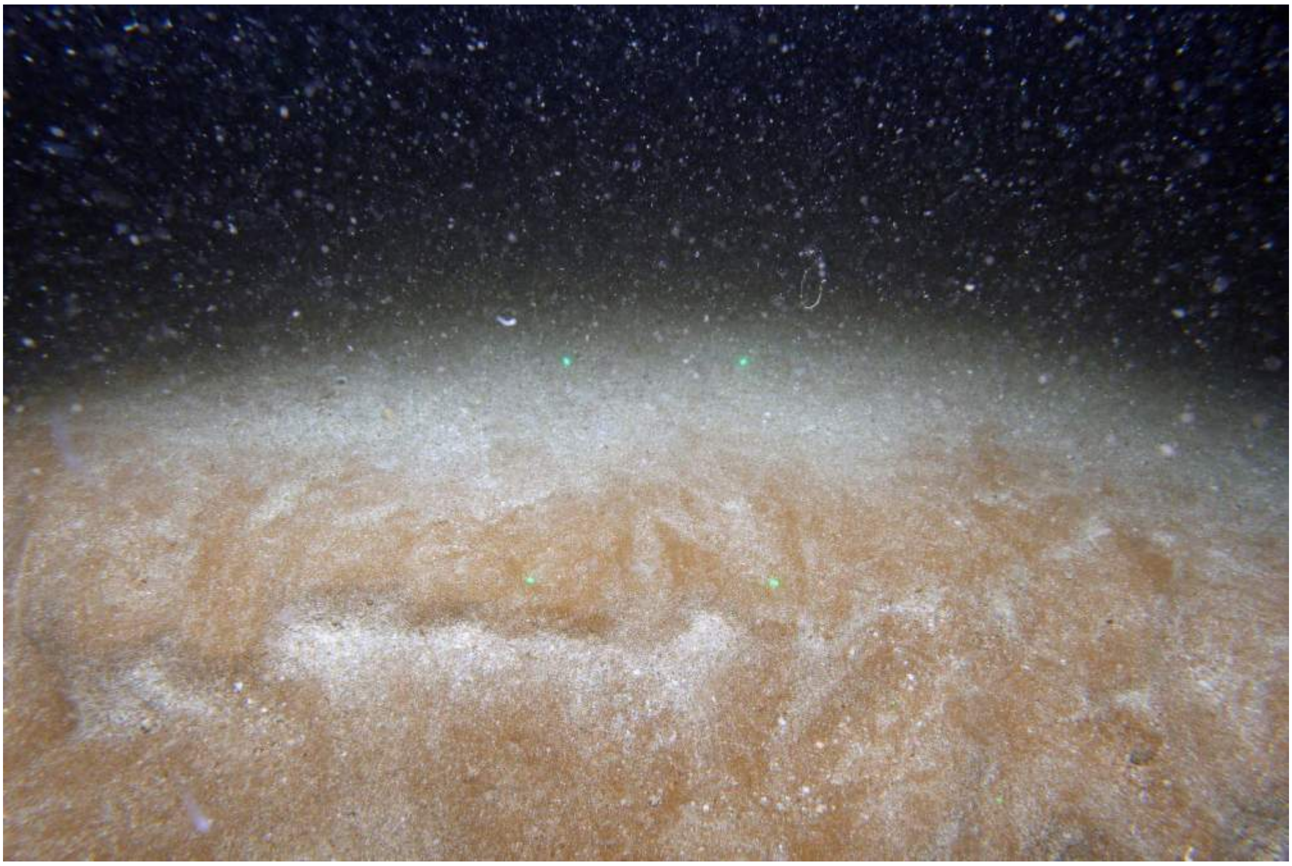


Plate 3-4: Small sand wave at site V11, with coarse, shelly sand at the crest

3.1.1.1.2 Spoil ground

The spoil ground sites all consisted of soft substrate habitat, which was only identified at one other site along the offshore pipeline route (V16). This habitat is defined by silty/clay sediment with medium density biota (soft corals, algae and Bryozoa). Biota commonly associated with this habitat were soft corals (gorgonians, *Junceella* spp. and Alcyoniidae), branching and encrusting sponges, Bryozoa (lace corals), invertebrate burrows, polychaete tubes, brown algae and occasional motile crinoids.

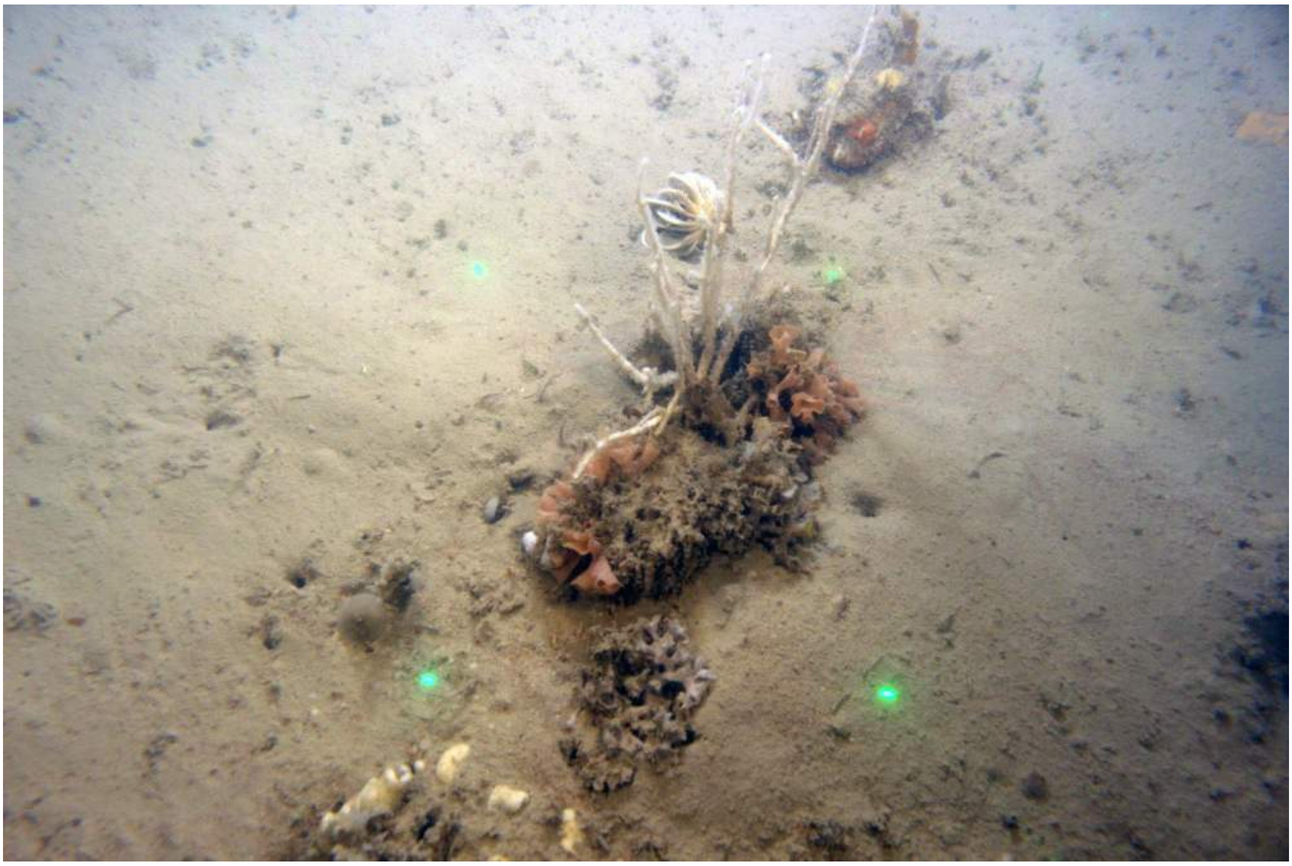


Plate 3-5: Silty/clay sediment with soft corals, Bryozoa (lace coral) and a motile crinoid at site SG10

3.1.1.1.3 Darwin Harbour

There were three main soft substrate habitat types identified in Darwin Harbour. The first comprised coarse shelly sand waves, less than 1 m in height with very sparse epibiota (Plate 3-6). This habitat was only recorded at three sites (HS78, HS79 and HS80), all of which were in the potential sand wave rectification zone at the outer edges of Darwin Harbour (Plate 3-7). While this habitat is very sparse in conspicuous epibiota, grab samples from one of the sites in this area (HS33) retrieved a very high density of hermit crabs (Plate 3-8), with over 100 crabs recorded from each grab.

The most common soft substrate habitat type within Darwin Harbour consisted of silty, shelly sand, with very sparse soft corals to no conspicuous epibiota (Plate 3-9). The epibiota recorded from this habitat included hydroids, occasional soft corals and sea pens (gorgonians, Pennatulacea, *Junceella* spp. and Alcyoniidae), Bryozoa (lace corals), sea urchins and sea stars.

The third habitat identified was a mixed habitat of silty shelly sand, with very sparse biota (soft corals) with scattered bombora was recorded at only one site, HS51 (Plate 3-10). The bombora supported assemblages of hydroids, soft corals (gorgonians), anemone colonies and encrusting sponges.

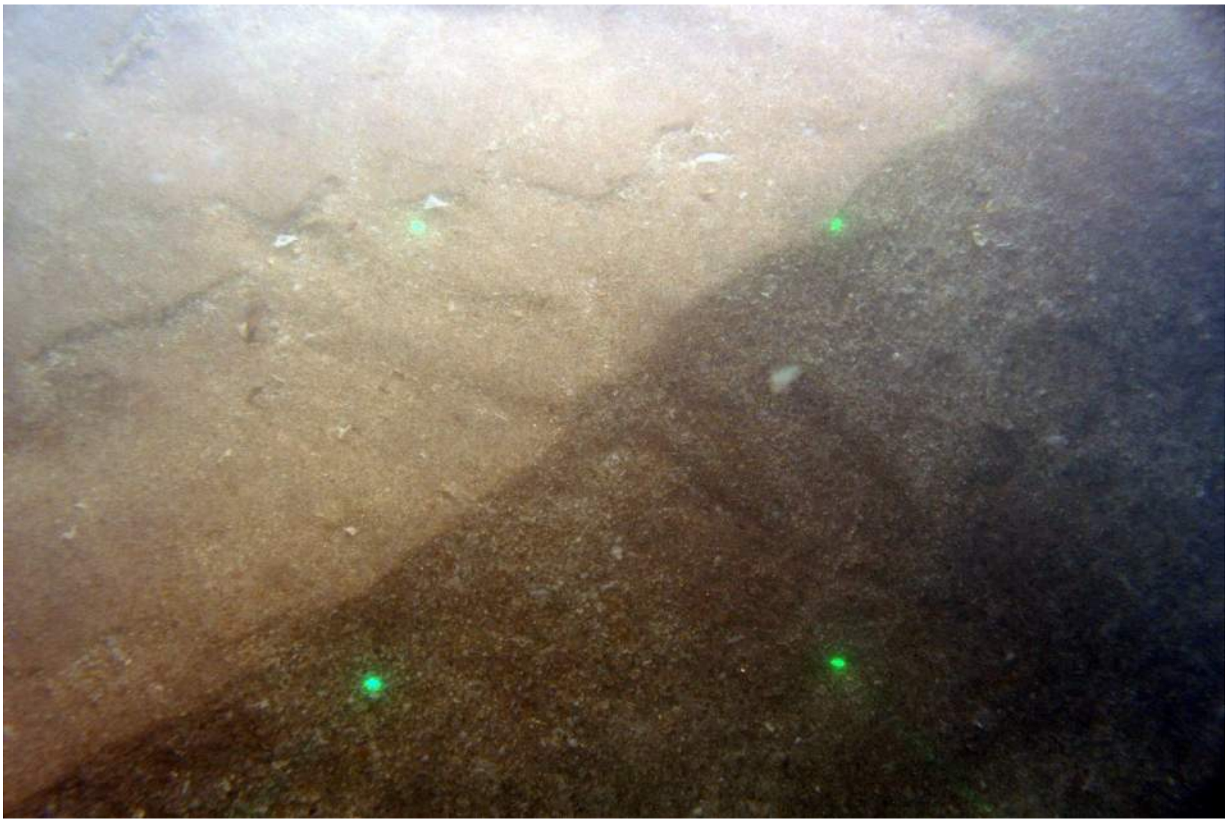


Plate 3-6: Coarse shelly sand waves with very sparse epibiota at site HS78

Plate 3-7: Coarse shelly sand from site HS34, inside the potential sand wave dredging zone at the outer edge of Darwin Harbour

Plate 3-8: Hermit crabs from site HS33

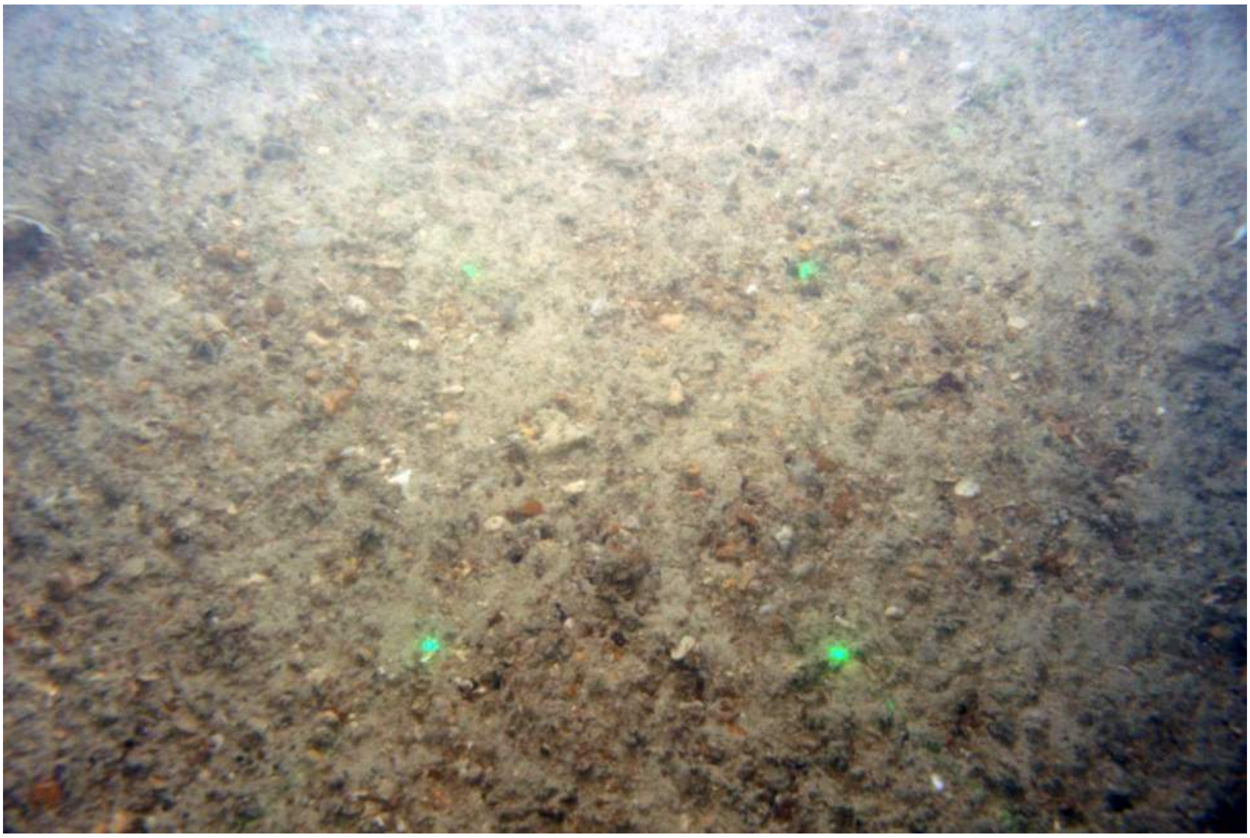


Plate 3-9: Silty shelly sand, with very sparse to no conspicuous epibiota at site HS73

Plate 3-10: Silty shelly sand and part of a bombora supporting assemblages of sponges, anemones and soft corals at site HS51

3.1.1.2 Hard substrate habitats

3.1.1.2.1 Darwin Harbour

The majority of hard substrates were recorded along the section of the pipeline route offshore from Fannie Bay with a number also recorded in the inner harbour. Most of these sites were hard bottom (consolidated rocks) with a shelly coarse sediment veneer and sparse to medium conspicuous epibiota (mainly soft corals and bryozoans) (Plate 3-11). However, low profile reef was recorded at sites HS61 and HSN2, with medium to high density epibiota. The epibiota associated with this habitat type included hydroids, soft corals (gorgonians, *Junceella* spp.), brown algae, bryozoans (lace corals), ascidians, and encrusting, digitate and globular sponges.

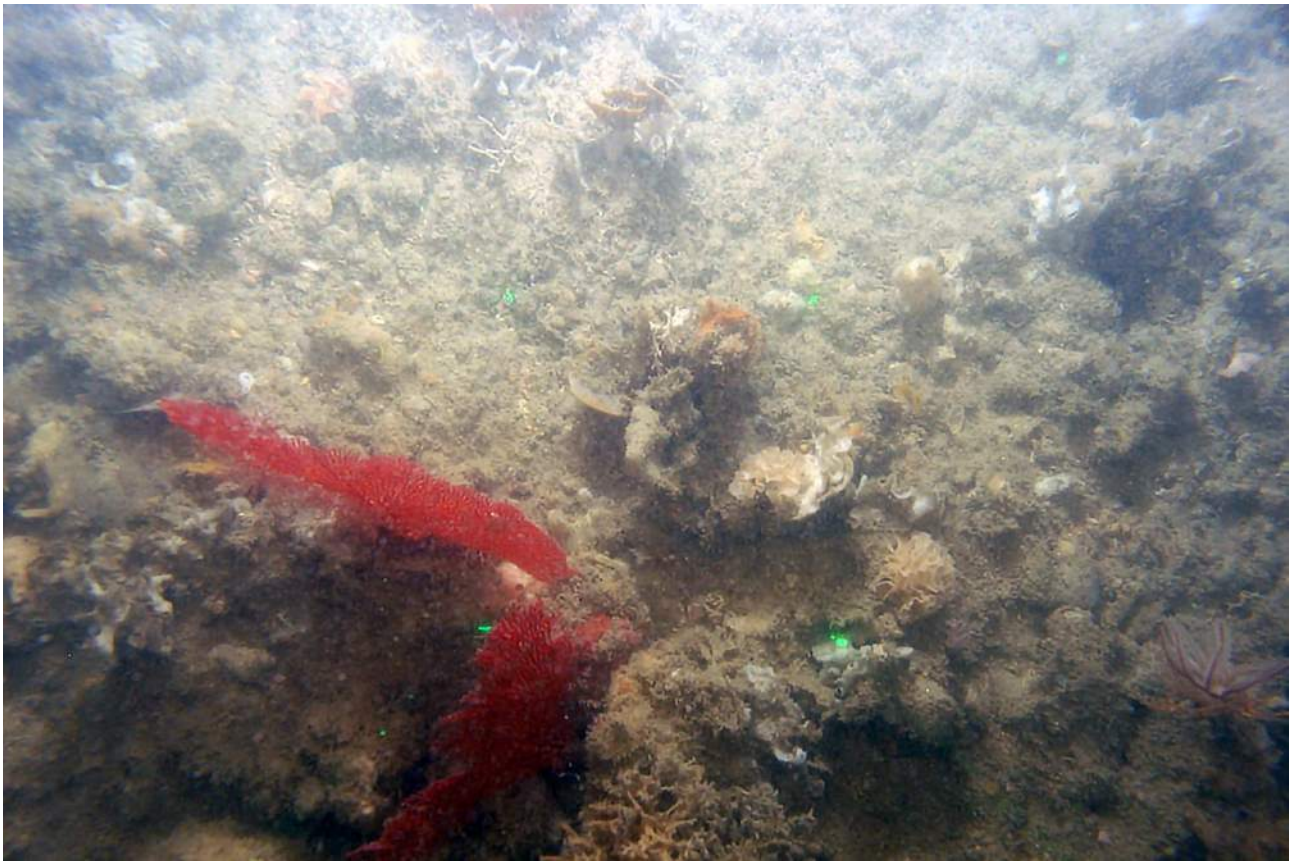


Plate 3-11: Hard bottom (consolidated granite rocks) with a shelly sediment veneer supporting gorgonians and bryozoans (lace corals) at site HS68

Plate 3-12: Low-profile reef with medium density gorgonians and sponges at site HSN2

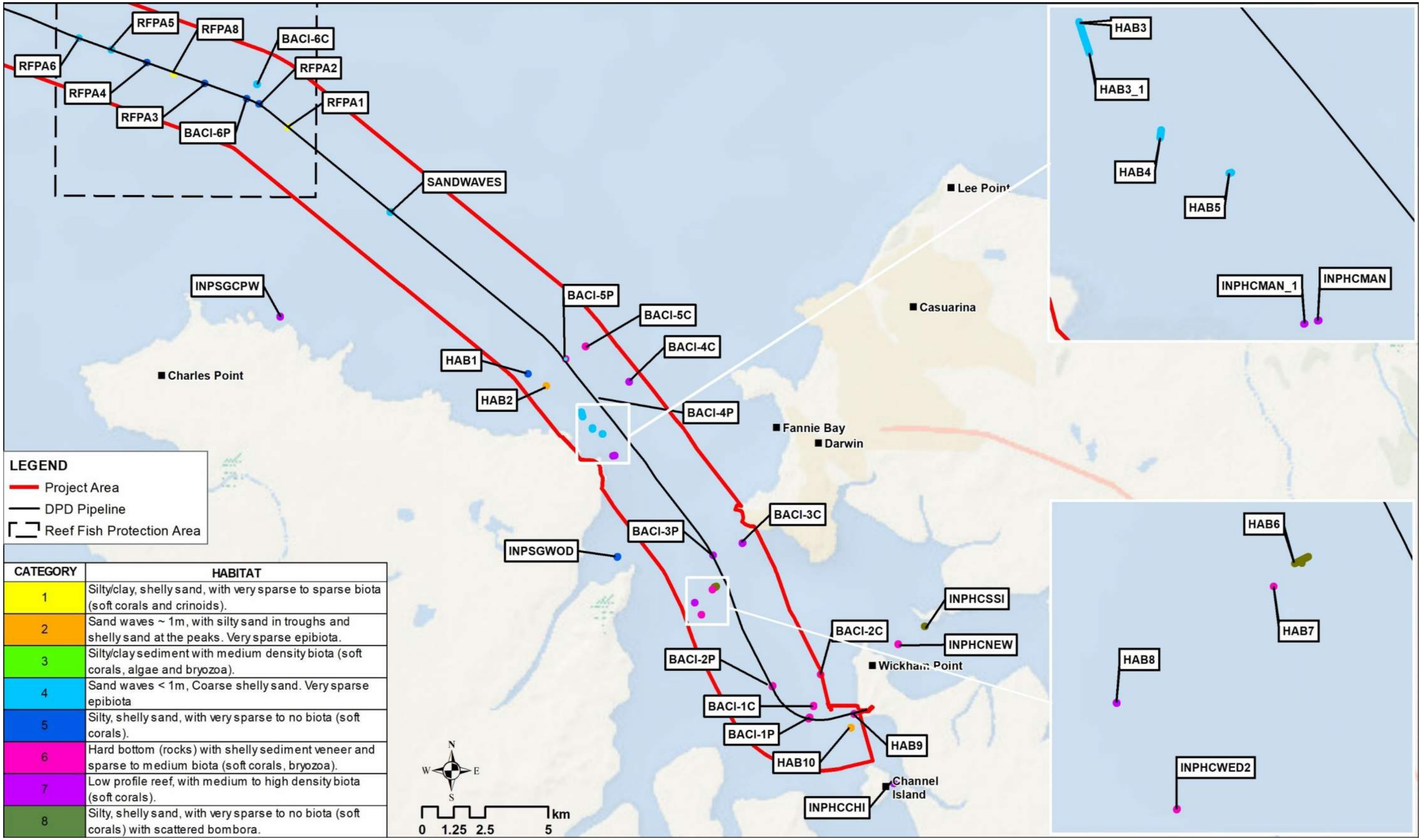
3.1.2 June 2022 survey

The June 2022 showed similar results to the October 2022 video transect surveys. Each site was evaluated in detail, and then sorted into the same broad habitat categories outlined for the October 2021 survey (Table 3-1). The harder substrates were limited to the inner Darwin Harbour and the coastal areas, while the offshore pipeline was dominated by silty sand substrate (Figure 3-6). Epibiota density also increased towards the inner Darwin Harbour, with the densest area surveyed occurring in rocky reefs located outside the project area, in the shallow protected areas of the inner harbour (Figure 3-6). The outer Darwin Harbour had more variation, and represented more of a transitional habitat, containing some area of rocky rubble and increased epibiota density, with large areas of bare silty sand with sparse epibiota (Figure 3-6). Overall, biota density and diversity were greatest in the rocky/hard substrate, which was predominantly located in the inner portions of Darwin Harbour, while the outer/offshore sections of the pipeline consisted mainly of silty to coarse sands.

Table 3-1: Transects conducted in June 2022 survey, describing substrate and predominate biota and the mapping habitat classification

Transect	Substrate	Biota	Mapping habitat classification
BACI_1C	Thin silt/shelly sand veneer over bedrock, some rock and boulders.	Turf with low to medium density epibiota (5–15%); gorgonians (sea fans and sea whips–some with crinoids attached), hydroids. Fish in burrows	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_1P	Rock, boulders, cobbles; broken low relief rock pavement; mixed sediments	Turf with low to medium density epibiota (5–15%); gorgonians (sea fans and whips- some with crinoids attached), sponges (encrusting), hydroids, sea pens). Fish in burrows.	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_2C	Medium sand veneer with gravel, over bedrock	Bioturbation (burrows and mounds), low density epibiota (1–2%); gorgonians (sea whips and fans), sponge (fan)	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_2P	Fine sand veneer, with gravel and some rubble	Bioturbation (fish burrows and mounds), very low density epibiota (<1–2%); soft corals (sea whip, sea fan, sea pen), hydroids	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_3C	Rock reef (medium relief), muddy shelly sand veneer, rocks/boulders	Turf with medium to dense large epibiota (20–70%); sponges (multiple forms: 60% cover), soft corals (sea fans and whips: 20–30% cover), hydroids (<1%), hydroid/bryozoan turf (60–80%)	Low profile reef, with medium to high density biota.
BACI_3P	Rock reef (high relief), muddy shelly sand veneer, rocks/ boulders	Turf with dense large epibiota (40–80%); sponges (multiple forms), soft corals (sea fans and whips). Hydroid/bryozoan turf (40–80%), Fish (big school of snapper, batfish). Areas of shelly sand and rubble with little conspicuous epibiota (<1–2%); hydroids	Low profile reef, with medium to high density biota.
BACI_4C	High profile reef with sediment veneer	Turf with dense large epibiota (40–60% cover); hydroids, sponges (large, with diverse morphologies on reef (up to 60% cover), gorgonians (mainly large sea fans (20% cover) and branching forms with fewer sea whips on reef), hydroid/bryozoan turf (<20%)	Low profile reef, with medium to high density biota.
BACI_4P	Rock, boulders, cobbles; broken low relief rock pavement; mixed sediments	Low density epibiota (5–30% cover). Hydroids and encrusting biota (inc. calcareous tube worms, <1% cover). Hydroid/bryozoan turf (40–100% cover). Rare to low density gorgonians (branching, sea fans: 20–30%) and sponges (tube and burrowing types: <5% cover). Occasional crinoids on larger epibiota.	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_5C	Thin silt/shelly sand veneer over bedrock	Turf and large epibiota; hydroids, sponges (erect forms: 10–20%, low forms <20% cover), gorgonians (sea fans and sea whips rare), hydroid/bryozoan turf (60-80%)	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, Bryozoa).
BACI_5P	Thin silt/shelly sand veneer over bedrock	Turf with low density large epibiota; hydroids, sponges (tubular form: 20%, coned/spherical forms: ~5%, encrusting sponge: 40–60% coverage), gorgonians (sea fans and sea whips; often patchy/rare: <10% coverage), crinoids on sea whips, hydroid/bryozoan turf (70–90%)	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_6C	Fine, rippled sand with rubble	Very sparse epibiota (<1%); soft corals, digitate sponges, brown macroalgae, sea pen, bivalve, hydroids, fish in burrows, octopus. Bryozoan turf (<1%)	Sand waves < 1m, Course shelly sand. Very sparse epibiota.
BACI_6P	Fine sand with rubble	Bioturbation. Low density epibiota (1–5%); Soft corals and gorgonians (1–5%), hydroids (<1%), brown macroalgae (<1–2%), ascidians (<1%), encrusting and digitate sponges (<1%), crinoid, starfish, bryozoan turf (<1%)	Silty, shelly sand, with very sparse to no biota (soft corals).
Fish aggregation site	Rock reef (medium relief), mixed sand veneer, rocks/boulders	Bioturbation, turf and medium density large epibiota (10–40%); soft corals (gorgonians: 10%), crinoids (1–2%), sponges (multiple morphotypes: 5–10%), ascidians, fish (golden snapper, cod, butterflyfish, stingray). Hydroids/bryozoan turf (40–60%)	Low profile reef, with medium to high density biota.
Hab1	Rippled sand, sand bank; sand ridges	Rare, low density soft corals/gorgonians (<1%)	Silty, shelly sand, with very sparse to no biota (soft corals).
Hab2	Rippled sand, sand bank; sand ridges and large sand waves.	Generally, no conspicuous epibiota; except for some very low-density turf epibiota (1–2% coverage) and two soft corals/gorgonians recorded.	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
Hab3	Coarse sand/shell, coarser with increased depth. Sand waves/ripples and large sand ridges, sand bank	Very low-density turf epibiota (1–2% coverage), single branched brown macroalgae and single large burrowing anemone (<1% coverage); rare soft corals (gorgonians: 1–3% coverage). Single crab.	Sand waves < 1m, Course shelly sand. Very sparse epibiota.
Hab4	Medium sand with some gravel. Sand ripples	Rare gorgonians (<1% coverage) and very rare macroalgae (<1% coverage)	Sand waves < 1m, Course shelly sand. Very sparse epibiota.
Hab5	Medium sand with some gravel. Sand ripples	Bioturbation. No conspicuous epibiota.	Sand waves < 1m, Course shelly sand. Very sparse epibiota.
Hab6	Mobile sediments, reef (high and low relief) and patchy rock	Turf (40–50% cover) and large epibiota on bedrock (10–15%); hydroids, sponges (multiple forms), gorgonians (sea fans and sea whips), anemones, hydroid/bryozoan turf, hard coral (1–5%)	Silty, shelly sand, with very sparse biota (soft corals) with scattered bombora.
Hab7	Patchy rock (occasional high relief ridges and outcrops) with thick coarse sediment veneer	Dense turf (60% cover) and moderate density large epibiota on bedrock (15–20% cover); hydroids, sponges (multiple forms), soft corals and gorgonians (sea fans and sea whips), hard coral (10–20% cover), hydroid/bryozoan turf (60% cover), starfish, bivalve	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Hab8	Patchy rock (frequent high relief ridges and outcrops) with thick coarse sediment veneer	Dense turf (70% cover) and dense large epibiota on bedrock (20–60% cover); hydroid/bryozoan turf (10–50%), sponges (branching: 5–20%; encrusting: 30–65%; burrowing: 5%; stalked: 5–10%; tubular: 3–5%), hard coral (5–10%), echinoderm (sea star), gorgonians (3–5%), macroalgae (green 1–7%; brown <2%), fish	Low profile reef, with medium to high density biota (soft corals).
Hab9	Sand veneer with patches of rocks	Bioturbation (mounds and burrows). Low to medium density large epibiota (5–40%); soft corals (gorgonian fans: 1–2%), anemones, brown macroalgae (20%), sponges (multiform: 10–20%)	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Hab10	Shelly coarse sand, large/wide sand waves	Bioturbation (burrows and mounds), little conspicuous epibiota- crinoids and soft coral (sea whips) (<1%), hydroid (1–2%), crab	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
Heritage_147	Thin silt/sand veneer over bedrock (areas of high relief); Areas of low relief flat bedrock	Dense turf and diverse large epibiota (40–60%); holes lined with stones; Lots of gorgonians (40%), some with crinoids. Schools of fish.	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Heritage_031	Rock with boulders and sediment veneer; change to thicker rippled sand veneer with exposed cobbles and epibiota	Medium density epibiota (20–50%); sponges (fans) and soft corals (sea fans), bryozoa turf (30–60%); less (patchier) epibiota (10–30%) on rippled sand; soft coral (sea whip), burrowing sponges, hydroids/bryozoans	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).

Transect	Substrate	Biota	Mapping habitat classification
Hertage_241	Rock with boulders and sediment veneer; depression	Low density sea fans (1–2%), tube and burrowing sponges, gorgonians, dense bryozoa turf (70%)	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
INPHCCHI	Low profile rocky reef, with thin shelly sediment veneer	Medium density epibiota (20–60%); brown algae (5–10%), hard corals (encrusting, foliose, massive: 10–50%), soft corals (sea fans and whips: 5–10%), sponge (multiple forms: 10–30%). Bryozoan turf (20–40%)	Low profile reef, with medium to high density biota.
INPHCNEW	Rock with patchy sand veneer	Low to medium density epibiota (20–60%); large soft corals (sea whips, fans: 2–10%) and sponges (diverse morphotypes: 10–40%), hard coral (encrusting: 1–5%) anemone, fish (butterflyfish, wrasse).	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
INPHCMAN	Low to medium profile rocky reef, with thin shelly sediment veneer	Turf with medium to high density large epibiota (30–60%); sponges (multiple forms: 5–40%), soft corals (gorgonian fans and sea whips: 1–10%), hydroids (<1–15%), Bryozoan turf (40–70%)	Low profile reef, with medium to high density biota.
INPHCMAN_1	Low to medium profile rocky reef, with thin shelly sediment veneer	Turf with medium to high density large epibiota (40–80%); sponges (multiple forms: 5–40%), hard corals (1–10%), soft corals (gorgonian fans and sea whips: 1–20%), hydroids (<1–15%). Bryozoan turf (40–70%)	Low profile reef, with medium to high density biota.
INPHCSSI	Fine sediment with patchy/scattered rocks	Bioturbation. Areas with no conspicuous epibiota. Patches of low to high density epibiota (20–80%); soft corals (10–20%), sponges (multiple morphotypes: 10–30%), gorgonians, hard coral (encrusting and massive: 20–60%), brown (10–60%) and green macroalgae (inc. *Halimeda* spp) (1–5%), ascidians, anemone, bivalves fish (wrasse, pufferfish, butterflyfish, shark (whaler sp. or Bull shark) Bryozoan turf (20–60%)	Silty, shelly sand, with very sparse to no biota (soft corals) with bombora.
INPSGCPW	Bedrock (inc. medium relief reef) with coarse shelly sand veneer (occasional rippled sand); scattered bombora; low relief reef	Bioturbation. Medium to high density epibiota (20–80%); coral (inc. plate, foliose, encrusting and massive corals: 40–90%). Gorgonians (fans and whips: 1–5%), ascidians, *Halimeda* spp. (green macroalgae: 2–10%), patchy coral, sponges (digitate and basket), fan worm. turf (10–30%). No conspicuous epibiota on rippled sand areas	Low profile reef, with medium to high density biota.
INPHCWED2	Fine sand veneer, some rubble and small rocks	Bioturbation, turf and low density epibiota (1–40%); soft corals (sea whips:1–5%) and sponges (multiple forms: 1–15%), hard coral (plate, encrusting: 1–30%), brown macroalgae (20–40%), green macroalgae (*Halimeda spp.* 1–2%), bryozoan turf (10–30%). Fish (snapper, wrasse, damselfish)	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
INPHCWOD	Rippled coarse sand, occasional shelly rubble	Bioturbation (large, deep burrows and large mounds), Low density seagrass (possibly *Halodule spp.*: 5–15%) along entire transect	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA1	Fine sediment with small rubble/rock	Bioturbation. Often no conspicuous epibiota. Hydroids (1–2%), soft corals (<1%), starfish, tubeworm, fish (blenny or goby)	Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
RFPA2	Fine sand veneer, some rubble and small rocks	Bioturbation. Low density epibiota (1–10%); Soft corals (1–5%), sponges (encrusting, digitate and branching: 1–5%), ascidians, crinoids, hydroids (1–2%), bryozoan turf (20–80%), starfish	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA3	Fine sand with scattered rocks and rubble	Bioturbation. Low density epibiota (1–15%); ascidians, crinoids, sponges (digitate and branching:1–5%) soft corals (fans and sea whips: 1–10%), white ascidians (patches: <1–5%), crinoids (<1–2%)	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA4	Mainly fine sand with occasional coral rubble	Bioturbation. Low density epibiota (<1–10%); soft corals (sea fans and whips), sponges (encrusting and branching), crinoids	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA5	Coarse, shelly rippled sand, sand waves	Areas of no conspicuous epibiota, bioturbation, fish; very low density/patchy epibiota (<1–2%); soft corals, macroalgae, hydroids, crinoids, sponges	Sand waves < 1m, Course shelly sand. Very sparse epibiota.
RFPA6	Coarse, shelly rippled sand, sand waves	Bioturbation; low density/rare epibiota (<1–5%); soft corals, hydroids, brittle star, starfish, macroalgae, crinoid, stingray, tube worms, blennies.	Sand waves < 1m, Course shelly sand. Very sparse epibiota.
RFPA8	Fine sediment, occasional rock	Bioturbation. Low density epibiota (<1–5%); soft corals (gorgonians: <1–2%), sponges (branching and encrusting), hydroids (1–2%), ascidians, nudibranch, starfish, brown macroalgae (1–2%), sea pens	Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
Sand waves	Rippled coarse shelly sand; sand waves; occasional coral rubble	Mainly no conspicuous epibiota; sparse soft corals (<1%), ascidians, crinoids (1–2%), polychaete tubes	Sand waves < 1m, Course shelly sand. Very sparse epibiota.



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high density biota (soft corals).
8	Silty, shelly sand, with very sparse to no biota (soft corals) with scattered bombora.

Figure 3-6: Benthic habitats along the proposed Barossa GEP pipeline, including outer pipeline, outer Darwin Harbour and inner Darwin Harbour survey sites (June 2022), including the Reef Fish Protection Area

3.1.2.1 Offshore pipeline

Similar to the October 2021 survey, the offshore seabed habitats were characterised by silty shelly sand from RFPA1 to RFPA8, including BACI_6C/P and Sand waves (Plate 3-13), with very sparse to sparse (1–5% coverage) epibiota (mainly soft corals, crinoids and sponges). Courser patches of sand where also observed in the outer offshore pipeline region. Areas of soft silty and shelly sand were also observed in the inner portions of Darwin Harbour, and near Wickham Point. Biota commonly associated with this habitat type included:

- Soft corals, including gorgonians, sea whips (*Junceella* spp.), Neptheidae and Alcyoniidae
- Sponges, including digitate and branching
- Echinoderms including sea urchins, sea stars, sea cucumbers and crinoids
- Crustaceans including shrimp
- Burrows and polychaete tubes.

Plate 3-13: Silty shelly sand with sparse soft corals at RFPA3

3.1.2.2 Outer Darwin Harbour

The outer Darwin Harbour region represented a transition between hard and soft substrates. Sites Hab1–Hab5 were located just on the opening of Darwin Harbour with substrate ranging from rippled sand to medium sand with gravel toward the harbour opening. These sites had epibiota less than 1% coverage, consisting mainly of sparse anemone, soft corals and macroalgae (Plate 3-14). The further south sites, such as INPHCMAN, had rockier substrate and increased epibiota (Plate 3-15). This region was dominated by sponges (diverse morphotypes), soft corals, macroalgae, echinoderms with some fish and crustacean presence.

Plate 3-14: Rippled course shelly sand with no to very sparse epibiota at Hab3

Plate 3-15: Rocky reef with medium to high density epibiota, including large soft corals (gorgonian fans and sea whips), hydroids, sponges (multiple morphotypes) and occasional hard coral at INPHCMAN

3.1.2.3 Inner Darwin Harbour

The inner portions of Darwin Harbour consisted of mainly hard rocky substrates, other than sites near Wickham Point. Hab6-Hab8 had increasingly rocky substrate and increasing biodiversity and epibiota density, similar to INPHCMAN (Plate 3-15), while Hab-9-Hab10 had decreasing epibiota density and increased potions of silty mobile sand towards Whickham Point (Plate 3-16). The sites located outside of the project area in the shallower protected areas of Darwin Harbour boasted the greatest epibiota densities and diversity, including sponges, soft and hard corals, echinoderms and schools of fish (Plate 3-17).

Plate 3-16: Coarse shelly sand with sparse epibiota and moderate bioturbation at Hab10

Plate 3-17: Rocky reef with diverse sponges, soft and hard corals, macroalgae and fish at INPHCCHI

3.2 Sediment quality

3.2.1 Offshore pipeline

3.2.1.1 Particle size distribution

Laboratory PSD results can be found in Appendix D. The data were analysed to characterise sediment samples in terms of Wentworth size classifications, which classify particle size into total clay (0-4 µm), total silt (4–63 µm), total sand (63–2000 µm) and total gravel (>2000 µm) (Table 3-2).

The offshore pipeline route was predominantly sand. The northern end of the pipeline route was gravelly silty sand, which became less gravelly and much siltier, with higher proportions of clay, towards the eastern end of the offshore pipeline route (Figure 3-7). The westernmost site (OP1) had 9.29% silt and 16.2% gravel, compared with the southernmost site (OP30) which had 39.22% silt and 0.28% gravel (Table 3-2). Proportions of clay in the sediment ranged from 1.86% at OP9, to 7.03% at OP30.

Table 3-2: Sediment particle size characteristics along the offshore pipeline route (from west (OP1) to Darwin Harbour limits (OP30)

Site	Total% clay (0–4 µm)	Total% silt (4–63 µm)	Total% sand (63–2000 µm)	Total% gravels (>2000 µm)
OP1	2.92	9.29	71.59	16.20
OP2	1.99	6.57	62.85	28.58
OP3	3.45	11.58	43.23	41.73
OP4	1.87	6.46	74.52	17.15
OP5	2.23	7.30	63.21	27.27
OP6	2.30	7.50	50.88	39.32
OP7	2.56	8.60	73.60	15.24
OP9	1.86	6.55	62.04	29.55
OP10	2.51	8.25	69.95	19.29
OP11	2.73	8.68	64.24	24.36
OP12	2.48	8.41	43.57	45.53
OP13	2.37	7.43	67.80	22.40
OP14	2.83	8.30	71.35	17.53
OP15	2.57	8.04	73.63	15.76
OP16	3.54	10.26	64.94	21.26
OP17	2.19	6.41	77.29	14.12
OP18	4.43	11.67	73.36	10.54
OP19	2.34	6.88	78.28	12.49
OP20	3.95	11.77	79.06	5.22
OP21	2.95	10.10	79.79	7.16
PTS-57.5-GS	3.43	11.11	76.09	9.36
OP22	3.07	9.49	66.71	20.72
PTS-62.5-GS	3.62	11.23	74.71	10.45
PTS-64.0-GS	3.29	10.23	66.40	20.09
OP23	5.32	14.11	61.18	19.38
OP24	2.33	7.66	54.83	35.19
OP25	5.42	16.78	72.35	5.45
OP26	5.03	17.16	73.39	4.42
OP27	6.77	22.88	61.48	8.88
OP28	5.86	22.38	60.57	11.19
OP29	6.03	25.18	57.40	11.39
OP30	7.03	39.22	53.47	0.28

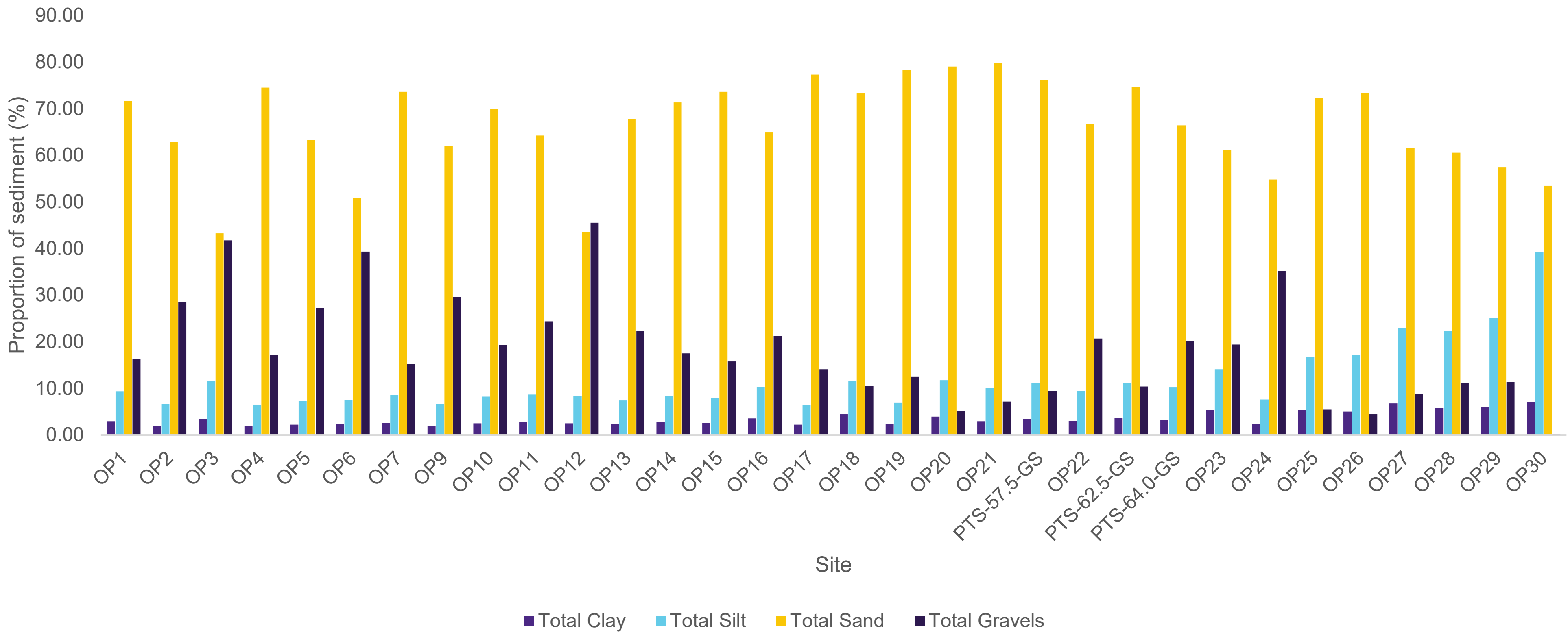


Figure 3-7: Sediment sample particle size characteristics along the offshore pipeline route

3.2.1.2 Infauna

A total of 744 individuals from ten phyla were recorded from the 29 offshore pipeline samples analysed. The dataset was dominated by crustaceans (350 individuals) and annelids (polychaete worms; 313 individuals). Crustaceans were the most abundant phylum at 16 of the 29 OP sites (55.2%), with Annelids the most abundant phylum at the other 13 sites (44.8%). The next most numerous phyla were an order of magnitude lower in abundance (Sipuncula, Echinodermata, Mollusca and Chordata, represented by 32, 23, ten and eight individuals, respectively). The remaining phyla, Brachiopoda, Cnidaria, Echiura, and Porifera, were only represented by doubletons (i.e. two individuals per phyla). The full dataset can be found in Appendix E.

Descriptive statistics of infaunal community data describing the number of species (S), abundance (N), Margalef's species richness (d), Pielou's evenness (J'), Shannon-Weiner diversity (H') and Simpson's alpha diversity index (1-λ) are presented in Table 3-3. All metrics were lowest at site OP30 (three individuals from one taxa). The number of species, Margalef's species richness and Shannon-Weiner diversity were greatest at site OP9 (39 individuals from 26 taxa). Abundance was greatest as site OP15 (n = 53), and Pielou's evenness and Simpson's index were greatest at sites OP25 and OP26 (J' = 1, 1- λ = 1).

Table 3-3: Descriptive statistics of offshore pipeline (OP) infaunal data

Site	Species (S)	Abundance (N)	Margalef's species richness (d)	Pielou's evenness (J')	Shannon-Weiner diversity (H')	Simpson's alpha diversity index (1-λ)
OP01	19	42	4.816	0.886	2.609	0.9233
OP02	22	48	5.425	0.9187	2.84	0.9468
OP03	13	20	4.006	0.9584	2.458	0.9526
OP04	24	33	6.578	0.9812	3.118	0.983
OP05	15	22	4.529	0.9465	2.563	0.9524
OP06	23	31	6.407	0.95	2.979	0.9677
OP07	26	46	6.53	0.9066	2.954	0.9372
OP09	28	49	6.938	0.9461	3.152	0.9677
OP10	18	23	5.422	0.9805	2.834	0.9802
OP11	16	22	4.853	0.9699	2.689	0.9697
OP12	22	29	6.236	0.9753	3.015	0.9803
OP13	14	24	4.091	0.9293	2.453	0.9348
OP14	22	39	5.732	0.9609	2.97	0.9676
OP15	24	53	5.793	0.8825	2.805	0.9238
OP16	19	26	5.525	0.9661	2.845	0.9723
OP17	26	48	6.458	0.9439	3.075	0.9654
OP18	18	24	5.349	0.9796	2.831	0.9783
OP19	13	18	4.152	0.9654	2.476	0.9608
OP20	8	9	3.186	0.9826	2.043	0.9722
OP21	9	10	3.474	0.9849	2.164	0.9778
OP22	14	17	4.588	0.9692	2.558	0.9706
OP23	14	17	4.588	0.95	2.507	0.9559
OP24	24	49	5.91	0.8758	2.783	0.9175
OP25	8	8	3.366	1	2.079	1
OP26	4	4	2.164	1	1.386	1
OP27	6	7	2.569	0.9755	1.748	0.9524
OP28	13	16	4.328	0.9796	2.513	0.975
OP29	6	7	2.569	0.9755	1.748	0.9524
OP30	1	3	0	††	0	0

Cluster analysis of with Similarity Profiles (SIMPROF) of offshore pipeline infauna data indicated that sites were clustered into three significant groupings with three outliers, which were 'groups' A to C (sites = OP30, OP20 and OP25; Figure 3-8).

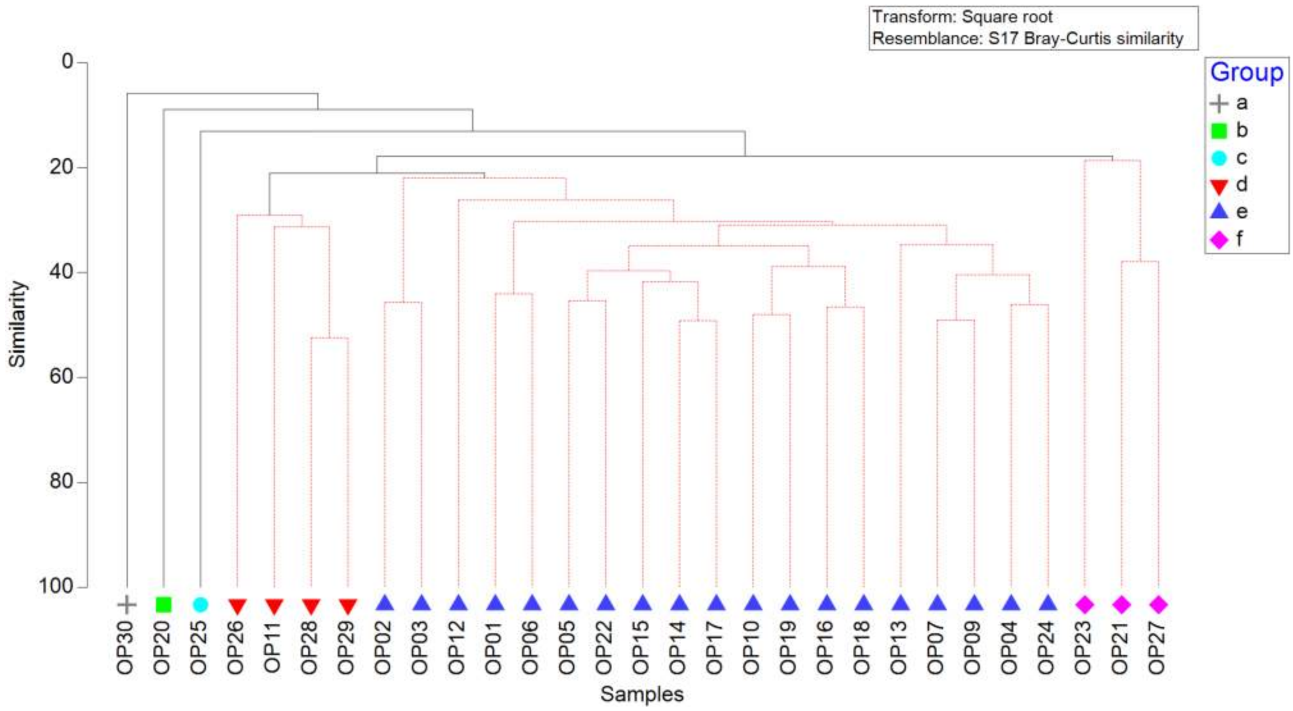


Figure 3-8: Offshore pipeline infaunal SIMPROF cluster groups

Group D – sites OP11, OP26, OP28 and OP29

This group was dominated by Anthuridea (elongate isopod crustaceans) and polychaete worms (*Eunice* sp., *Axiothella* sp. and *Nepthys* sp.). The average abundance of these taxa are higher than, e.g. group F, which is likely due to a greater range of particle sizes in the substrate, as indicated by the dominance of Anthuridea, which live in crevices, empty calcareous worm tubes or structurally complex epibiota. Review of the particle size data (Section 3.2.1.1) indicated sediment at these sites had a higher % gravel component, but also a higher silt component than Group F.

Group E – sites OP1 to OP7, OP9, OP10, OP12 to OP19, OP22, OP24

Group E was characterised by a much more diverse community, with 30 taxa comprising the top 90% of taxa characterising the biological assemblage (as opposed to four and five taxa for Groups D and F, respectively). The crustaceans (mainly amphipods, tanaids and isopods) and polychaetes (mainly deposit-feeding tube worms and free-living taxa) were the dominant taxa, with echinoderms (Ophiuroidea) and sipunculids also represented. Group E was the coarsest sediment in terms of particle size, and with the lowest silt/clay component which would have provided a more complex substrate and potentially better sediment oxygenation in surficial sediments.

Group F – sites OP21, OP23 and OP27

This group was dominated by brittlestars (Ophiuroidea) and polychaetes (*Lumbrineris* sp., spionids, *Nephtys* sp. and *Axiothella* sp.). These taxa are generally surface deposit feeders and/or carnivores/scavengers, with several capable of interface feeding (switching between e.g. deposit feeding and suspension/filter feeding), which is a trait often associated with harsh or nutrient-poor environments, such as the fine or sandy sediments these taxa inhabit.

3.2.1.3 Metals

The metals and metalloid concentrations for all sites (see Appendix G) were compared to the NAGD screening levels (CoA, 2009). Of the metals and metalloids in the sediments sampled from offshore pipeline route; only mercury was below the LoR for all sites.

Aluminium concentrations were all above the LoR and ranged from 3,500 to 12,000 mg/kg. There is no NAGD screening level for aluminium in marine sediments.

Arsenic concentrations were all above the LoR and ranged from 7 mg/kg to 35 mg/kg. There were 13 sites that had arsenic concentrations above the NAGD screening level of 20 mg/kg but were below the Sediment Quality Guideline (SQG)-High value of 70 mg/kg. Most of these sites were towards the western end of the offshore pipeline (Figure 3-9).

Barium concentrations were all above the LoR and ranged from 5.5 to 13 mg/kg, except for one outlier site (OP19) which had a barium concentration of 81 mg/kg. This outlier is potentially an error and was removed from the graphs. Barium concentrations were higher at the southern end of the offshore pipeline route (towards Darwin Harbour) (Figure 3-9). There is no NAGD screening level for barium in marine sediments.

Cadmium concentrations were all above the LoR, except for oner site (OP27). Concentrations were relatively consistent along the offshore pipeline route and ranged from <0.1 to 0.3 mg/kg. All sites had cadmium concentrations below the NAGD screening level of 1.5 mg/kg (Figure 3-9).

Chromium concentrations were all above the LoR and ranged from 11 to 26 mg/kg. All concentrations were well below the NAGD screening level of 80 mg/kg.

Cobalt concentrations were all above the LoR and ranged from 2.6 to 6.3 mg/kg. There is no NAGD screening level for cobalt in marine sediments (Figure 3-9).

Copper concentrations were all above the LoR and ranged from 1.2 to 4.7 mg/kg. Copper concentrations were higher at the southern end of the offshore pipeline route (towards Darwin Harbour). All concentrations were well below the NAGD screening level of 65 mg/kg (Figure 3-9).

Iron concentrations were all above the LoR and ranged from 8,300 to 15,000 mg/kg. There is no NAGD screening level for iron in marine sediments. Iron concentrations were lowest at site OP1 (Figure 3-9).

Nickel concentrations were all above the LoR and ranged from 4 mg/kg to 8.7 mg/kg. All sites were below the NAGD screening level of 21 mg/kg (Figure 3-9).

Zinc concentrations were all above the LoR and ranged from 4.5 to 16 mg/kg. Zinc concentrations were higher at the southern end of the offshore pipeline route (towards Darwin Harbour). All concentrations were well below the NAGD screening level of 200 mg/kg (Figure 3-9).

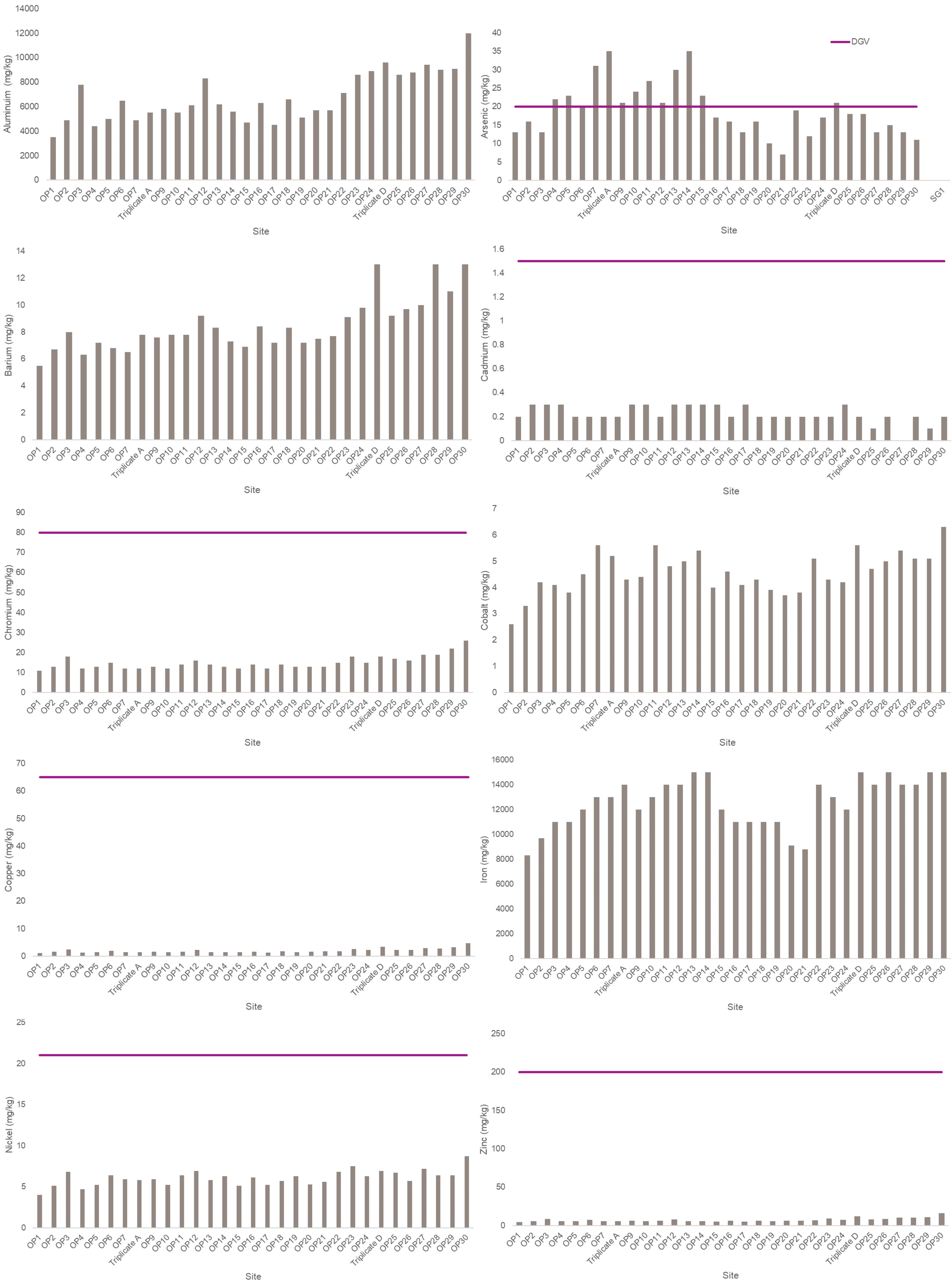


Figure 3-9: Metal concentrations along the offshore pipeline route (from west (OP1) to east (OP30))

Arsenic is considered to become concentrated in sedimentary rocks through sedimentation processes. Studies have shown that iron formations and iron rich sediments can contain very large concentrations of natural arsenic (Tanaka, 1988). Thirteen samples had arsenic concentrations above the NAGD screening level (Figure 3-9). Arsenic concentrations were therefore plotted against iron concentrations along the offshore pipeline route to determine if there was a correlation between arsenic and iron. A weak positive polynomial correlation between iron concentrations and arsenic concentrations was identified (R^2 value of 0.2) (Figure 3-10).

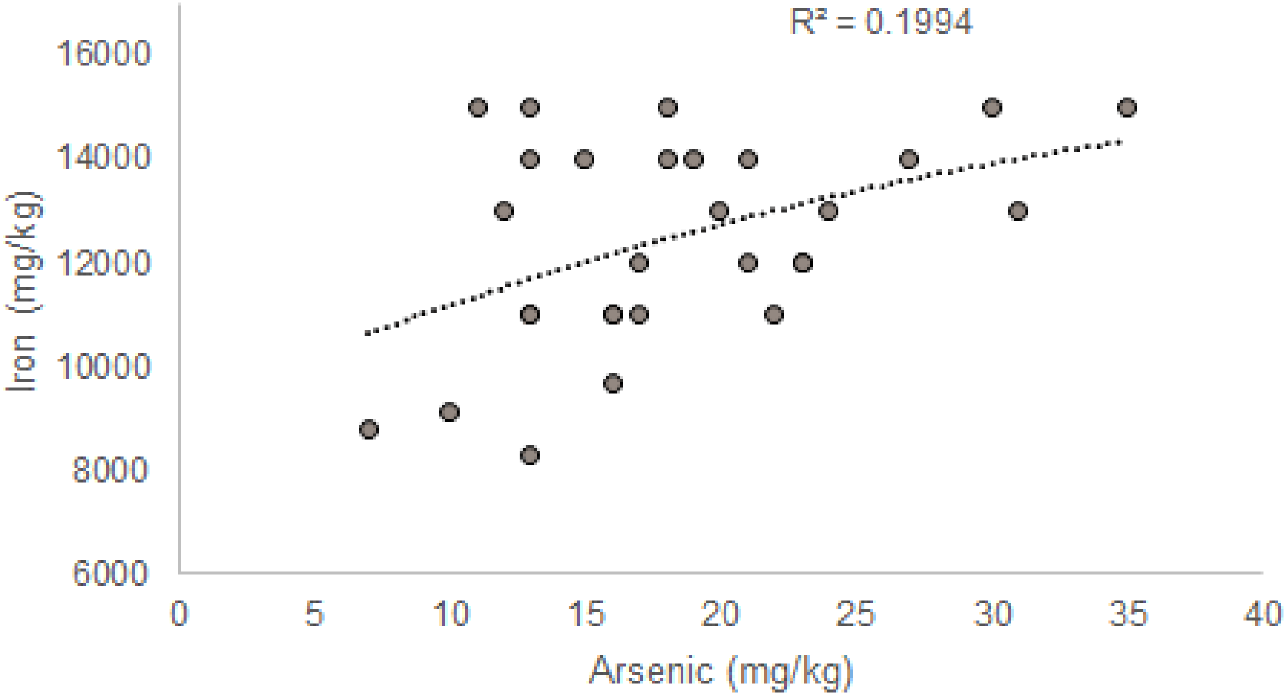


Figure 3-10: Correlation between iron and arsenic concentrations along the offshore pipeline route

3.2.1.4 Nutrients

TKN concentrations exhibited low variability across sites, ranging from 0.3 to 0.6 mg.N/g (Table 3-4; Appendix G). TP concentrations also exhibited low variability across sites, ranging from 0.36 to 0.59 mg.P/g (Table 3-4). TOC concentrations were also low, ranging from 0.2 to 0.5%. Levels were generally higher at the eastern (Darwin Harbour) end of the offshore pipeline route.

3.2.1.5 Hydrocarbons

TRH and BTEXN concentrations at offshore pipeline sites were below the LoR for all samples (Appendix H). Therefore, no PAH analysis was undertaken at these sites.

3.2.1.6 Naturally occurring radioactive materials

All samples taken along the offshore pipeline route had NORMs concentrations above the LoR for all three analytes (radium-226, radium-228 and thorium-228; Appendix F). Radium-226 concentrations ranged from 3.6 to 17.0 Bq/kg, radium-228 concentrations ranged from 4.2 to 26.0 Bq/lg and thorium-228 concentrations ranged from 4.3 to 24.0 Bq/kg (Figure 3-11). These results were calculated with a 95% level of confidence, with the measurement uncertainty ranging from ± 0.4 to 3.0 Bq/kg. All concentrations were well below the guideline value of 35 Bq/g (=35,000 Bq/kg) screening level (effects range-low) (CoA 2009).

The concentrations of all three NORMs analytes were lower further offshore and increased towards Darwin Harbour (Figure 3-11).

Table 3-4: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations along the offshore pipeline route

Site	Total Kjeldahl nitrogen as N (mg.N/g)	Total phosphorus as P (mg.P/g)	Total organic carbon (%)
OP1	0.3	0.36	0.2
OP2	0.3	0.42	0.2
OP3	0.6	0.47	0.4
OP4	0.3	0.49	0.2
OP5	0.3	0.52	0.2
OP6	0.5	0.53	0.3
OP7	0.3	0.53	0.2
Triplicate A	0.3	0.59	0.2
OP9	0.4	0.50	0.2
OP10	0.3	0.53	0.2
OP11	0.3	0.53	0.3
OP12	0.6	0.55	0.2
OP13	0.3	0.57	0.2
OP14	0.3	0.56	0.2
OP15	0.3	0.50	0.2
OP16	0.4	0.44	0.2
OP17	0.3	0.42	0.3
OP18	0.4	0.41	0.2
OP19	0.3	0.40	0.3
OP20	0.5	0.37	0.3
OP21	0.5	0.37	0.2
OP22	0.4	0.48	0.4
OP23	0.5	0.38	0.3
OP24	0.5	0.49	0.3
Triplicate D	0.4	0.46	0.3
OP25	0.4	0.48	0.4
OP26	0.5	0.55	0.4
OP27	0.5	0.45	0.4
OP28	0.4	0.43	0.5
OP29	0.5	0.38	0.2
OP30	0.6	0.45	0.2

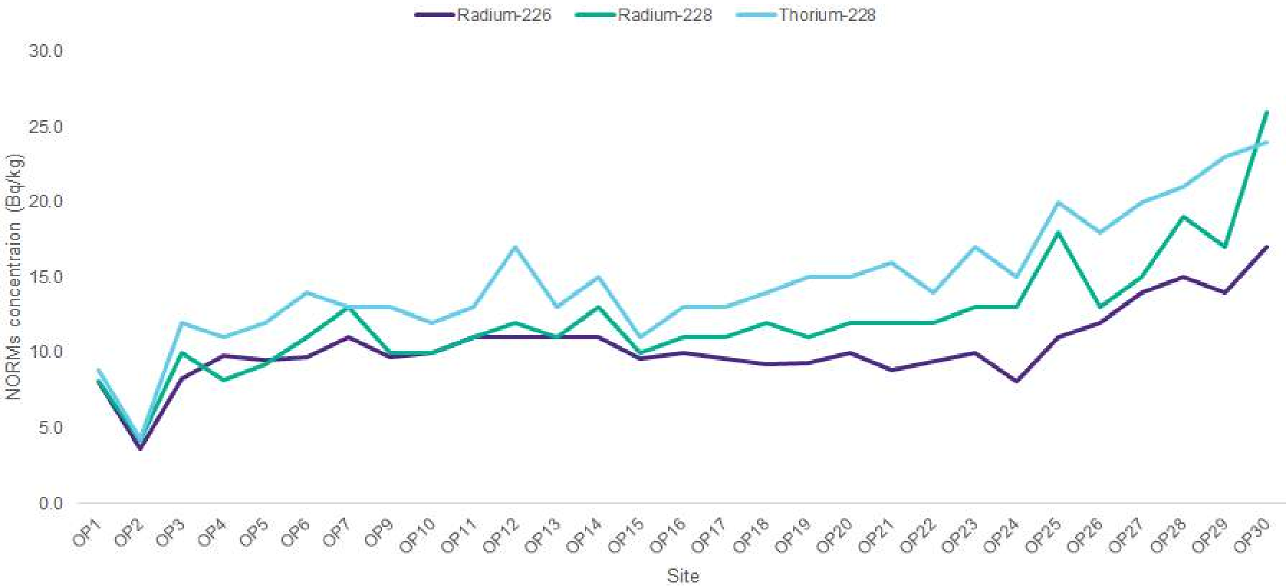


Figure 3-11: NORMs concentrations along the offshore pipeline route (from west (OP1) to east (OP30))

3.2.2 Darwin Harbour pipeline

3.2.2.1 Particle size distribution

Laboratory PSD results can be found in Appendix D. The data were analysed to characterise sediment samples in terms of Wentworth size classifications, which classify particle size into total clay (0–4 µm), total silt (4–63 µm), total sand (63–2000 µm) and total gravel (>2000 µm).

The particle size distribution varied from south to north along the pipeline route in Darwin Harbour. The northernmost site (HS49) had a very high proportion of silt (46%) and clay (10%) (Table 3-5), similar to high silt and clay content found at the southern end of the offshore pipeline route (OP30, Section 3.2.1.1). The sand wave dredge area (HS48–HS32) had very high proportions of sand (68–93%), while the southern end of the pipeline route consisted of gravelly silty sand (Figure 3-12).

Table 3-5: Sediment particle size characteristics along the Darwin Harbour pipeline route (from south (HS01) to north (HS49)

Site	Total clay % (0-4 µm)	Total silt% (4–63 µm)	Total sand% (63–2000 µm)	Total gravels % (>2000 µm)
HS01	3.12	14.50	55.48	26.90
HS02	4.60	18.25	43.63	33.52
HS03	3.68	12.90	23.63	59.79
HS04	5.68	21.19	41.73	31.40
HS05	6.92	24.55	41.55	26.98
HS06	3.06	11.05	52.66	33.23
HS07	3.38	12.57	57.86	26.19
HS08	3.21	11.78	40.47	44.54
HS09	3.31	11.84	39.79	45.07
HS10	3.92	14.20	58.42	23.47
HS11	2.42	8.99	38.72	49.87
HS12	3.57	13.57	42.95	39.91
HS13	3.36	12.82	46.50	37.31
HS14	4.25	14.48	41.85	39.42
HS15	3.18	11.37	22.22	63.24
HS16	2.94	10.18	29.79	57.09

Site	Total clay % (0-4 µm)	Total silt% (4–63 µm)	Total sand% (63–2000 µm)	Total gravels % (>2000 µm)
HS17	2.84	9.19	53.38	34.59
HS18	2.49	8.76	53.69	35.06
HS19	3.76	13.83	35.57	46.83
HS20	4.44	16.67	48.51	30.38
HS21	3.33	13.16	41.58	41.93
HS22	1.04	6.14	56.66	36.16
HS23	3.26	12.99	38.14	45.60
HS25	1.52	7.01	40.85	50.62
HS26	2.31	8.94	33.80	54.95
HS27	1.79	7.02	34.72	56.46
HS31	1.99	7.47	34.49	56.05
HS70	3.54	13.12	54.36	28.98
HS74	2.79	11.76	53.10	32.35
HS75	2.35	10.65	49.41	37.59
HS77	3.02	14.00	65.16	17.82
HS32	0.46	3.95	68.69	26.91
HS33	0.29	2.59	76.76	20.35
HS34	0.00	1.36	86.70	11.94
HS35	1.51	6.76	69.83	21.90
HS36	0.05	2.12	88.33	9.50
HS37	0.00	0.60	88.20	11.20
HS38	2.17	8.36	69.87	19.60
HS39	0.00	0.79	80.44	18.77
HS40	1.40	6.50	70.44	21.65
HS41	2.02	9.99	75.50	12.49
HS42	4.05	17.33	67.88	10.74
HS44a	0.13	1.20	76.77	21.90
HS44b	0.14	1.78	76.49	21.60
HS45	0.68	3.16	70.04	26.12
HS46	0.08	0.74	92.85	6.33
HS47	2.66	14.24	77.63	5.47
HS48	4.31	20.61	70.46	4.62
HS49	9.95	45.67	44.16	0.22

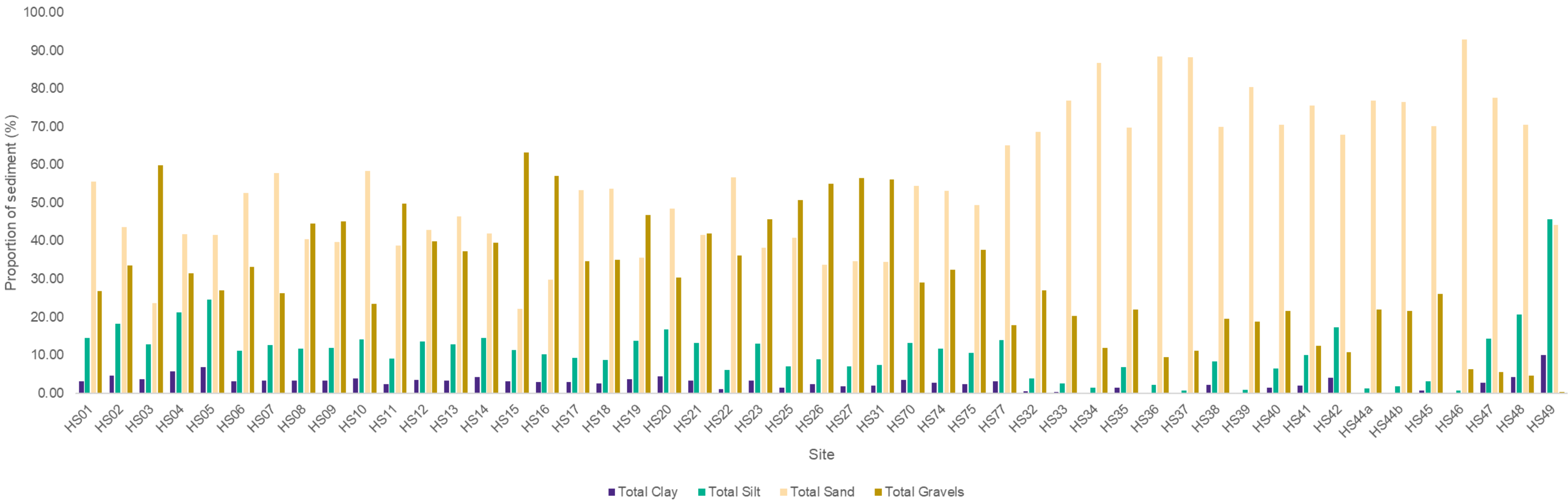


Figure 3-12: Sediment sample particle size characteristics inside Darwin Harbour (from south (HS01) to north (HS49))

3.2.2.2 Metals

The metals and metalloid concentrations for all sites (see Appendix G) were compared to the NAGD screening levels (CoA, 2009), where available. Of the metals and metalloids in the sediments sampled from Darwin Harbour; cadmium, mercury and silver were below the LoR for all sites.

Aluminium concentrations were all above the LoR and ranged from 1,330 to 14,600 mg/kg. There is no NAGD screening level for aluminium in marine sediments (Figure 3-13).

Antimony concentrations were above the LoR at 18 sites, ranging from <0.5 to 1.07 mg/kg (Figure 3-13). All the sites in the potential sand wave dredging area were below the LoR. All samples were below the NAGD screening level for antimony of 2 mg/kg (Figure 3-13).

Arsenic concentrations were found to be very high inside Darwin Harbour. All samples were above the LoR, and only seven samples were below the NAGD screening level of 20 mg/kg., all of which were within the potential sand wave dredging area. Arsenic concentrations ranged from 8.27 to 108 mg/kg, with a total of nine samples (HS06, HS07, HS08, HS09, HS10, HS11, HS12, HS20 and HS24) above the NAGD SQG-High of 70 mg/kg (Figure 3-13).

Chromium concentrations were above the LoR at all sites and ranged from 6.9 to 114 mg/kg. Only one sample (HS31) was above the NAGD screening level of 80 mg/kg (Figure 3-13). However the 95% upper confidence limit of the samples in the Darwin Harbour pipeline (32.6 mg/kg) meet the NAGD screening level.

Cobalt concentrations were above the LoR at all sites, ranging from 1 to 10.9 mg/kg. There is no NAGD screening level for cobalt in marine sediments. Cobalt concentrations were generally high at the southern end of the pipeline, with lower concentrations found within the potential sand wave dredging area (Figure 3-13).

Eleven sites had copper concentrations below the LoR. These sites were all within the potential sand wave dredging area. Copper concentrations within Darwin Harbour ranged from <1 to 7.6 mg/kg. All sites were well below the NAGD screening level 65 mg/kg (Figure 3-13).

Iron concentrations were all above the LoR at all sites and ranged from 8,140 to 58,100 mg/kg. There is no NAGD screening level iron in marine sediments. Iron concentrations were lowest within the potential sand wave dredge area (Figure 3-13).

Lead concentrations were all above the LoR and ranged from 1.6 to 28 mg/kg. All sites were below the NAGD screening level of 50 mg/kg. Lead concentrations were slightly lower within the sand wave dredge area (Figure 3-13).

Manganese concentrations were variable across Darwin Harbour but were generally high within the proposed sand wave dredging area. Manganese concentrations were all above the LoR and ranged from 169 to 800 mg/kg (Figure 3-13). There is no NAGD screening level for manganese in marine sediments.

Nickel concentrations were all above the LoR at all sites and ranged from 1.6 to 9.8 mg/kg. All sites were below the NAGD screening level of 21 mg/kg (Figure 3-13).

Zinc concentrations were all above the LoR at all sites and ranged from 2 to 20.3 mg/kg. All sites were all below the NAGD screening level of 200 mg/kg (Figure 3-13).

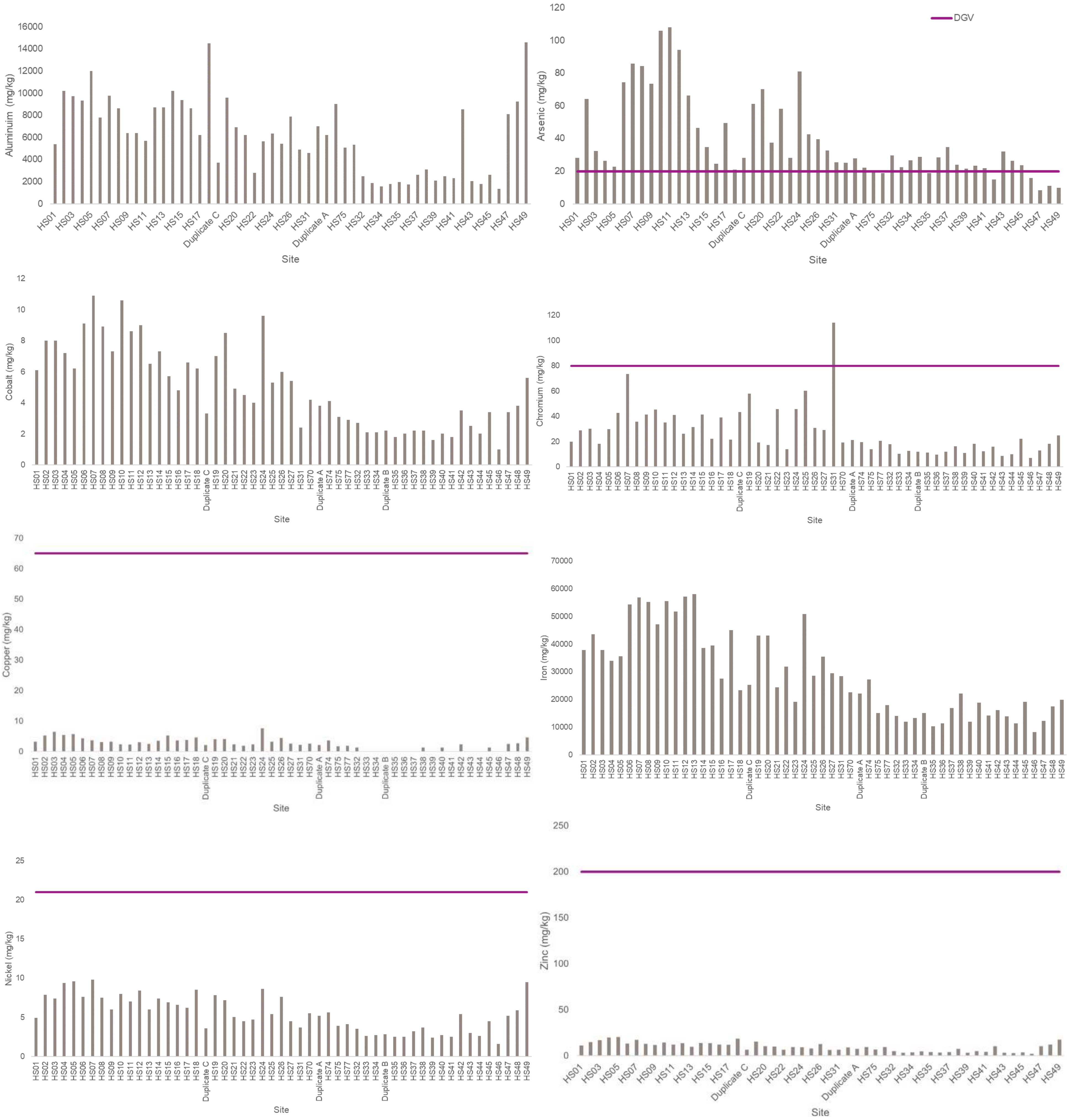


Figure 3-13: Metal concentrations along the offshore pipeline route (from south (HS1) to north (HS49))

Arsenic concentrations were plotted against iron concentrations along the Darwin Harbour pipeline route to determine if there was a correlation between arsenic and iron. A strong positive polynomial correlation between iron concentrations and arsenic concentrations was identified (R^2 value of 0.76) (Figure 3-14).

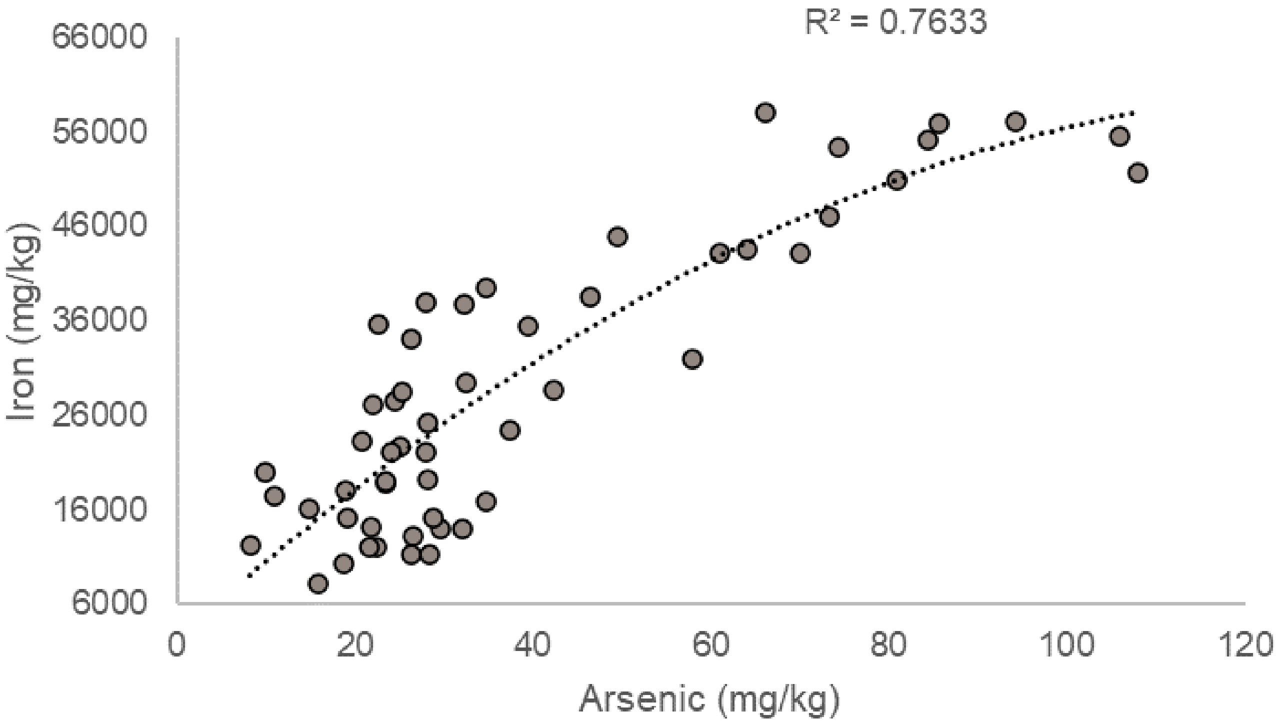


Figure 3-14: Correlation between iron and arsenic concentrations along the Darwin Harbour pipeline route (HS1 to HS49)

3.2.2.3 Nutrients

TKN concentrations exhibited high concentrations and variability across sites (Table 3-6; Appendix G). TKN in Darwin Harbour ranged from 20 to 540 mg/kg. TP concentrations also exhibited high concentrations and variability across sites, ranging from 86 to 1,130 mg/kg. TKN and TP concentrations were generally lower within the proposed sand wave dredging area. TOC concentrations were also variable, ranging from 0.08% to 2.24%, and with peak concentrations much higher than recorded for the offshore pipeline section.

Table 3-6: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations in Darwin Harbour

Site	Total Kjeldahl nitrogen as N (mg/kg)	Total phosphorus as P (mg/kg)	Total organic carbon (%)
HS01	280	549	0.36
HS02	350	428	0.34
HS03	380	540	0.26
HS04	370	297	0.46
HS05	540	416	0.55
HS06	180	1120	0.21
HS07	300	635	0.24
HS08	330	834	0.24
HS09	300	589	0.20
HS10	330	631	0.22
HS11	270	697	0.22
HS12	290	1130	0.23
HS13	360	661	0.28

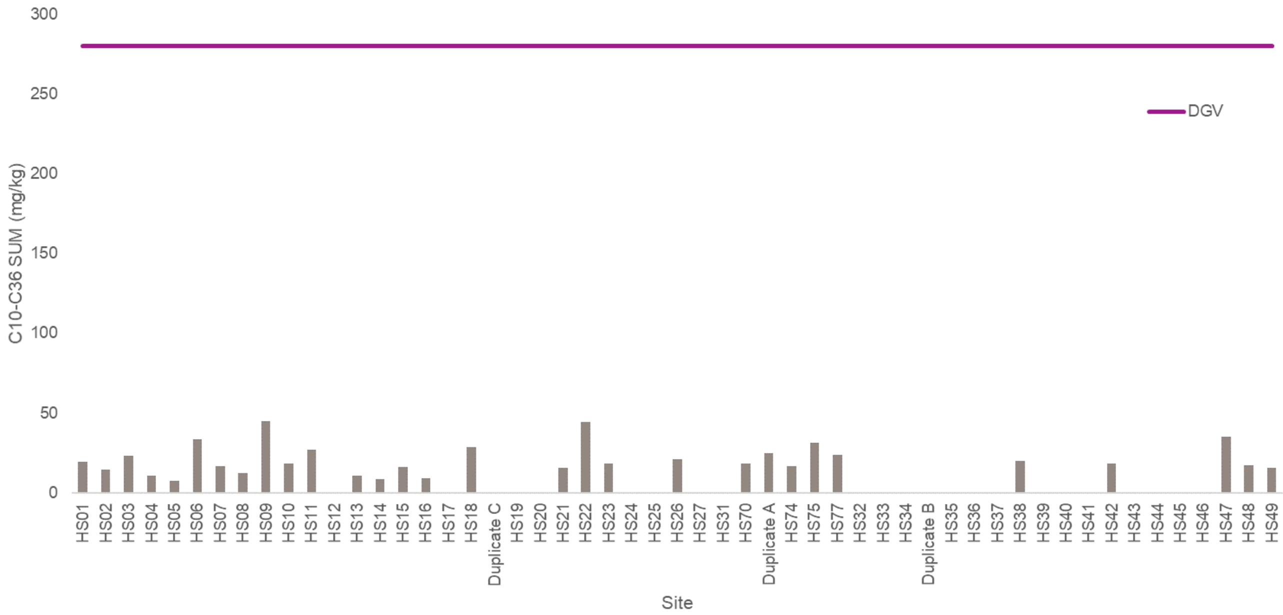
Site	Total Kjeldahl nitrogen as N (mg/kg)	Total phosphorus as P (mg/kg)	Total organic carbon (%)
HS14	310	555	0.34
HS15	270	322	0.31
HS16	270	485	0.32
HS17	280	483	0.14
HS18	480	696	0.14
Duplicate C	270	319	0.22
HS19	260	626	0.19
HS20	130	569	0.20
HS21	250	422	0.26
HS22	220	704	0.09
HS23	220	482	0.22
HS24	120	758	0.14
HS25	150	499	0.15
HS26	240	394	0.19
HS27	190	152	0.12
HS31	160	86	0.16
HS70	180	244	0.22
Duplicate A	220	398	0.20
HS74	380	508	0.18
HS75	240	553	0.19
HS77	410	270	0.21
HS32	80	331	0.09
HS33	110	344	0.11
HS34	90	408	0.08
Duplicate B	60	371	0.09
HS35	180	317	0.13
HS36	60	338	0.09
HS37	20	219	0.08
HS38	160	281	0.15
HS39	50	250	2.24
HS40	100	308	0.10
HS41	230	197	0.11
HS42	180	403	0.22
HS43	40	291	0.08
HS44	40	256	0.08
HS45	40	212	0.08
HS46	30	200	0.08
HS47	270	353	0.17
HS48	300	310	0.35
HS49	470	341	0.51

3.2.2.4 Hydrocarbons

Total petroleum hydrocarbons (TPH) and TRH were detected at 35 of the 53 Darwin Harbour sites, these ranged from <3 to 9 mg/kg (raw data) (Table 3-7; Appendix H). TPH and TRH results were normalised to 1% total organic carbon (TOC). The normalised TPH and TRH concentrations were below the Default Guideline Value (DGV) of 280 mg/kg across all sites (Figure 3-15). Analysis of PAHs were requested for these 35 sites. All PAH concentrations were below the LoR.

Table 3-7: Total recoverable hydrocarbons detected above the LOR in Darwin Harbour sediments, normalised to 1% TOC

Analyte	TOC (%)	C10–C40 (sum) (mg/kg)	C10–C36 (sum) (mg/kg)
DGV			280
HS01	0.36	25.00	19.44
HS02	0.34	17.65	14.71
HS03	0.26	30.77	23.08
HS04	0.46	17.39	10.87
HS05	0.55	9.09	7.27
HS06	0.21	42.86	33.33
HS07	0.24	25.00	16.67
HS08	0.24	20.83	12.50
HS09	0.20	60.00	45.00
HS10	0.22	27.27	18.18
HS11	0.22	36.36	27.27
HS13	0.28	14.29	10.71
HS14	0.34	14.71	8.82
HS15	0.31	19.35	16.13
HS16	0.32	12.50	9.38
HS17	0.14	21.43	<3
HS18	0.14	42.86	28.57
Duplicate C	0.22	18.18	<3
HS19	0.19	21.05	<3
HS20	0.20	20.00	<3
HS21	0.26	19.23	15.38
HS22	0.09	55.56	44.44
HS23	0.22	27.27	18.18
HS24	0.14	28.57	<3
HS26	0.19	31.58	21.05
HS31	0.16	25.00	<3
HS70	0.22	22.73	18.18
Duplicate A	0.20	30.00	25.00
HS74	0.18	27.78	16.67
HS75	0.19	42.11	31.58
HS77	0.21	28.57	23.81
HS35	0.13	30.77	<3
HS38	0.15	26.67	20.00
HS42	0.22	22.73	18.18
HS47	0.17	41.18	35.29
HS48	0.35	22.86	17.14
HS49	0.51	19.61	15.69



Note duplicate samples were collected from the site directly to the left of the duplicate reference code

Figure 3-15: Total recoverable hydrocarbons (normalised to 1% TOC) in Darwin Harbour (from south (HS01) to north (HS49)

3.2.2.5 Pesticides

Pesticide analysis was undertaken for 33 out of the 53 Darwin Harbour sediment samples across the study area. All pesticide chemicals analysed were below the LoR across all sites (Appendix I).

3.2.2.6 Tributyltin

Tributyltin concentrations were below the limit of reporting (LOR) of 0.5 µg/kg in all sediment samples and thus well below the NAGD screening level of 9 µg.Sn/kg (Appendix J).

3.2.2.7 Naturally occurring radioactive materials

All samples had NORMs concentrations above the LoR for all three analytes (radium-226, radium-228 and thorium-228). radium-226 concentrations ranged from 5.2 to 79.1 Bq/kg, radium-228 concentrations ranged from 5.6 to 59.5 Bq/lg and thorium-228 concentrations ranged from 5.8 to 63.8 Bq/kg (Figure 3-16). These results were calculated with a 95% level of confidence, with the measurement uncertainty ranging from ± 1.1 to 6.7 Bq/kg. All concentrations were well below the guideline value of 35,000 Bq/kg NAGD screening level (effects range-low) (CoA 2009).

NORMs concentrations were relatively consistent between HS01 and HS27 (radium-228 and thorium-228) and HS28 (radium-226), then peaked at sites HS27 and HS31 along the pipeline route. The laboratory report for NORMs analysis is in Appendix F.

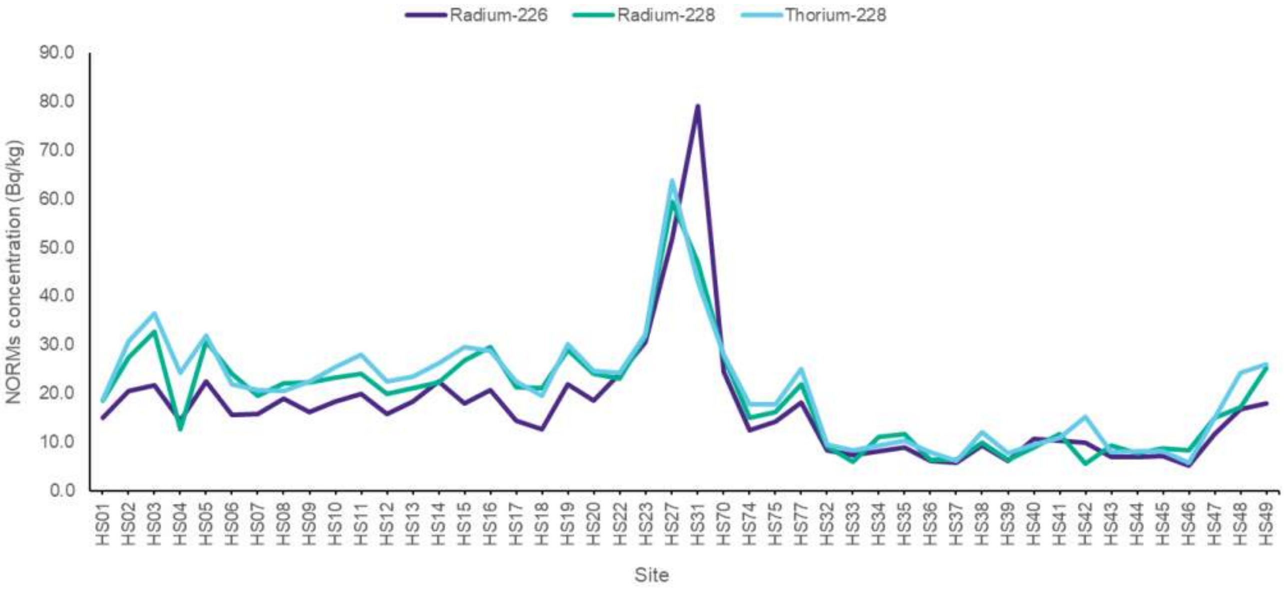


Figure 3-16: NORMs concentrations along the Darwin Harbour section of the pipeline route (from South (HS01) to North (HS49))

3.2.3 Spoil ground

3.2.3.1 Particle size distribution

Laboratory PSD results can be found in Appendix D. The data were analysed to characterise sediment samples in terms of Wentworth size classifications, which classify particle size into total clay (0–4 µm), total silt (4–63 µm), total sand (63–2000 µm) and total gravel (>2000 µm).

The particle size distribution was consistent across the spoil ground, comprising of sandy sediment with some gravel and silt (Figure 3-17). The total proportion of sand ranged from 51.75 to 72.79% across the spoil ground (Table 3-8).

Table 3-8: Sediment particle size characteristics at the spoil ground

Site	Total clay % (0–4 µm)	Total silt % (4–63 µm)	Total sand % (63–2000 µm)	Total gravels % (>2000 µm)
SG1	4.58	12.82	64.00	18.60
SG2	4.78	14.36	62.58	18.28
SG3	3.76	14.45	72.79	9.00
SG4	4.83	17.60	51.75	25.81
SG5	4.13	15.54	57.38	22.96
SG6	4.28	16.80	63.14	15.78
SG7	4.11	17.46	66.78	11.65
SG8	4.20	15.22	62.94	17.64
SG9	3.74	14.01	53.73	28.52
SG10	4.64	19.26	63.24	12.87
SG11	5.07	22.86	56.10	15.97
SG12	4.62	14.59	59.26	21.53
SG13	4.89	15.85	61.69	17.57

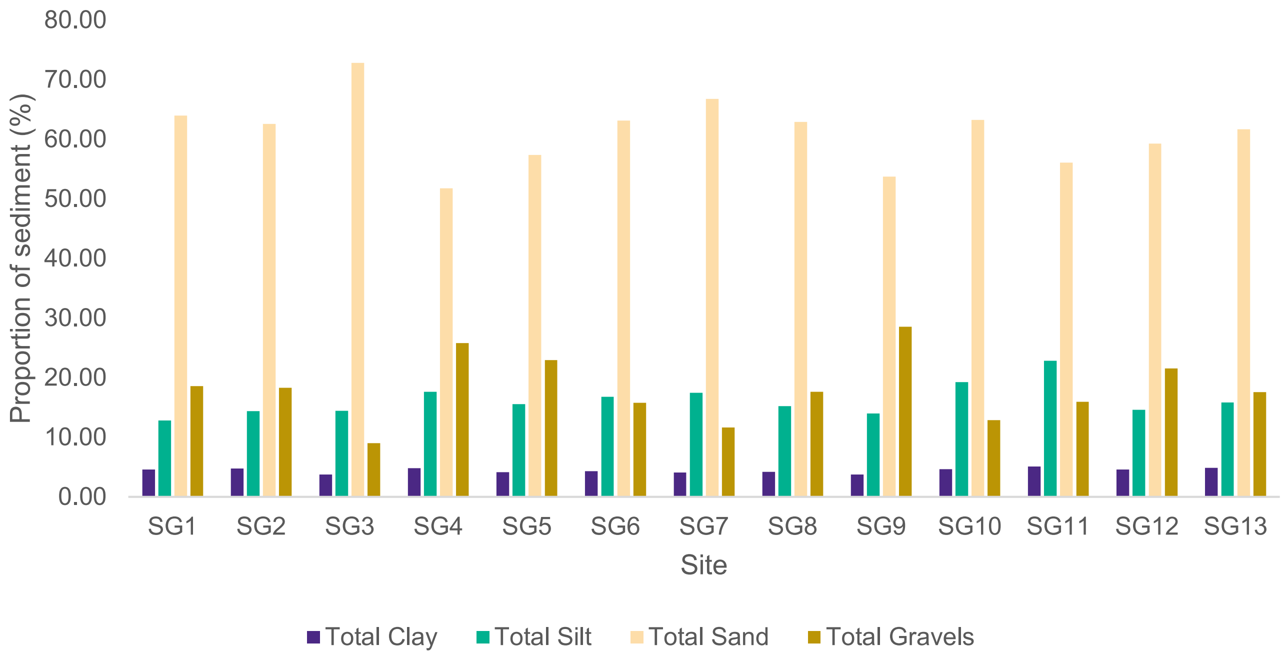


Figure 3-17: Sediment sample particle size characteristics at the spoil ground

3.2.3.2 Infauna

A total of 185 individuals from five phyla were recorded from the 13 spoil ground samples analysed. The dataset was dominated by crustaceans (107 individuals) and annelids (polychaete worms; 55 individuals), with the next most numerous phyla being Echinodermata, Sipuncula and Nematoda, represented by 16, six and one individual, respectively). The full dataset can be found in Appendix E.

Descriptive statistics of infaunal community data describing the number of species (S), abundance (N), Margalef's species richness (d), Pielou's evenness (J'), Shannon-Weiner diversity (H') and Simpson's alpha diversity index (1-λ) are presented in Table 3-9. The number of species, Margalef's species richness and Shannon-Weiner diversity were all greatest as site SG11 (S = 21, d = 6.002, H' = 2.936 and 1- λ = 0.9735). Abundance was greatest at site SG13 (one of the control sites; N = 30). Pielou's evenness and Simpson's index were greatest at site SG12 (the other control site; J' = 1, 1- λ = 1). All metrics were lowest at site OP30 (three individuals from one taxa). The number of species, Margalef's species richness and Shannon-Weiner diversity were greatest at site OP9 (39 individuals from 26 taxa).

Table 3-9: Descriptive statistics of spoil ground infaunal data

Site	Species (S)	Abundance (N)	Margalef's species richness (d)	Pielou's evenness (J')	Shannon-Weiner diversity (H')	Simpson's alpha diversity index (1-λ)
SG01	6	8	2.404	0.9306	1.667	0.8929
SG02	5	6	2.232	0.9697	1.561	0.9333
SG03	6	8	2.404	0.9306	1.667	0.8929
SG04	3	4	1.443	0.9464	1.04	0.8333
SG05	8	12	2.817	0.9518	1.979	0.9242
SG06	13	21	3.942	0.9359	2.401	0.9381
SG07	12	18	3.806	0.9772	2.428	0.9608
SG08	7	8	2.885	0.9796	1.906	0.9643
SG09	13	28	3.601	0.8661	2.221	0.8889
SG10	6	11	2.085	0.8597	1.54	0.8
SG11	21	28	6.002	0.9644	2.936	0.9735
SG12	3	3	1.82	1	1.099	1
SG13	11	30	2.94	0.8243	1.976	0.8322

No significant clusters of spoil ground infaunal samples were found following cluster analysis with SIMPROF (in PRIMER v7). Analysis of the ranked total abundance and frequency of occurrence of each taxa identified that the spoil ground was characterised by crustaceans, echinoderms and polychaete worms. Pseudozeuthidae (tanaids) were both the most abundant (35 individuals from the 13 samples, with a maximum abundance of 11 individuals at any one site) and frequently-occurring taxa (11 of 13 samples, or 84.6%).The spoil ground was also characterised by Anthuridae (elongate isopods; 17 individuals between seven sites or 53.8% of samples), Ophiuridae (brittlestars; 13 individuals between six sites or 46.2% of samples), Ampeliscidae (tube-building amphipods; 11 individuals between six sites or 46.2% of samples), *Nephtys* sp. (catworms; eight individuals between four sites or 30.8% of samples) and Meltidiae (amphipods; eight individuals between two sites or 15.4% of samples).

3.2.3.3 Metals

The metals and metalloid concentrations for all sites (see Appendix G) were compared to the NAGD screening levels (CoA, 2009, where available. Of the metals and metalloids sampled at the Spoil Ground, mercury was the only one below the LoR at all sites.

Aluminium concentrations were all above the LoR and ranged from 6,200 to 10,000 mg/kg. There is no NAGD screening level for aluminium in marine sediments (Figure 3-18).

Arsenic concentrations were all above the LoR and ranged from 18 to 38 mg/kg. There were 12 sites that had arsenic concentrations above the NAGD screening level of 20 mg/kg but were below the NADG SQG-High value of 70 mg/kg (Figure 3-18).

Barium concentrations were all above the LoR and ranged from 11 to 15 mg/kg. There is no NAGD screening level for barium in marine sediments (Figure 3-18). Cadmium concentrations were all above the LoR and ranged from 0.1 to 0.3 mg/kg. Cadmium concentrations were all well below the NAGD screening level of 1.5 mg/kg (Figure 3-18).

Chromium concentrations were all above the LoR and ranged from 14 to 20 mg/kg. Chromium concentrations were all well below the NAGD screening level of 80 mg/kg (Figure 3-18). Cobalt concentrations were all above the LoR and ranged from 4.2 to 5.8 mg/kg. There is no NAGD screening level for cobalt in marine sediments (Figure 3-15).

Copper concentrations were all above the LoR and ranged from 2.2 to 4.7 mg/kg. Copper concentrations were all well below the NAGD screening level of 65 mg/kg (Figure 3-18). Iron concentrations were all above the LoR and ranged from 14,000 to 23,000 mg/kg. There is no NAGD screening level for iron in marine sediments. Iron concentrations were highest at site SG2 (Figure 3-18).

Nickel concentrations were all above the LoR and ranged from 5.3 to 7.3 mg/kg. Nickel concentrations were all below the NAGD screening level of 21 mg/kg (Figure 3-18). Zinc concentrations were all above the LoR and ranged from 8.7 to 12.0 mg/kg. Zinc concentrations were all well below the NAGD screening level of 200 mg/kg (Figure 3-18).

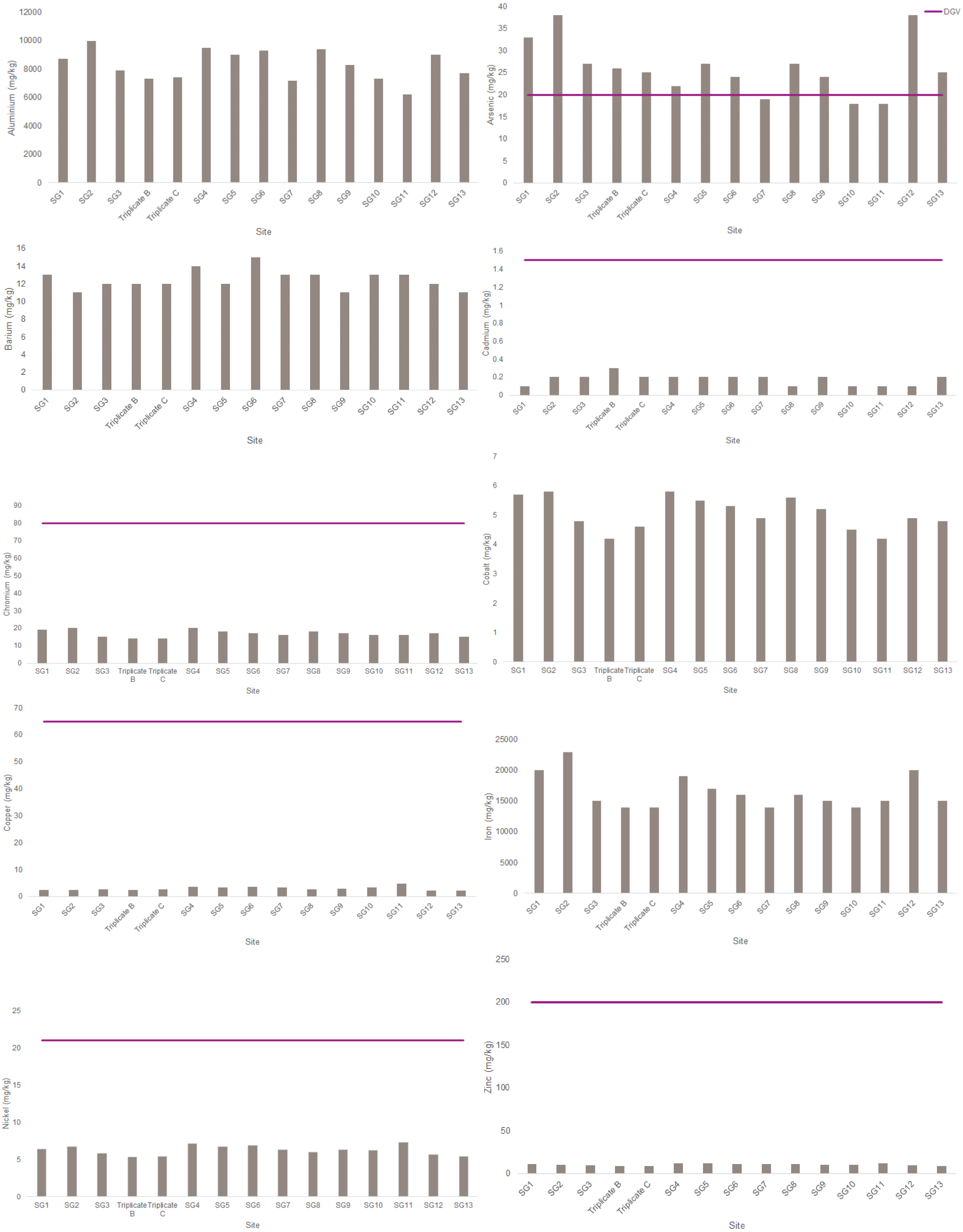


Figure 3-18: Metal concentrations at the spoil ground

Arsenic is considered to have a geological source (see Section 3.2.1.3). Twelve samples had arsenic concentrations above the NAGD screening level (Figure 3-18). Arsenic concentrations were therefore plotted against iron concentrations along the offshore pipeline route to determine if there was a correlation between arsenic and iron. A strong positive polynomial correlation between iron concentrations and arsenic concentrations was identified (R^2 value = 0.73) (Figure 3-19).

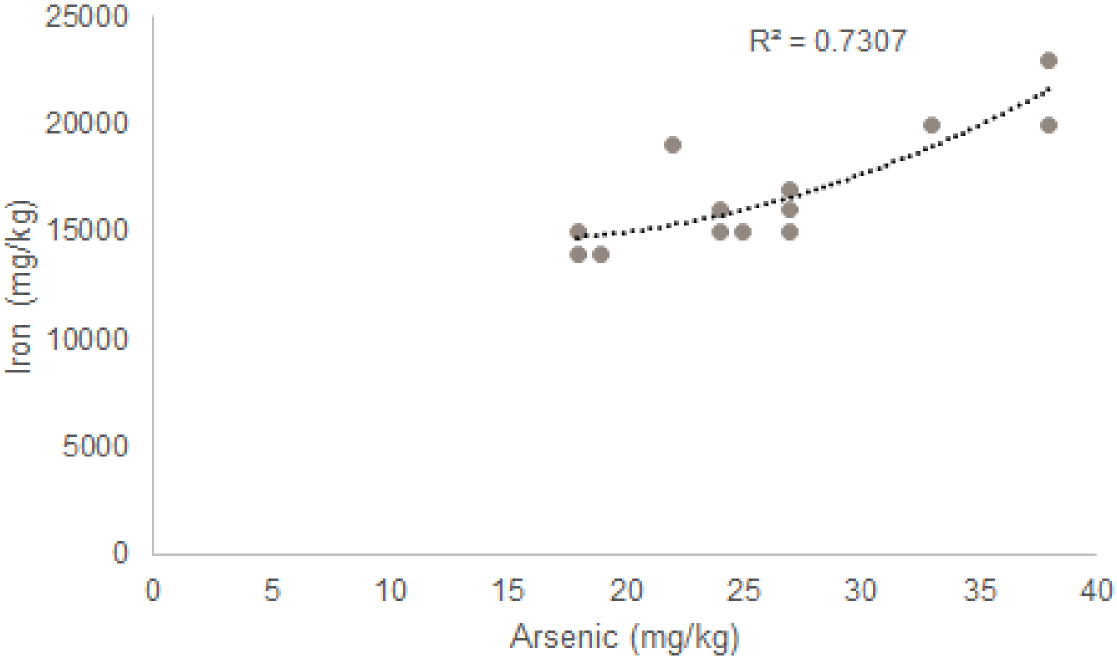


Figure 3-19: Correlation between iron and arsenic concentrations inside the spoil ground

3.2.3.4 Nutrients

TKN concentrations exhibited low variability across sites, ranging from 0.3 to 0.5 mg.N/g (Table 3-10; Appendix G). TP concentrations also exhibited low variability across sites, ranging from 0.37 to 0.62 mg.P/g (Table 3-10). Similarly, variability in TOC concentrations between sites was low, with TOC ranging from 0.2% to 0.4%.

Table 3-10: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations at the spoil ground

Site	Total Kjeldahl nitrogen as N (mg.N/g)	Total phosphorus as P (mg.P/g)	Total organic carbon (%)
SG1	0.4	0.59	0.3
SG2	0.4	0.6	0.3
SG3	0.4	0.5	0.3
Triplicate B	0.4	0.51	0.3
Triplicate C	0.4	0.53	0.2
SG4	0.4	0.48	0.4
SG5	0.4	0.5	0.3
SG6	0.4	0.45	0.3
SG7	0.4	0.45	0.3
SG8	0.4	0.58	0.3
SG9	0.4	0.51	0.4
SG10	0.3	0.38	0.3
SG11	0.3	0.37	0.3
SG12	0.4	0.62	0.3
SG13	0.5	0.54	0.4

3.2.3.5 Hydrocarbons

The spoil ground TRH and BTEXN concentrations were below the limit of reporting (LoR) for all samples (Appendix H). The spoil ground samples were, therefore, not tested for PAHs.

3.2.3.6 Naturally occurring radioactive materials

All samples taken at the spoil ground had NORMs concentrations above the LoR for all three analytes (radium-226, radium-228 and thorium-228; Appendix F). radium-226 concentrations ranged from 0.8 to 15.0 Bq/kg, radium-228 concentrations ranged from 1.1 to 19.0 Bq/lg and thorium-228 concentrations ranged from 1.4 to 21.0 Bq/kg (Figure 3-20). Site SG1 had considerably lower levels of radium-226, radium-228 and thorium-228 than any other sample. For example, radium-226 at SG1 was 0.8 Bq/kg, compared with the next lowest 9.0 Bq/kg art SG13 (Figure 3-20).

These results were calculated with a 95% level of confidence, with the measurement uncertainty ranging from ± 0.09 to 3.0 Bq/kg. All concentrations were well below the NAGD screening level of 35,000 Bq/kg (NAGD screening levels (effects range-low) (CoA 2009).

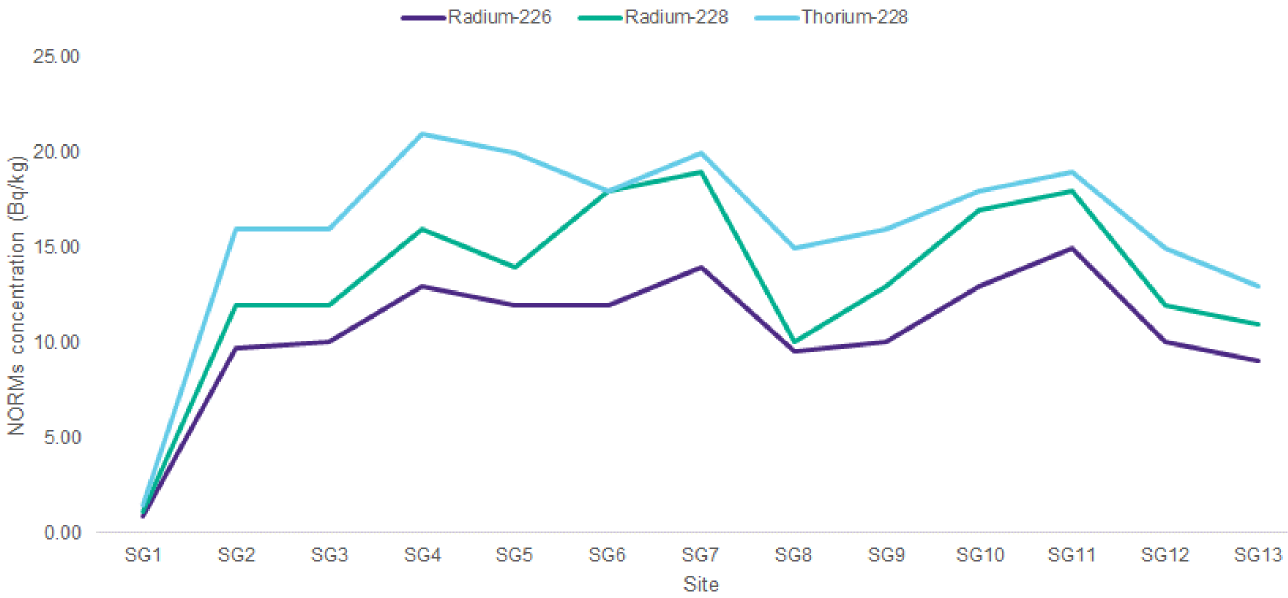


Figure 3-20: NORMs concentrations at the spoil ground

3.2.4 Darwin Harbour sediment survey

3.2.4.1 Particle size distribution

Laboratory PSD results can be found in Appendix D. The data were analysed to characterise sediment samples in terms of Wentworth size classifications, which classify particle size into total clay (0–4 µm), total silt (4–63 µm), total sand (63–2000 µm) and total gravel (>2000 µm) (Table 3-11, Figure 3-21).

The particle size distribution across the sediment survey area followed the same trend as the Darwin Harbour pipeline PSD results (Section 3.2.2.1). The northern side of the Darwin Harbour pipeline route had a very high proportion of sand (89.34% at the most northern site, KP92-75_L), with low proportions of gravel (8.41%) and silt (1.95%). These proportions shift towards the southern end of the pipeline route, from site KP102-7, to much higher proportions of gravel (40.66% at KP102-7_U).

Table 3-11: Sediment particle size characteristics from the sediment survey

Sample	Total clay (%)	Total silt (%)	Total sand (%)	Total gravels (%)
KP92-75_U	0.42	2.65	86.35	10.58
KP92-75_L	0.31	1.95	89.34	8.41
KP92-85_U	0.22	1.21	90.13	8.44
KP92-85_L	0.19	1.54	85.01	13.26
KP92-85_U_1	0.23	1.80	89.95	8.02
KP92-95_U	2.96	12.31	73.20	11.53
KP92-95_U_1	4.17	15.42	66.25	14.16
KP93-7_U	0.16	3.28	75.63	20.93
KP93-8_U	0.06	1.41	81.70	16.83
KP93-8_L	0.07	1.47	83.21	15.26
KP93-23	0.02	1.05	83.43	15.50
KP93-23_U	0.01	1.03	87.80	11.16
KP102-7_U	7.06	20.98	36.71	35.26
KP102-7_L	8.80	17.83	32.71	40.66
KP103-1_U	8.47	17.20	43.07	31.26
KP103-1_L	9.37	17.63	43.51	29.50
KP103-5_U	2.95	10.32	36.75	49.98
KP104-9_U	9.55	19.13	35.65	35.68
KP106_U_a	6.10	23.39	39.51	31.01
KP106-0_U	4.45	18.31	33.56	43.68
KP106-0_L	3.68	14.39	43.20	38.73
KP110-4_U2	2.77	9.24	33.72	54.28
KP112-4_U	1.16	5.75	34.76	58.33
KP119-7_U	7.24	22.09	35.75	34.91
KP119-7_L	9.38	24.53	26.88	39.22
KP119-8_U	3.46	10.71	19.64	66.18
KP120-5_U	2.19	7.53	20.54	69.74
KP120-6	6.85	17.63	29.60	45.92
KP120-6_U	7.50	18.74	22.43	51.33

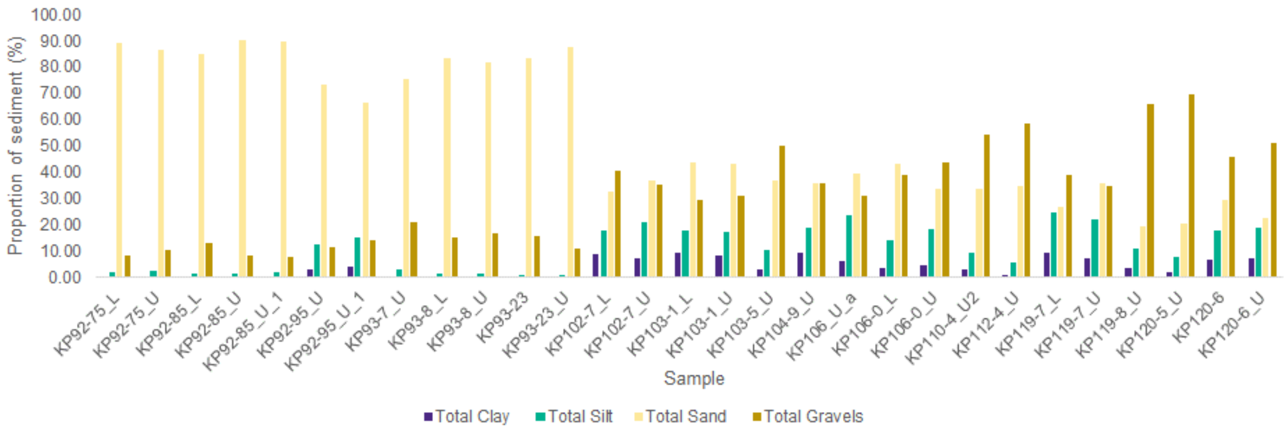


Figure 3-21: Sediment sample particle size characteristics at the sediment sampling sites (from north to south)

3.2.4.2 Metals

The metals and metalloid concentrations for all sites (see Appendix G) were compared to the NAGD screening levels (CoA, 2009), where relevant. Of the metals and metalloids in the sediments sampled from Darwin Harbour; antimony, cadmium and silver were below the LoR for all sites. Mercury was at or below the LoR for all samples except sample KP106.0 L (>0.5 m core depth) where a concentration of 0.02 mg kg was recorded (Figure 3-22). This value was below the guideline value of 0.15 mg/kg (ANG, 2018).

Aluminium concentrations were all above the LoR and ranged from 340 to 9,520 mg/kg (Figure 3-22). There is no NAGD screening level for aluminium in marine sediments.

All arsenic concentrations were above the LoR and ranged from 8.27 to 108 mg/kg (Figure 3-22). Four samples (KP93.8_U, KP119-7_U, KP119-7_L and KP119-8_U) were above the NAGD screening level of 20 mg/kg, but all were below the GV-High value of 70 mg/kg.

Chromium concentrations were above the LoR at all sites and ranged from 1.7 to 37 mg/kg (Figure 3-22). All samples were below the NAGD screening level of 80 mg/kg.

All but one cobalt concentration were above the LoR at all sites, ranging from 0.5 to 8.7 mg/kg (Figure 3-22). There is no NAGD screening level for cobalt in marine sediments.

Five samples had copper concentrations below the LoR. These sites were all within the potential sand wave dredging area. Copper concentrations within Darwin Harbour ranged from <1 to 6.1 mg/kg (Figure 3-22). All sites were well below the NAGD screening level of 65 mg/kg.

Iron concentrations were all above the LoR at all sites and ranged from 1,680 to 32,300 mg/kg (Figure 3-22). There is no NAGD screening level for iron in marine sediments.

Lead concentrations were all above the LoR and ranged from 1.9 to 24.1 mg/kg. All sites were below the NAGD screening level of 50 mg/kg.

Manganese concentrations were all above the LoR and ranged from 10 to 710 mg/kg. There is no NAGD screening level for manganese in marine sediments.

Nickel concentrations were all above the LoR at all sites and ranged from 1 to 9.8 mg/kg (Figure 3-22). All sites were below the NAGD screening level of 21 mg/kg.

Zinc concentrations were all above the LoR at all sites and ranged from 1.3 to 17.2 mg/kg (Figure 3-22). All sites were all below the NAGD screening level of 200 mg/kg.

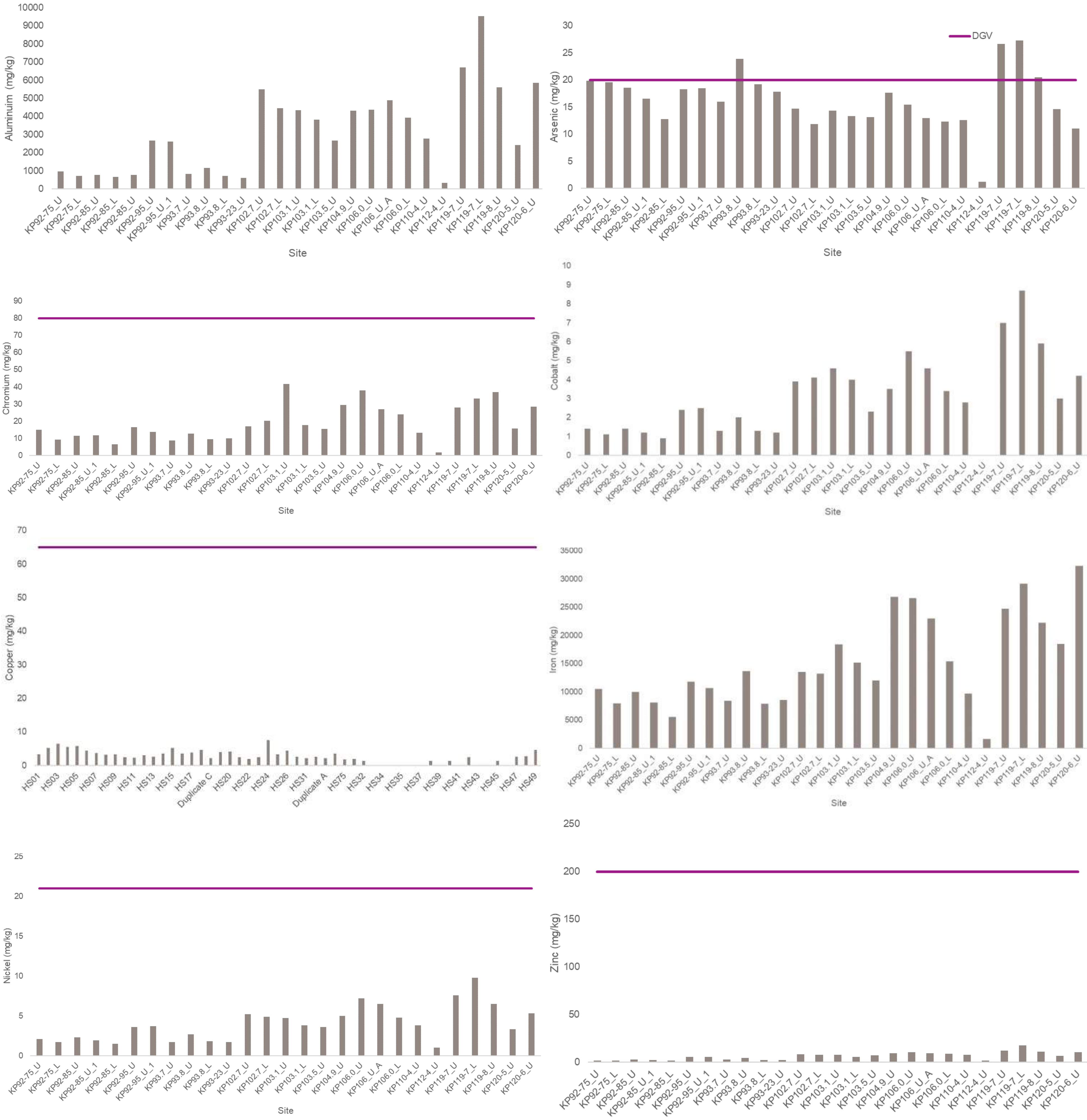


Figure 3-22: Metal concentrations along the Darwin Harbour sediment cores (L = lower (0 to 50 cm core depth), U = upper (>50 cm))

Arsenic concentrations were therefore plotted against iron concentrations along the offshore pipeline route to determine if there was a correlation between arsenic and iron. A weak positive polynomial correlation between iron concentrations and arsenic concentrations was identified (R^2 value of 0.099) (Figure 3-10).

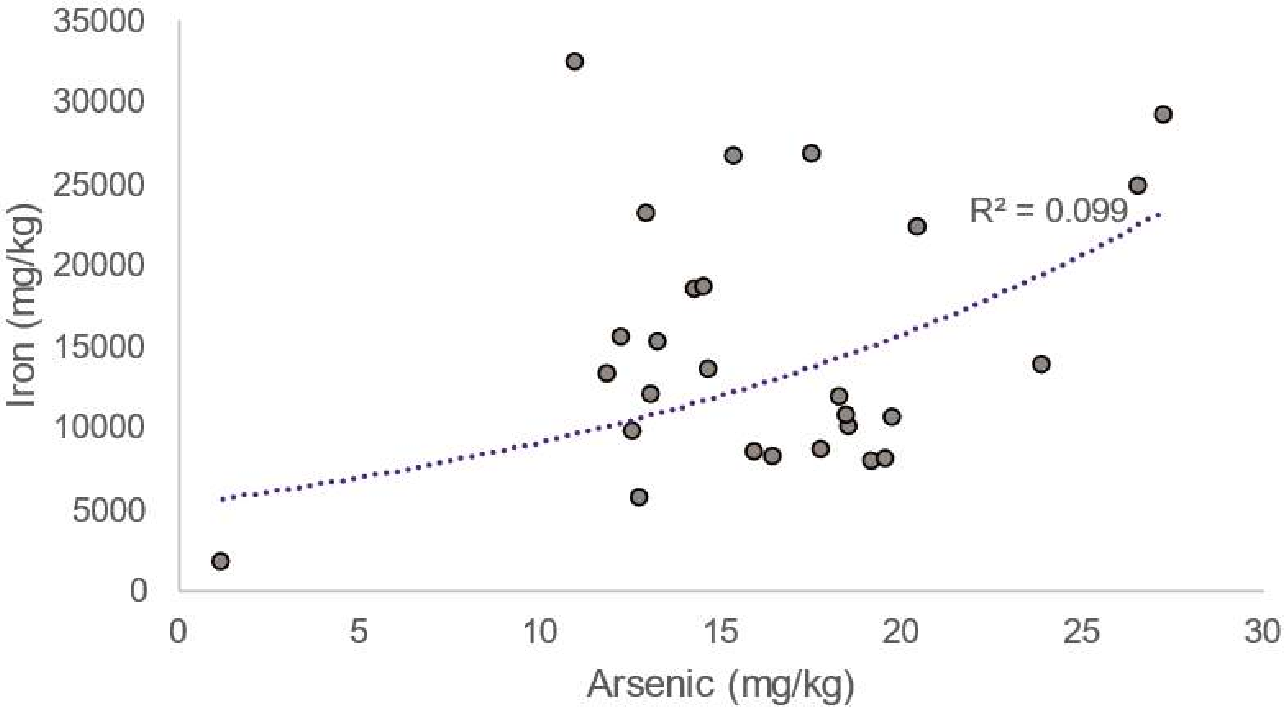


Figure 3-23: Correlation between iron and arsenic concentrations in Darwin Harbour sediment core samples

3.2.4.3 Nutrients

Total Kjeldahl nitrogen (TKN) concentrations exhibited high concentrations and variability across sites (Table 3-12; Appendix G). TKN in Darwin Harbour ranged from 40 to 240 mg/kg. Total phosphorus (TP) concentrations also exhibited high concentrations and variability across sites, ranging from 27 to 647 mg/kg. Total organic carbon (TOC) was generally very low and ranged from 0.02% to 0.6%.

3.2.4.4 Hydrocarbons

Total petroleum hydrocarbons (TPH) and total recoverable hydrocarbons (TRH) were detected above LoRs in 21 of the 27 Darwin Harbour samples, these ranging from <3 to 22 mg/kg (raw data). TPH and TRH results were normalised to 1% Total organic carbon (TOC). The normalised TPH and TRH concentrations were below the NAGD screening level of 550 mg/kg across all samples (Table 3-13; Appendix H). Polycyclic aromatic hydrocarbons (PAHs) were requested for these samples. All PAH concentrations were below the LoR.

3.2.4.5 Pesticides

Pesticide analysis was undertaken for all 27 of the Darwin Harbour sediment core samples. All pesticide chemicals analysed were below the LoR in all samples (Appendix I).

3.2.4.6 Tributyltin

Tributyltin concentrations were below the limit of reporting (LOR) in all core samples and thus well below the NAGD screening level of 9 µg.Sn/kg (Appendix J).

3.2.4.7 Potential for acid sulfate soils

Net acidity results were all below the LoR (0.02% S) (Table 3-14; Appendix K). The highest net acidity excluding acid neutralising capacity) and potential acidity (CRS) values recorded were 0.53% S (KP119-7_L). Titratable Actual Acidity (TAA) concentrations for all samples were below the LoR (0.02% pyrite S), likely due to the Acid Neutralising Capacity (ANC) present in the samples. All pH results were indicative of non-acid sulfate soils (ASS) being present – i.e. >4 pH units. All samples were found to contain significant levels of Acid Neutralising Capacity (ANC). The highest ANC concentration was 15.6% S, with the mean concentration being 10.8% S. The amount of ANC present is likely to buffer inorganic sulfur acidity within the samples. Although significant amounts of ANC are present in all samples; these are potentially an over estimation of ANC due to the crushing of large shell grit and other carbonate material during analysis – increasing the reactive surface area. The data supports a conclusion that although inorganic sulfur is present in the sediments, there is significant ANC kinetically available to neutralise the oxidation products from the inorganic sulfur.

Table 3-12: Total Kjeldahl nitrogen, total phosphorus and total organic carbon concentrations in Darwin Harbour

Sample	Total Kjeldahl nitrogen as N (mg/kg)	Total phosphorus as P (mg/kg)	Total organic carbon (%)
KP92-75_L	60	292	0.04
KP92-75_U	50	247	0.05
KP92-85_L	90	346	0.06
KP92-85_U	60	312	0.05
KP92-85_U_1	80	355	0.06
KP92-95_U	140	335	0.12
KP92-95_U_1	160	283	0.6
KP93-23_U	60	315	0.04
KP93.7_U	90	336	0.07
KP93.8_L	60	242	0.05
KP93.8_U	90	238	0.05
KP102.7_L	210	560	0.24
KP102.7_U	80	55	0.27
KP103.1_L	90	97	0.21
KP103.1_U	110	128	0.14
KP103.5_U	180	291	0.13
KP104.9_U	200	428	0.12
KP106.0_L	220	290	0.18
KP106.0_U	120	647	0.12
KP106_U_A	170	282	0.14
KP110-4_U	170	262	0.11
KP112-4_U	50	44	0.02
KP119-7_L	210	210	0.53
KP119-7_U	40	27	0.56
KP119-8_U	60	35	0.2
KP120-5_U	240	340	0.14
KP120-6_U	110	181	0.15

Table 3-13: Total recoverable hydrocarbons detected above the LOR, normalised to 1% TOC

Sample	TRH C10-C40 (Sum) (mg/kg)	TRH C10-C36 (Sum) (mg/kg)
KP92-75_L	< 3	< 3
KP92-75_U	< 3	60
KP92-85_L	< 3	50
KP92-85_U	< 3	60
KP92-85_U_1	< 3	< 3
KP92-95_U	33.3	33.3
KP92-95_U_1	< 3	5
KP93-23_U	< 3	< 3
KP93.7_U	< 3	< 3
KP93.8_L	140	220
KP93.8_U	60	60
KP102.7_L	45.8	62.5
KP102.7_U	48.1	59.3
KP103.1_L	23.8	42.9
KP103.1_U	64.3	150
KP103.5_U	115.4	123.1
KP104.9_U	50	100
KP106.0_L	83.3	88.9
KP106.0_U	133.3	166.7
KP106_U_A	128.6	157.1
KP110-4_U	81.8	72.7
KP112-4_U	< 3	< 3
KP119-7_L	5.7	7.5
KP119-7_U	5.4	< 3

Table 3-14: Summary of acid sulfate soil results

Analyte	Unit	(NT guideline levels)	Maximum result	Average result
Net acidity	% S		<0.02	<0.02
Chromium reducible sulfur (CRS)	% S		0.53	0.08
Acidity - chromium reducible sulfur	mole H+/t		328	68.2
Titratable actual acidity (TAA)	% pyrite S		<0.02	<0.02
pH_{KCl}	pH units		9.10*	9.57
Acid neutralising capacity (ANC)	% pyrite S		15.6	10.8
Net acidity excluding ANC (sulfur units)	% S		0.52	0.11
Net acidity excluding ANC (acidity units)	mole H+/t		328	68.2
Liming rate excluding ANC	kg CaCO3/t		25	5.2

*The minimum pH result has been reported, representing the most acidic (i.e. maximum) sample

3.2.5 Soft substrate benthic habitats across the study area

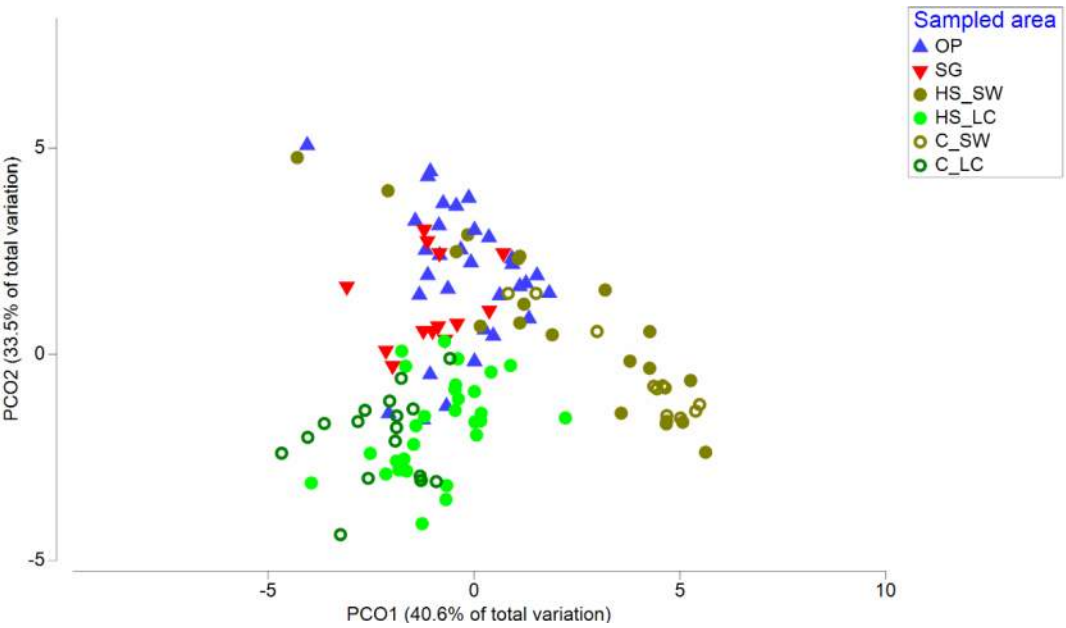
Additional comparison of particle size distributions and infauna between study areas was undertaken where relevant to provide additional understanding of broad-scale local to regional context of the seabed sediment characteristics, relative changes in substrate along the pipeline route and benthic assemblages.

3.2.5.1 Particle size distribution

Particle size data was collected from four different study areas, with two different sampling methods used in areas identified for potential dredging/trenching (both in line with the National Assessment Guidelines for Dredging (NAGD; CoA 2009). For the purposes of undertaking comparisons between the four study areas, these were defined as:

- Offshore pipeline route (OP) (from ~KP-3 to ~KP89)
- Potential spoil ground (SG)
- Darwin Harbour samples (from ~KP90 to KP122), comprising van Veen grab samples (HS#) and core samples (KP#):
  - Potential sand wave (SW) rectification area (between KP91 and KP95)
  - Landward/(shore) crossing (LC) dredging/trenching area (between KP95 and KP122.5).

Principal coordinates ordination of the particle size data from all grab and core samples indicated there were differences between the study areas, and that 74.1% of the total variation could be identified by the PCO1 and PCO2 axes (Figure 3-24). Therefore, the majority of variation can be identified from trends that can be observed in the ordination plot. For example, PCO1 identified 40.6% of total variation. By looking at trends along the x-axis, it appeared that the largest contributor to variation is the relative difference of the sand wave samples (to the right of the x-axis) to all other samples within and outside of Darwin Harbour. There also appeared to be some difference between the results of the grab sample data and core data closest to the shore crossing (e.g. KP119 and KP120, and HS1–HS5). A permutational multivariate analysis of variance (PERMANOVA) in PRIMER 7 was used to test for significant differences between the study areas (Anderson 2008). The results confirmed a significant difference in particle size distribution between study areas (Pseudo-F = 20.755, P(perm) = 0.001). Pairwise analysis in PERMANOVA identified that all sampled areas were significantly different (P(perm) = <0.05). To simplify further interpretation of relationships between grouping, cluster analysis was undertaken on the ‘average distance between/within groups’ resemblance matrix, which is one of the outcomes of the PERMANOVA pairwise comparison test (Figure 3-25). Although all groups are significantly different, the cluster analysis provided context of relative difference between each group. This showed that the particle size distribution data from the sand wave area (both grab and core samples) were less dissimilar from each other than from the other sampled areas. The cluster diagram then split, separating the offshore pipeline and spoil ground samples from the landward Darwin Harbour/shore crossing samples. The sand wave samples were characterised by very low average silt content (<2%), in contrast to the other sampled areas (>10%).



Key: OP = offshore pipeline, SG = spoil ground; HS_SW = Darwin Harbour grab sample in the sand wave area; HS_LC = Darwin Harbour grab sample in the lower harbour / shore crossing area; C_SW = core samples in the sand wave area; C_LC = core samples in the lower harbour / shore crossing area

Figure 3-24: Principal coordinates ordination (PCO) plot showing particle size distribution samples by study area

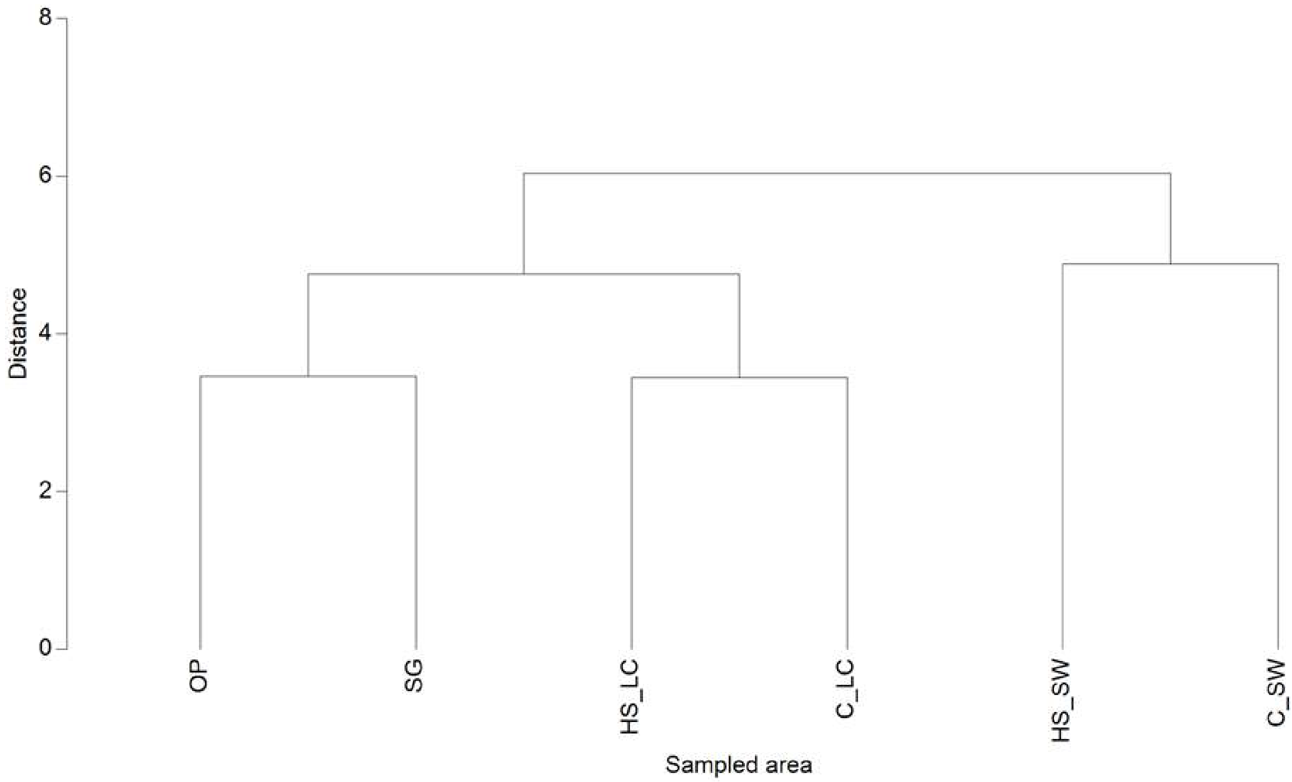


Figure 3-25: Cluster analysis of average distance between/within study area groups

3.2.5.2 Infauna

Infauna analysis was completed in two study areas: the offshore pipeline and potential spoil ground. The infaunal assemblages in these areas were dominated by crustaceans and polychaetes. Amphipod crustaceans were commonly recorded as the dominant characteristic taxa in the assemblages. These observations were consistent with investigations of soft substrate infaunal assemblages within Darwin Harbour previously completed as part of the INPEX Ichthys project baseline studies (INPEX Browse Ltd, 2010). The INPEX study recorded 416 individuals from 17 families from a total of 39 × ~0.15 m^2 van Veen grab samples (total sampled area = 5.85 m^2). This equates to an average of approximately 71.1 individuals and 2.9 families per m^2 of seabed. In the present study, 29 × 0.1 m^2 van Veen grab samples were collected from the offshore pipeline route (outside of the Darwin Port limit) with a total of 744 individuals from 81 families, which equates to approximately 256.6 individuals and 27.9 families per m^2. The thirteen 0.1 m^2 van Veen grab samples collected from the potential spoil grounds contained 185 individuals from 45 families, equating to approximately 142.3 individuals and 34.6 families per m^2. These results indicate that the soft sediment benthic habitats of the offshore pipeline route and potential spoil ground are more abundant and diverse than the Darwin Harbour soft sediment habitats reported by INPEX Browse Ltd (2010).

The results from the offshore pipeline and spoil ground infaunal analysis herein indicated a difference between the two study areas and PERMANOVA confirmed a significant difference between the two datasets (Pseudo-F = 3.4179, p(perm) = 0.001). A PCO was used to visualise the differences between datasets, and to identify the variation explained by individual axes (Figure 3-26). A total of 24.2% of the total variance is identified by the PCO1 and PCO2 axes. Similarity percentages breakdown (SIMPER) analysis was used to characterise the taxa contributing to the variability between the two datasets. Of the top 70% of taxa contributing to the variation between the two datasets, 26 OP taxa (11 crustaceans, 14 polychaetes and two sipunculids representing 53.61% of 70.17%)) were identified as different by virtue of greater abundance. The remaining 16.56% of the variation was comprised of crustacean (three taxa), echinoderm (one taxa) and polychaetes (three taxa) taxa with increased abundance in the SG sites.

This difference between the OP and SG sites is likely to be due to a combination of factors. For example, there were more than twice as many OP sites collected over a much greater spatial area (>90 km of the proposed pipeline route), along a transitional environment (the Beagle Gulf) between the eastern area influenced by the narrows and Darwin Harbour to the western area, influenced by the open ocean. In contrast, the SG sites were collected over an area of generally flat seabed (in terms of relief) of approximately 5 km by 5 km and therefore the potential for seabed and infaunal community heterogeneity is therefore much more limited.

The transitional environment of the Beagle Gulf and along the proposed pipeline route was also evident in the particle size data (refer to Sections 3.2.5.1). Sediments in Darwin Harbour and in the spoil ground were characterised by mixed sediments, with relatively high silt/gravel to sand contributions (silt = 16.4% and 19.2%, respectively; gravel = 50.7% and 31.7%, respectively; sand = 30.6% and 49.1%, respectively). The western sediments were dominated by the sand fraction (average ~60%), and with lower silt (~11.4%) and gravel content (~29%). Infauna community composition is influenced by environmental factors such as PSD, and therefore PSD is both an indicator of a transitional habitat and a contributory cause of infaunal community heterogeneity in the dataset.

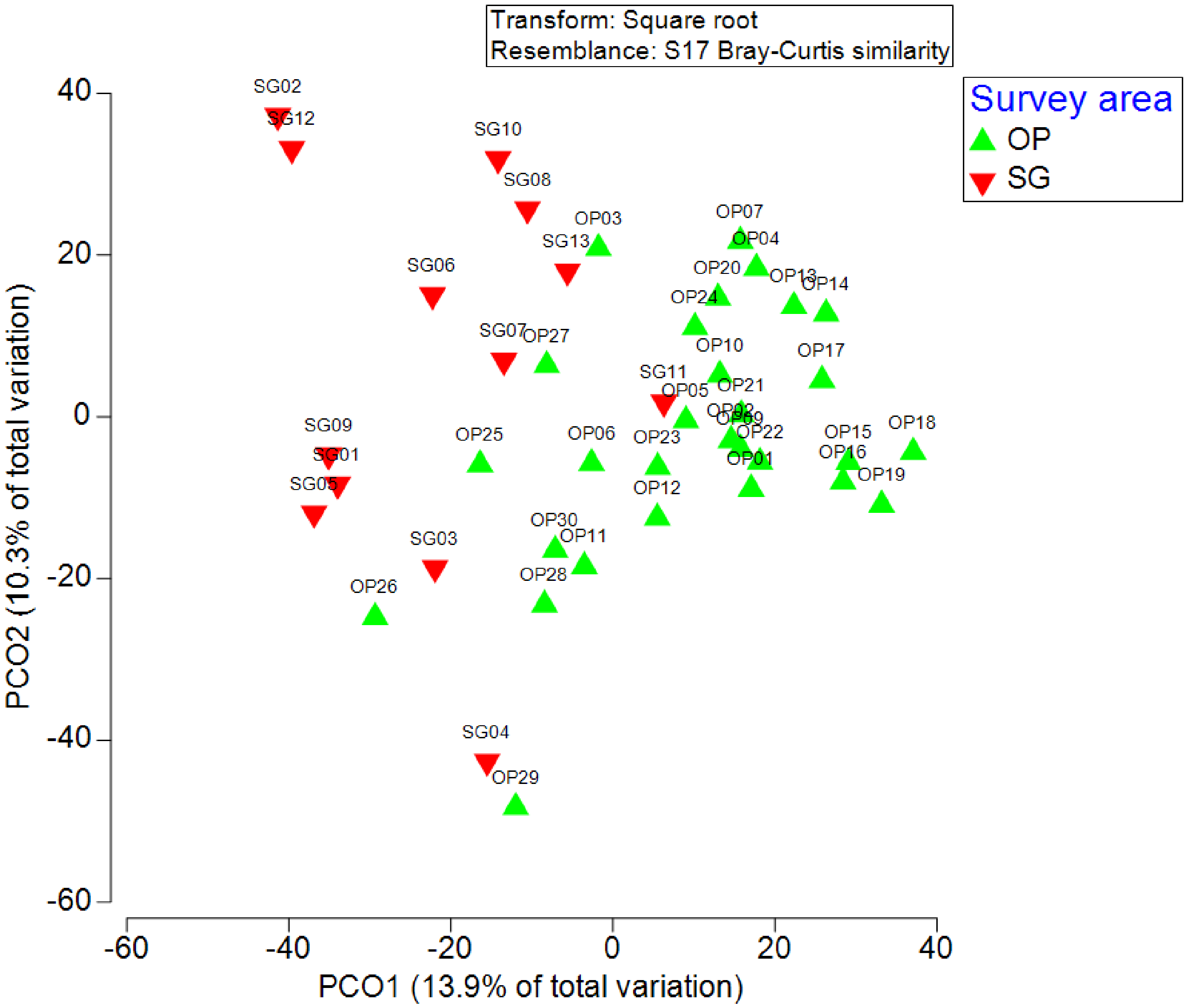


Figure 3-26: Principal coordinates ordination (PCO) of offshore pipeline (OP) and spoil ground (SG) infaunal data

3.3 Water quality

3.3.1 Offshore pipeline

3.3.1.1 CTD Data

CTD profile data from the offshore pipeline water sampling locations are presented in Figure 3-27 to Figure 3-36. Temperature was either consistent with depth at sample sites or decreased by up to >1 degree over >40 m depth range (e.g. OP2).

Salinity was either consistent or changed marginally over depth – except at sites OP1b and OP2b, where an increase in salinity was recorded over the 0–10 m depth range (particularly notable at site OP1).

Turbidity at sites OP1 to OP6 (except OP2) decreased in the 0 to 15–20 m depth range, then gradually increased with increasing depth. A similar trend may occur at sites OP7, but less obviously. Turbidity at sites OP2 and OP8 were relatively consistent over the depth profile. Turbidity increased with depth at site OP10.

Oxygen levels tended to increase with increasing depth at sites OP1 to OP4 and sites OP7 to OP10. At site OP5, oxygen increased between the surface and around 20 m, with gradually decreased with increasing depth. At site OP6, oxygen levels decreased between the surface and around 10 m, then remained fairly consistent through the water column.

pH decreased with increased depth at sites OP1, OP3, OP4, OP7, OP8 and OP9. In contrast, pH profiles increased with increasing depth at sites OP6b and OP10. At site OP2, pH gradually increased with depth. But an increase in pH was recorded between ~25 m and ~35 m, before decreasing. At site OP5, pH was relatively consistent throughout the water column, except at depths ~15 to 20 m and ~35 m to >50 m where there was a relatively large drop from a pH of 11.5 to 9.5.

3.3.1.2 Metals

Five of the filtered and unfiltered metals and metalloids were below the LoR for all sites, except OP1S. These were cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni) and mercury (Hg). OPS1 had filtered nickel and unfiltered chromium concentrations that were above the LoR (1.5 µg/L and 0.3 µg/L, respectively; Appendix G).

Filtered and unfiltered copper (Cu) concentrations ranged from <0.2 to 8.4 µg/L (Figure 3-37). Three of the copper samples were above the ANZG (2018) DGV (for slightly to moderately Figure 3-37 disturbed marine offshore ecosystems, at the 95% species protection level) of 1.3 µg/L, in slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level (Figure 3-37). These results were for unfiltered copper at OP1S and Triplicate B (taken from sample OP8S), and for filtered copper at OP2S. The highest filtered copper concentration was recorded at OP2S (8.4 µg/L), while all other samples had copper concentrations under 1.6 µg/L.

Unfiltered zinc (Zn) concentrations ranged from <1 to 9 µg/L and were at or above the ANZG (2018) DGV of 8 µg/L at two sites (OP1S and OP5S). Filtered zinc concentrations ranged from 1 to 9 µg/L, with three samples being at or above the DGV (Figure 3-37). The filtered and unfiltered arsenic (As) concentrations were very similar. Samples ranged from 1.3 to 1.9 µg/L, with all recorded concentrations below the ANZG (2018) DGV of 4.5 µg/L (Figure 3-37). Filtered and unfiltered lead (Pb) concentrations ranged from <0.1 to 5.4 µg/L (Figure 3-37). Ten unfiltered lead samples below the LoR, whilst six filtered lead samples were below the LoR. One sample of filtered lead (OP5S) was above the ANZG (2018) DGV of 4.4 µg/L in slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level.

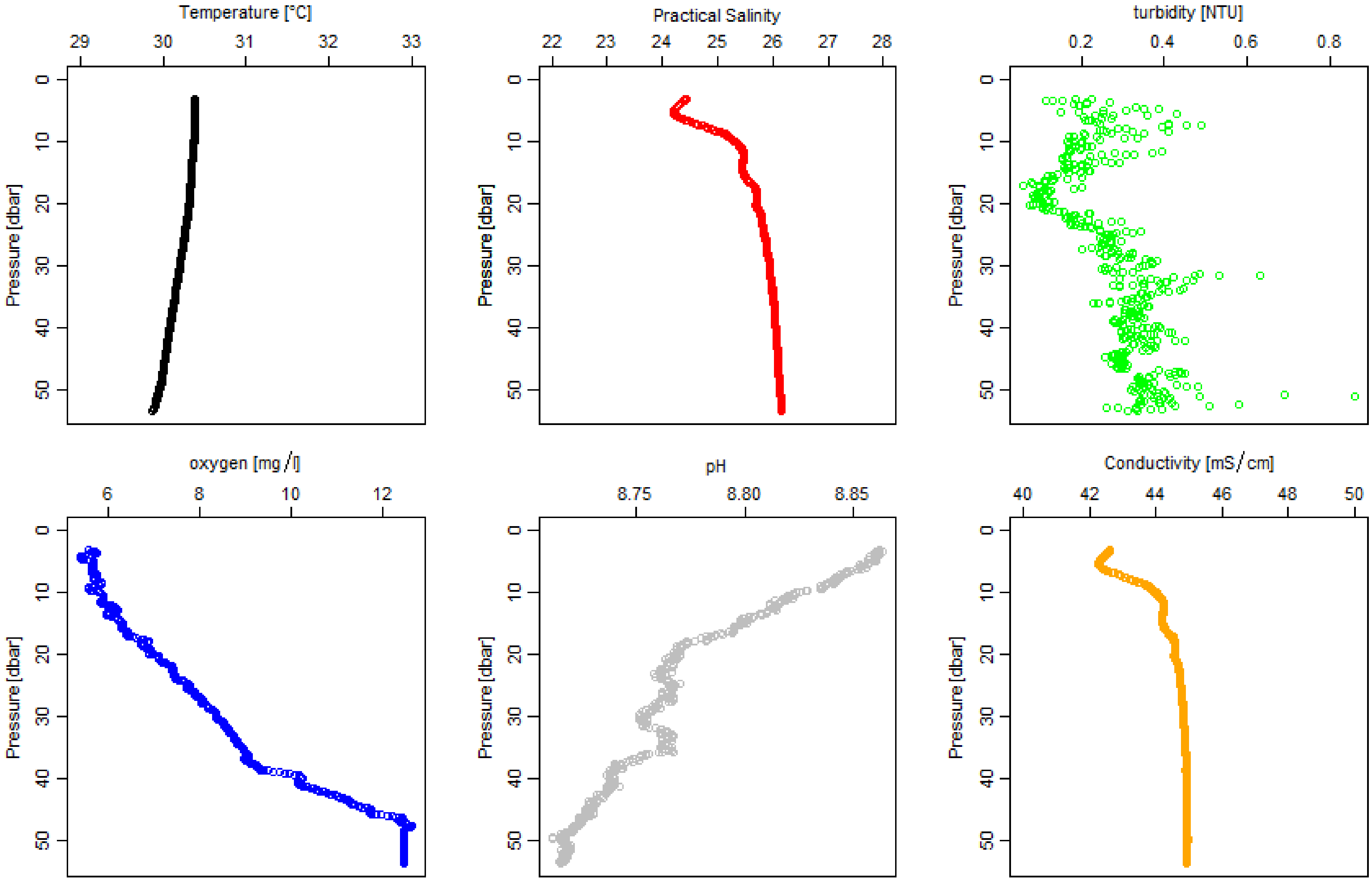


Figure 3-27: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP1

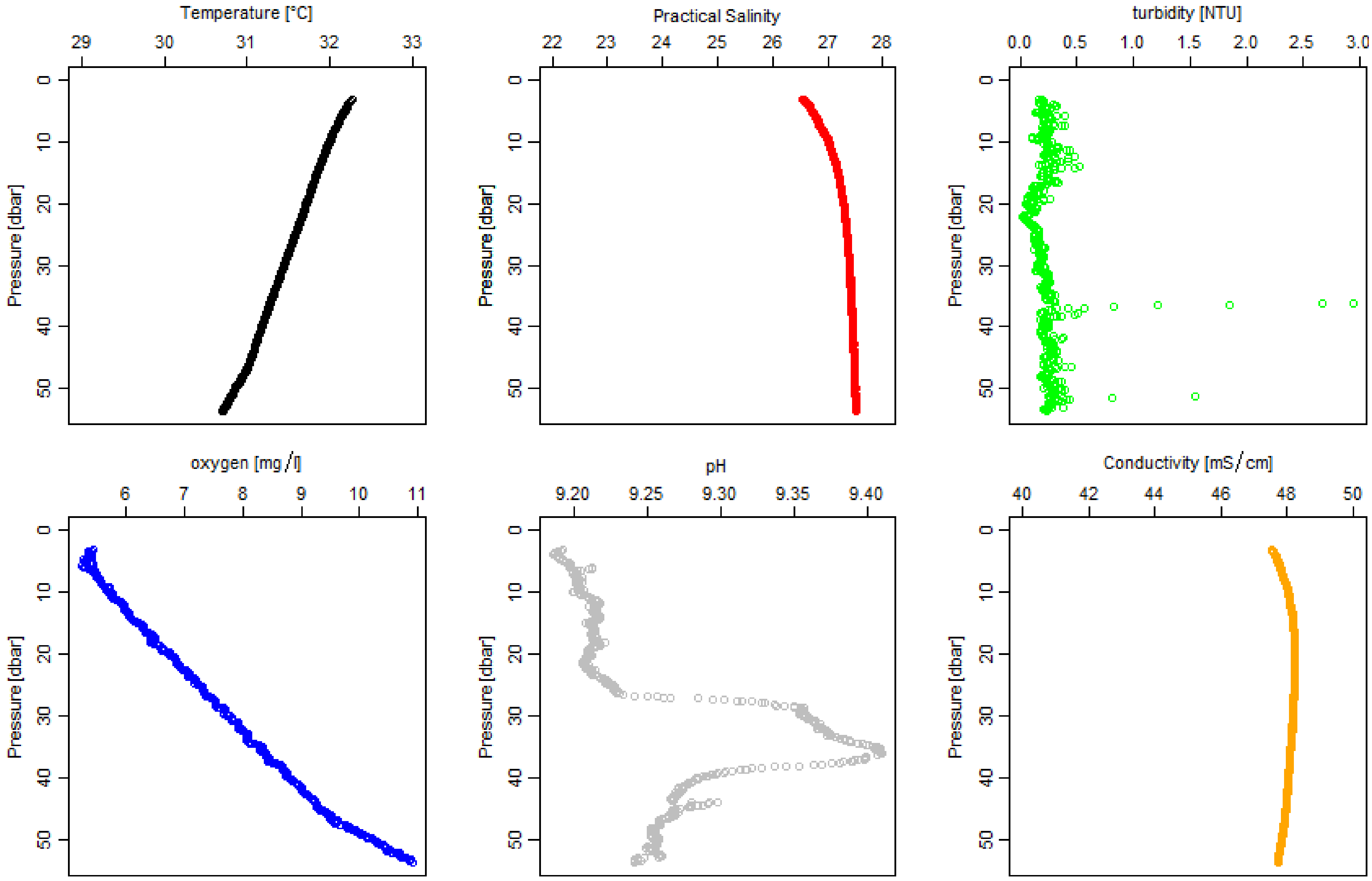


Figure 3-28: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP2

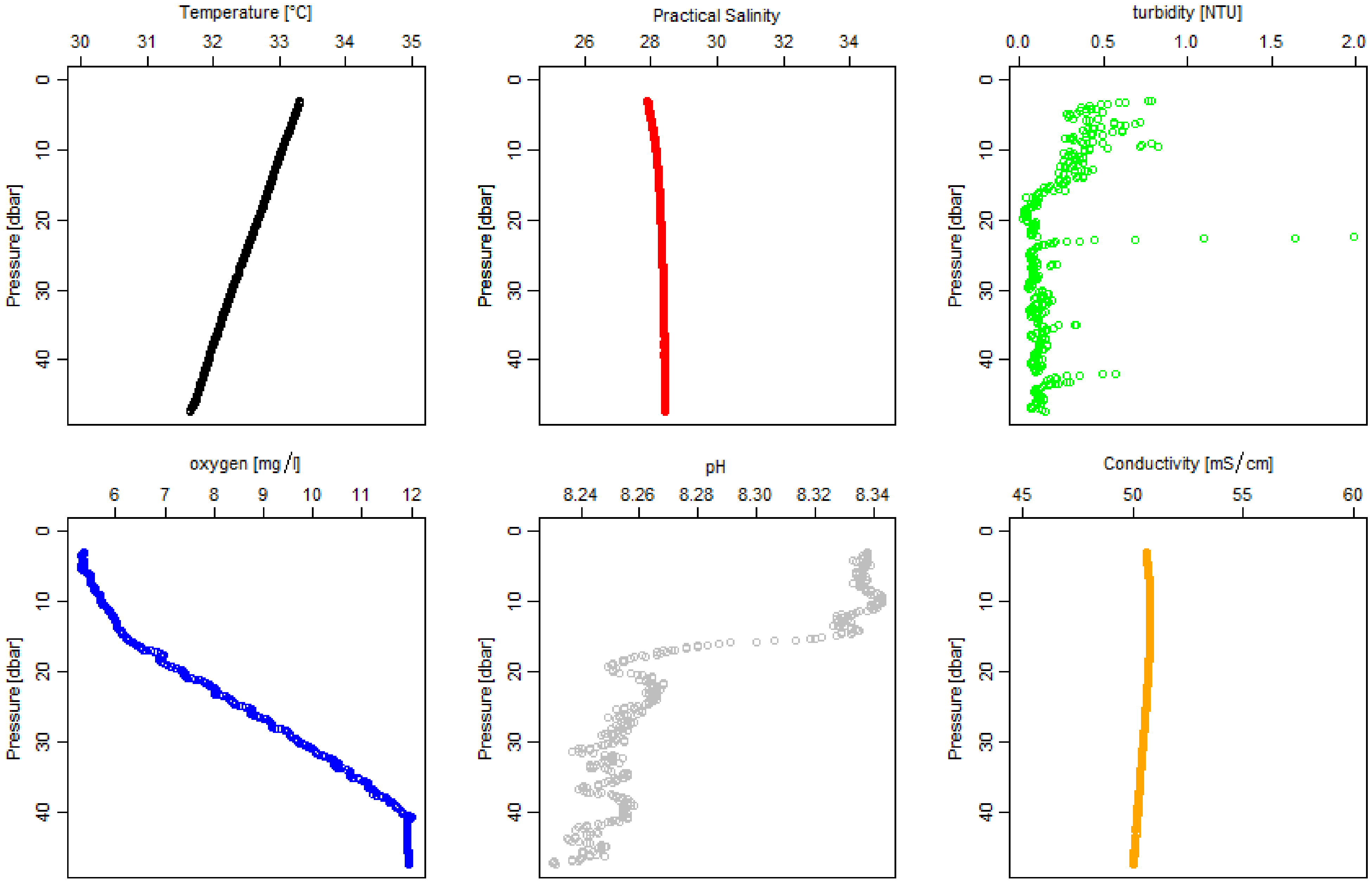


Figure 3-29: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP3

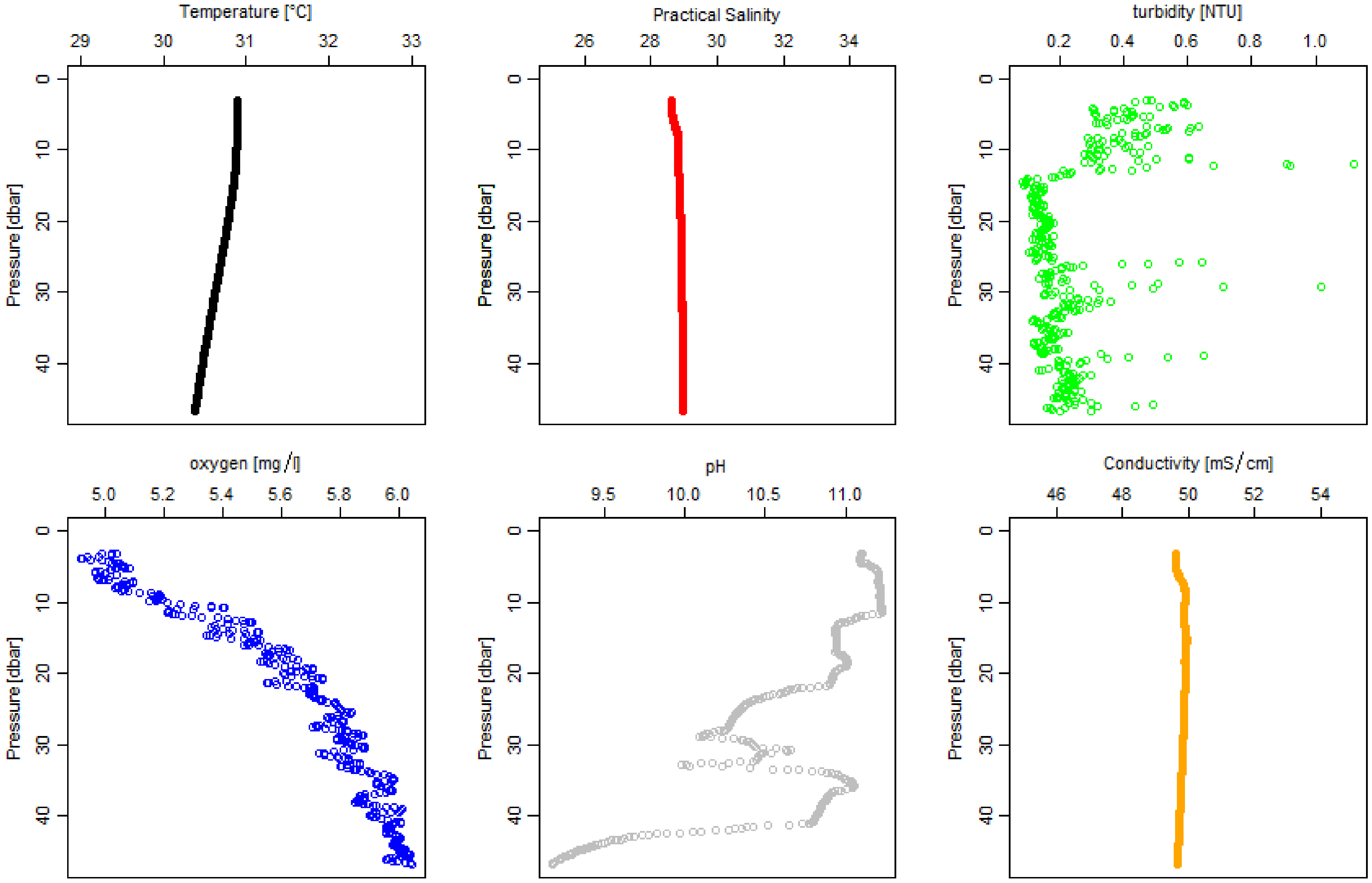


Figure 3-30: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP4

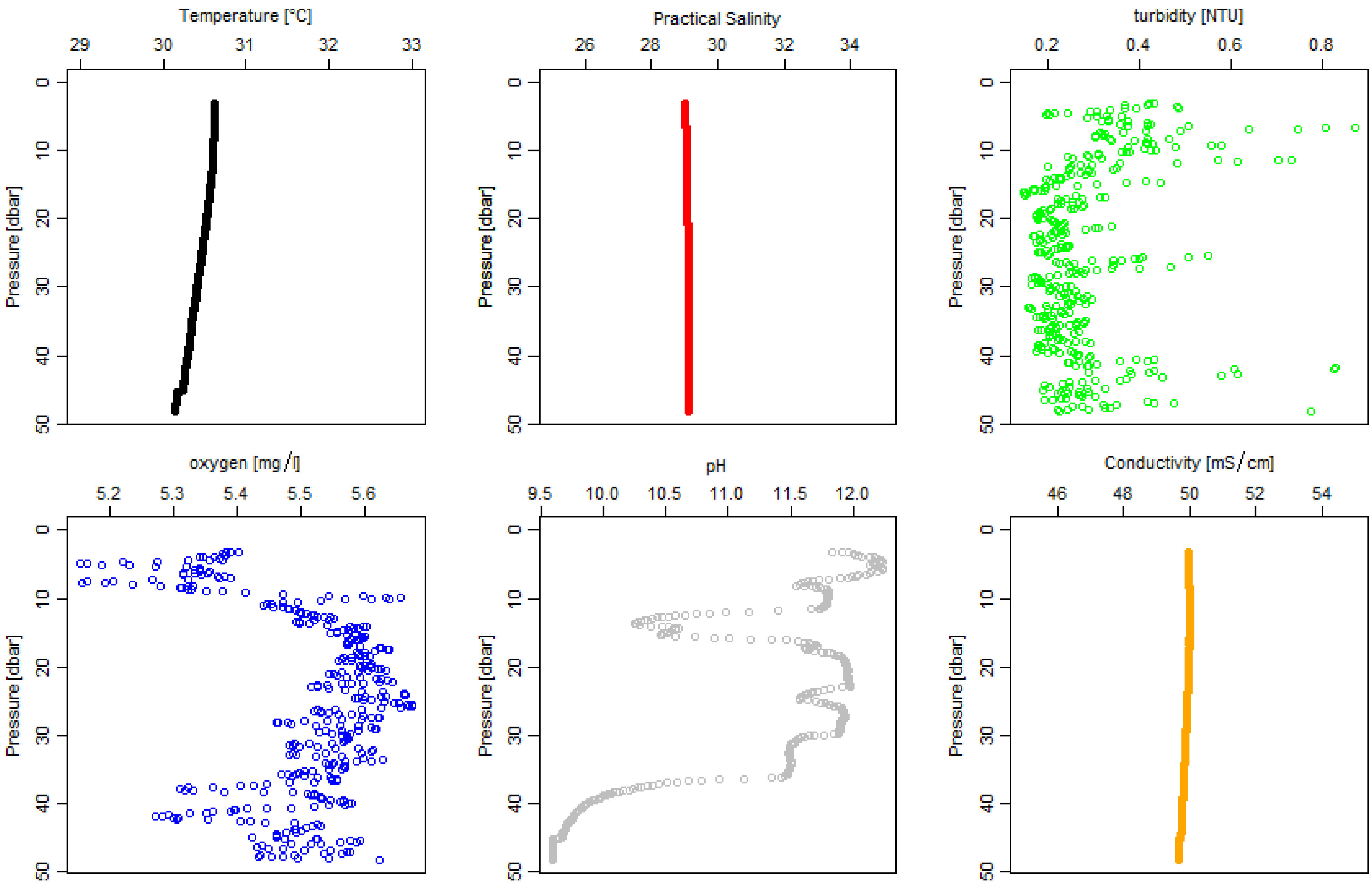


Figure 3-31: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP5

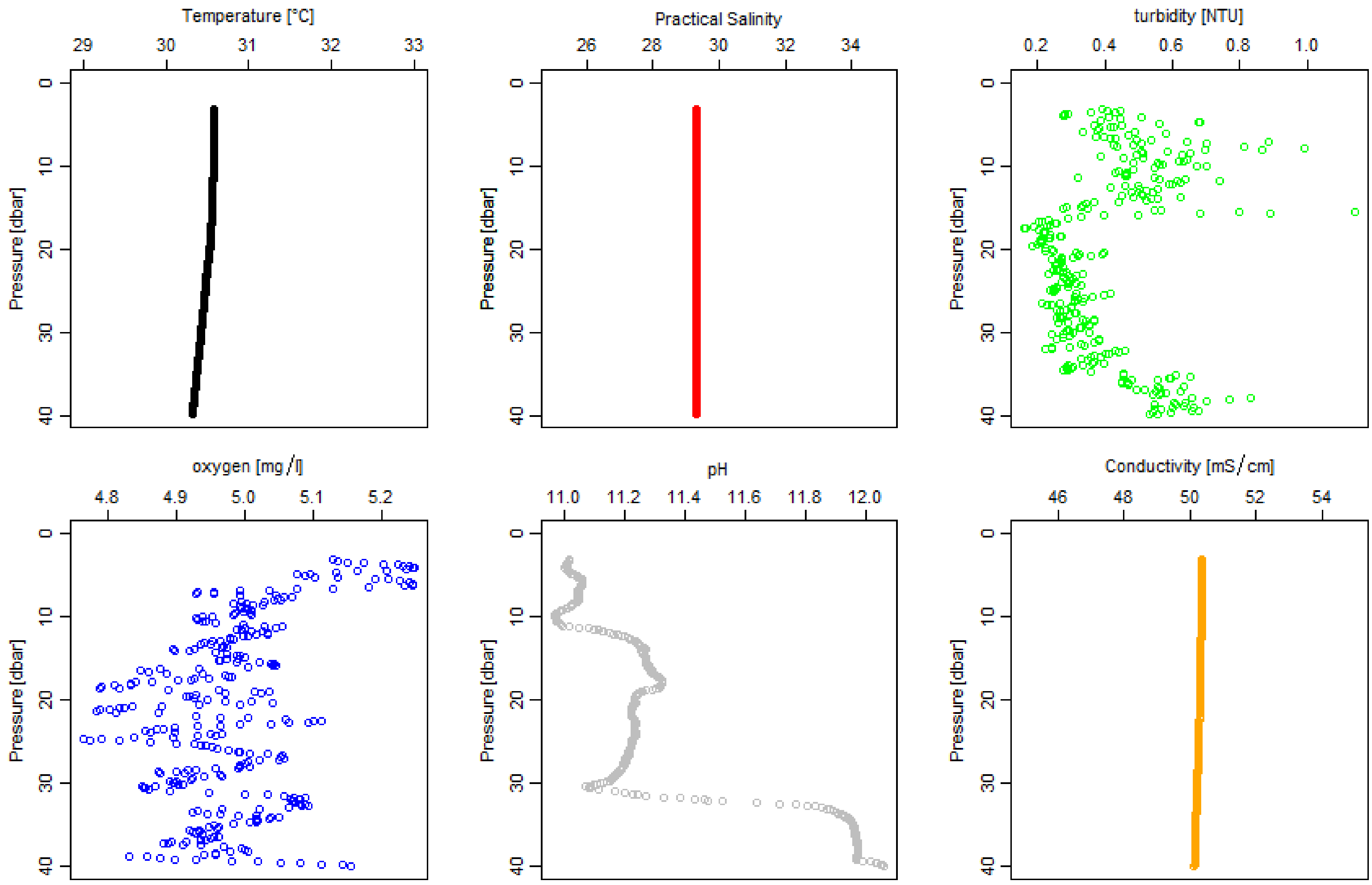


Figure 3-32: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP6

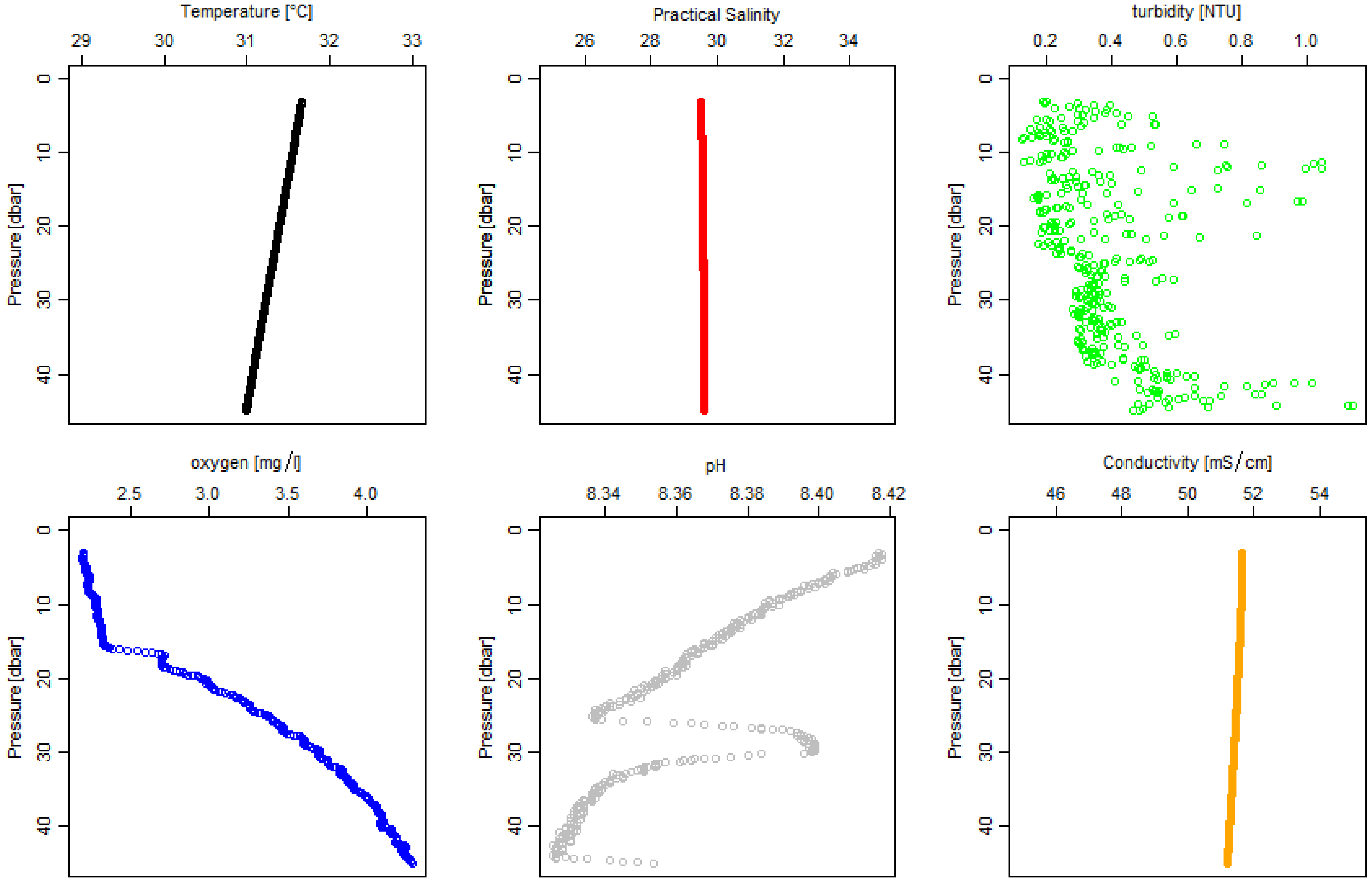


Figure 3-33: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP7

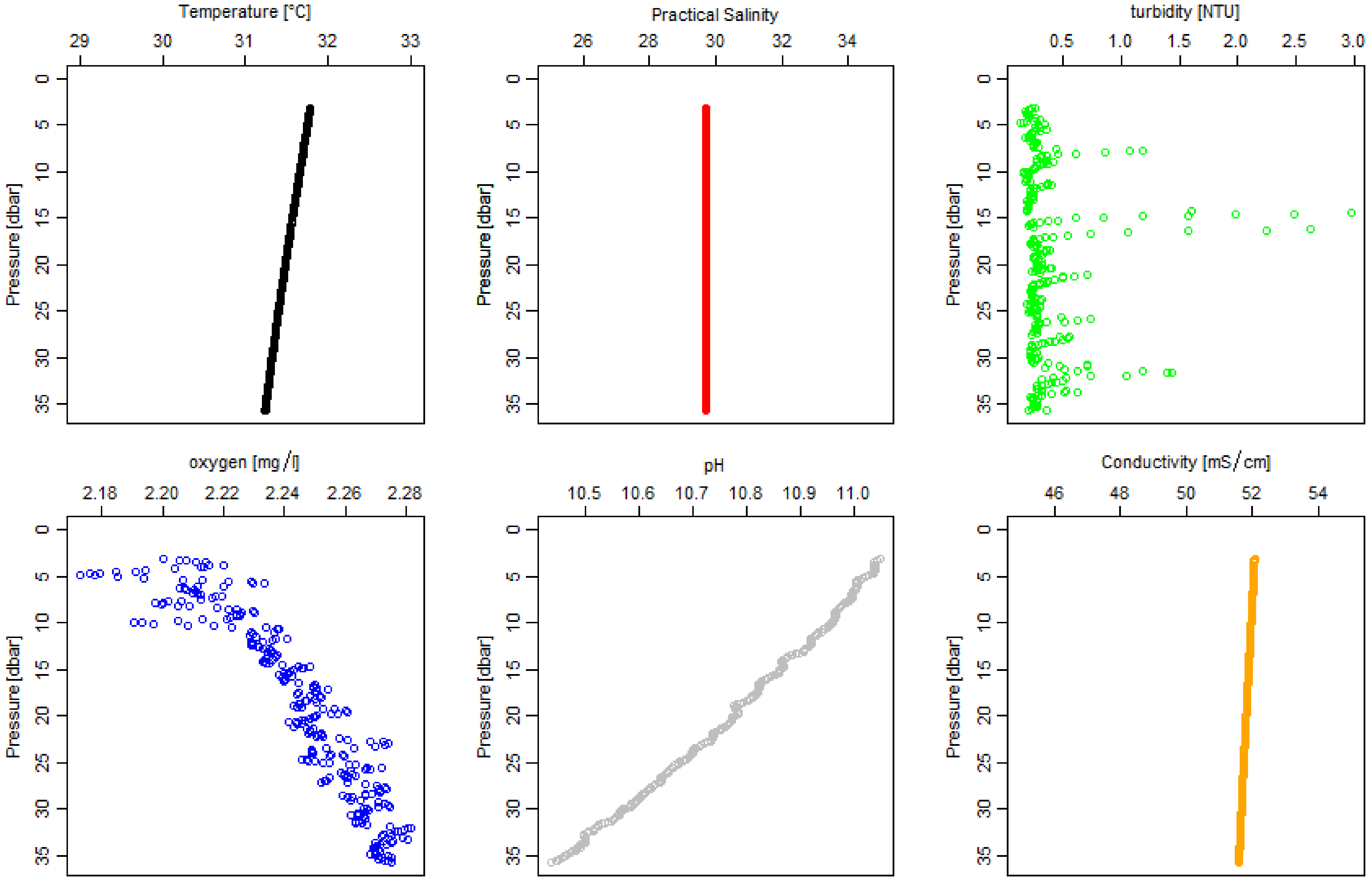


Figure 3-34: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP8

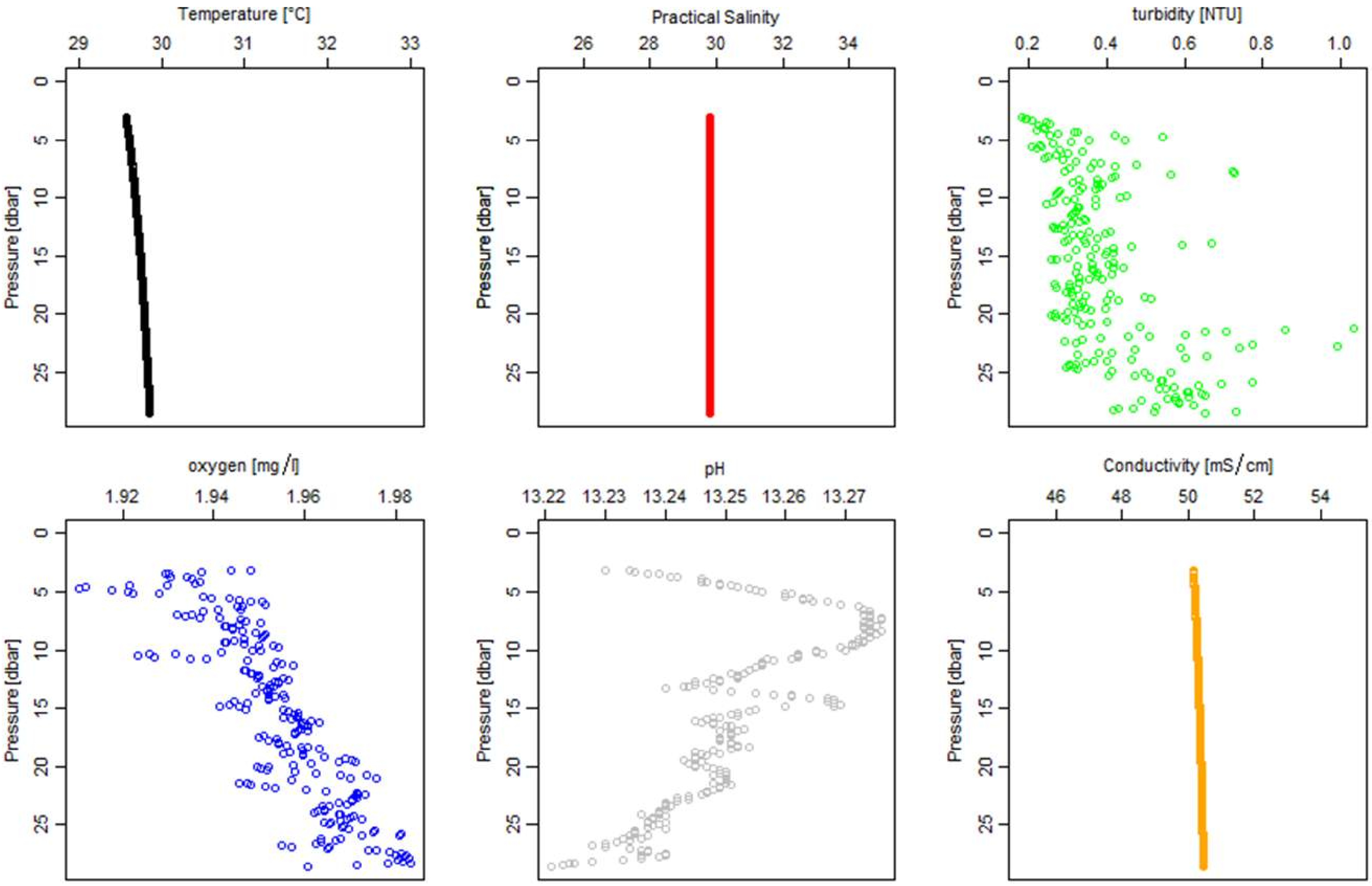


Figure 3-35: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP9

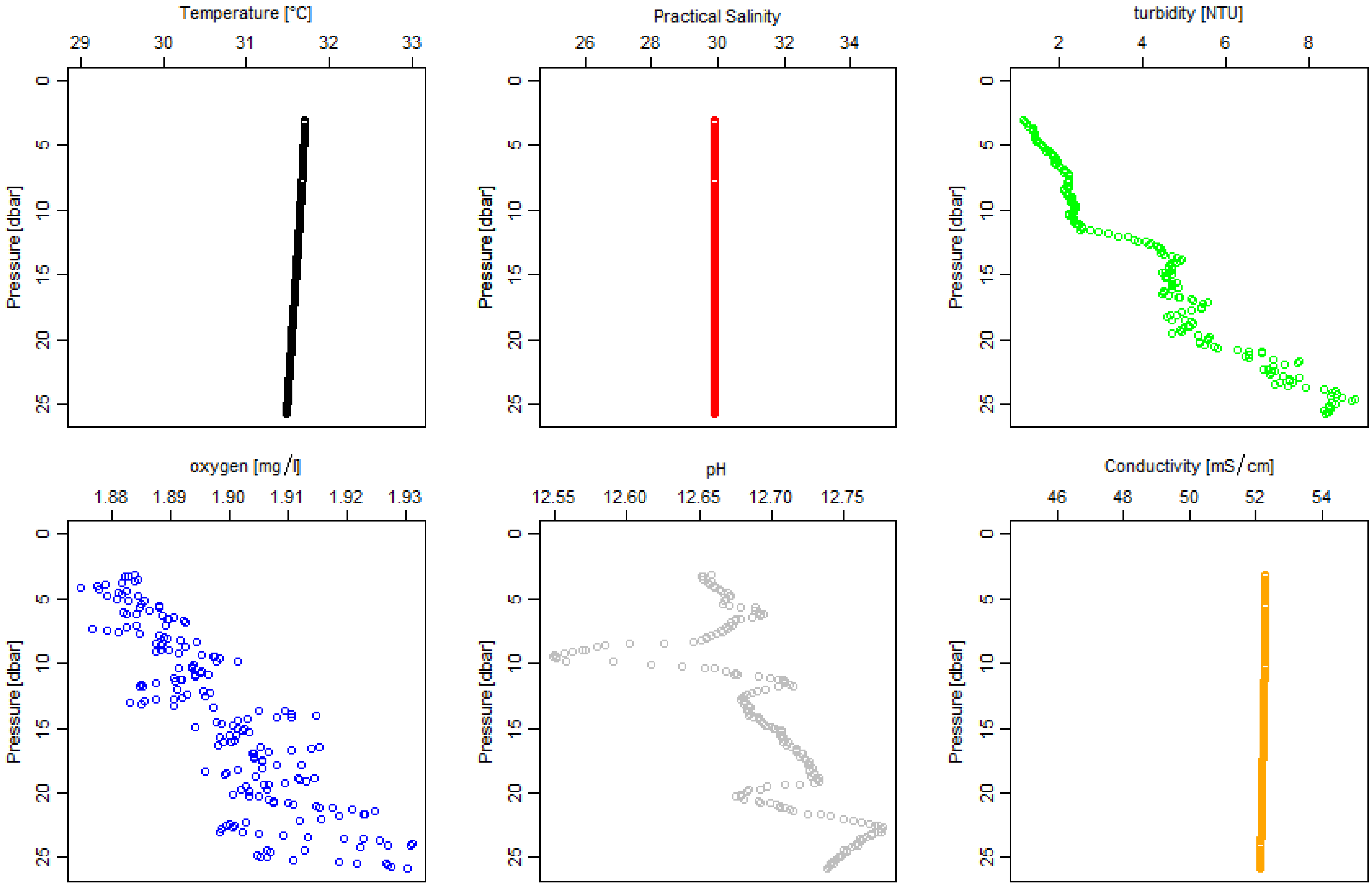


Figure 3-36: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site OP10

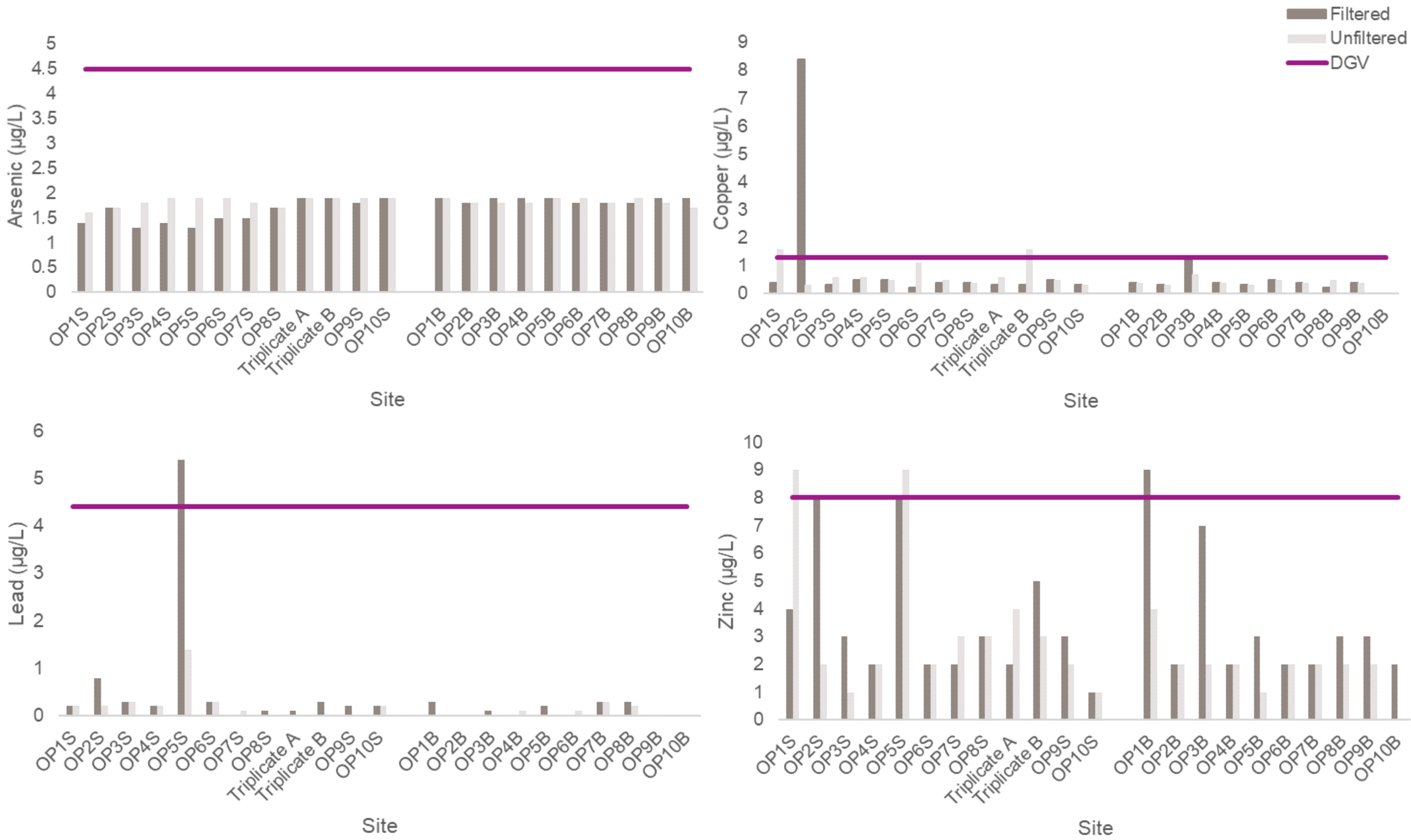


Figure 3-37: Filtered and unfiltered metal concentrations above LoRs from the offshore pipeline route (from south to north)

3.3.1.3 Nutrients and pigments

3.3.1.3.1 Nitrogen

The test for total nitrogen provided data for all nitrogen compounds in the water samples, namely nitrite (NO_2), nitrate (NO_3), ammonia (NH_4+) and organic nitrogen compounds (Appendix G).

Nitrite and nitrate were recorded at detectable levels at all sites, except for site OP8S/B. Nitrite and nitrate were recorded at concentrations of <2 to 15 µg.N/L in the bottom water samples, with all surface samples being below the LoR. These values are below the ANZG (2018) DGV for physical and chemical stressors in the Anson Beagle bioregion for nitrate in summer of 0.181 µmol NO_3-N/L (11.22 µg.N/L) in surface waters and 1.717 µmol NO_3-N/L (106.46 µg.N/L) in bottom waters.

Ammonia was detected in 11 samples, with ten of those being bottom (near seabed) samples. Only one surface sample had detectable concentrations of Ammonia (OP5S), with a concentration of 7 µg.N/L being recorded from this sample. All samples were below the ANZG (2018) DGV (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) of 910 µg.N/L.

Total nitrogen concentrations indicated the presence of other organic nitrogen compounds, with no samples (excluding the field and transport blanks) being below the LoR concentration of 50 µg.N/L. Total nitrogen concentrations ranged from 80 to 150 µg.N/L. There is no ANZG (2018) default guideline value for total nitrogen.

3.3.1.3.2 Phosphorus

The results for TP comprise the concentration of phosphorus that occurs in orthophosphate and organic phosphate compounds (Appendix G).

Orthophosphate (filterable reactive phosphorus) concentrations ranged from <2 to 8 µg.P/L. All but two samples were above the LoR, and both samples were surface samples (OP3S and OP4S). No samples exceeded the ANZG (2018) DGV for physical and chemical stressors in the Anson Beagle bioregion for phosphate of 0.209 µmol PO_4-P/L (19.85 µg.P/L) in surface waters and 0.427 µmol PO_4-P/L (40.55 µg.P/L) in bottom waters for summer.

TP concentrations ranged from 9 to 17 µg.P/L. There is no ANZG (2018) default guideline value for TP.

3.3.1.3.3 Pigments

Chlorophyll-a concentrations were used as an indicator of the likely level of phytoplankton biomass across the offshore pipeline area. Chlorophyll-a concentrations ranged from 0.4 to 1.5 µg/L (Figure 3-38; Appendix G). All concentrations were below the ANZG (2018) DGV for physical and chemical stressors in the Anson Beagle bioregion value for chlorophyll-a of 2.568 µg/L in summer. Concentrations were variable across surface and bottom samples.

Phaeophytin-a was also sampled as this pigment is a breakdown product of chlorophyll-a and can be used to indicate if phytoplankton are blooming or declining. Phaeophytin-a was detected in ten samples, the majority of which were at the surface (Figure 3-38). Concentrations ranged from <0.2 µg/L (i.e. below the LoR) to 0.6 µg/L. There is no ANZG (2018) default guideline value for phaeophytin-a.

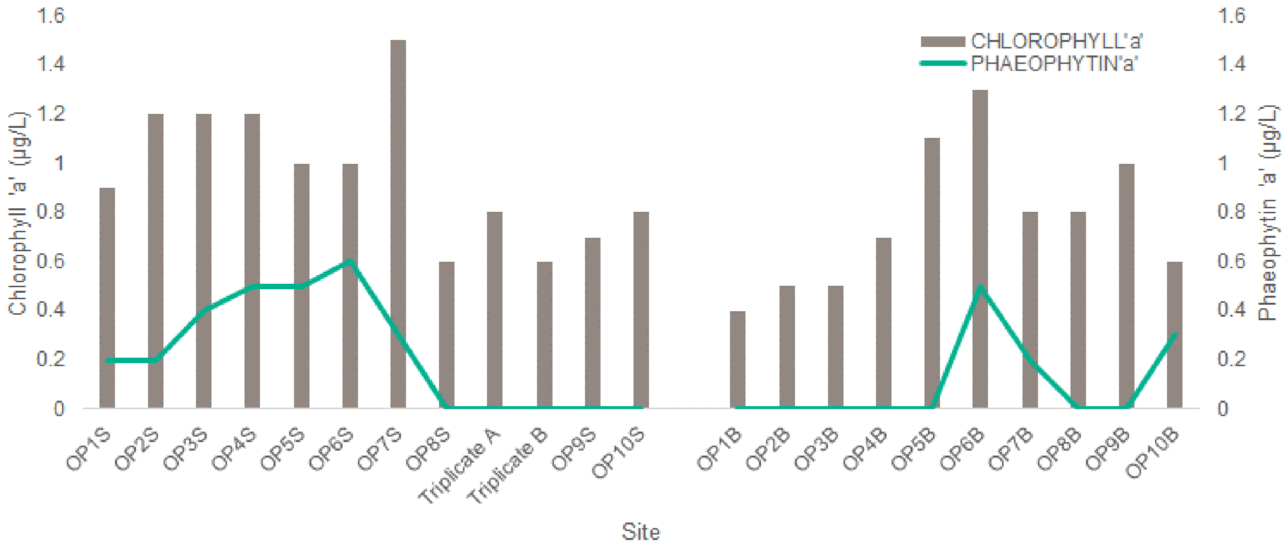


Figure 3-38: Surface and bottom chlorophyll-a and phaeophytin-a concentrations along the offshore pipeline route

3.3.1.3.4 Total suspended solids

Total suspended solid (TSS) concentrations were all above the LoR (0.5 mg/L) and ranged from 1.7 to 8.6 mg/L (Appendix G). Most sites had TSS between 1.7 and 4 mg/L, however site OP10S/B was much higher, with 8.6 mg/L at the surface and 7.7 mg/L at the bottom. OP10S/B was the closest water quality site to Darwin Harbour but was sampled on an incoming tide. There was no correlation between depth and TSS.

3.3.1.4 Hydrocarbons

The offshore pipeline TRH and BTEXN concentrations were below the limit of reporting (LoR) for all samples (Appendix H). The offshore pipeline samples were, therefore, not tested for PAHs.

3.3.1.5 Naturally occurring radioactive materials

NORMS were detected in near-seabed samples at two of the offshore pipeline sites. Radium-226 was recorded at concentrations of 0.023 Bq/L in sample OP4B and 0.018 Bq/L in sample OP6B (Appendix F).

3.3.2 Spoil ground

3.3.2.1 CTD data

Data from the CTD profiles are presented in Figure 3-39 to Figure 3-45. Temperature was either consistent with depth or decreased by up to <0.5 degrees over ~20 m depth range. Salinity was generally consistent with depth or increased slightly (with no evidence of a halocline). Turbidity generally increased with increasing depth, with the most marginal change recorded at site SG1 and the greatest increase recorded at site SG8. Oxygen levels increased by 0.5 to 1 mg/l over a >20 m depth profile at all sites. The pH data from the spoil ground sites was inconsistent, and it was likely that the pH probe had developed a fault during these deployments.

3.3.2.2 Metals

Five of the filtered and unfiltered metals and metalloids were below the LoR concentrations for all sites. These were cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni) and mercury (Hg) (Appendix G). Due to an issue with the sample jar, unfiltered metals were not analysed for Triplicate D.

Filtered and unfiltered copper (Cu) concentrations ranged from <0.2 to 0.6 µg/L (Figure 3-46). Only two unfiltered copper samples were below the LoR (Triplicate C and SG7B), while five filtered copper samples were below the LoR (SG12S, Triplicate D, SG13S, SG4S and SG7B). None of the copper samples were above the ANZG (2018) DGV (for slightly to moderately disturbed marine offshore ecosystems, at the 9% species protection level) of 1.3 µg/L (Figure 3-46).

Unfiltered zinc (Zn) concentrations ranged from <1 to 2 µg/L and were below the ANZG (2018) DGV (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) of 8 µg/L for all sites. Filtered zinc concentrations ranged from 2 to 18 µg/L, four of these samples were at or above the DGV (Figure 3-46). The highest zinc concentration was at SG4B.

The filtered and unfiltered arsenic (As) concentrations were above the LoR and were very similar. Samples ranged from 1.6 to 1.9 µg/L, with all recorded concentrations below the ANZG (2018) DGV (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) of 4.5 µg/L (Figure 3-46).

Filtered and unfiltered lead (Pb) concentrations ranged from <0.1 to 0.4 µg/L (Figure 3-46). Only three unfiltered lead samples were below the LoR (Triplicate C, SG8S and SG1B), while six filtered lead samples were below the LoR (SG12S, Triplicate C, Triplicate D, SG8S, SG4S, SG13B and SG8B). All lead samples were well below the ANZG (2018) DGV (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) of 4.4 µg/L.

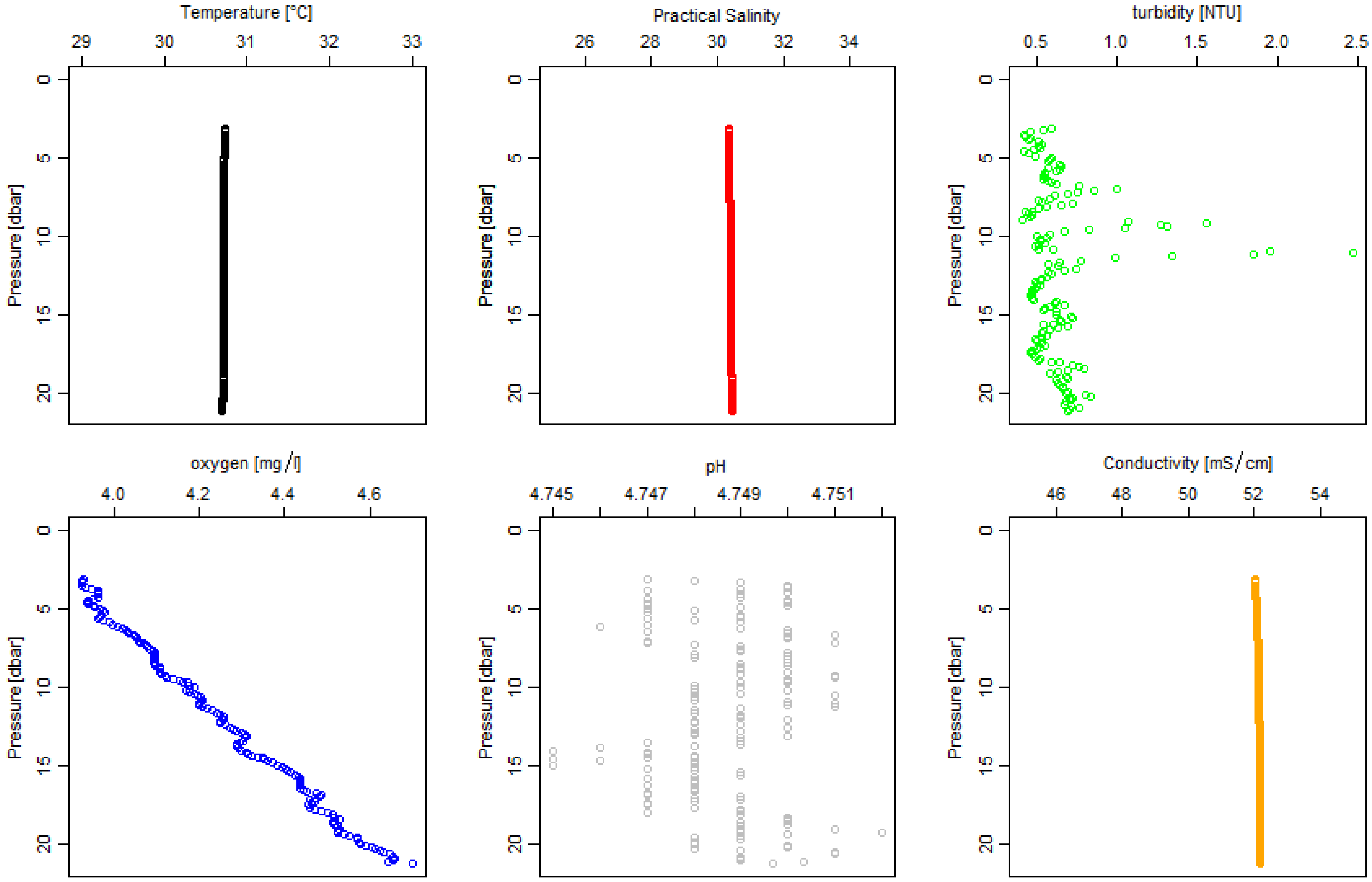


Figure 3-39: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG1

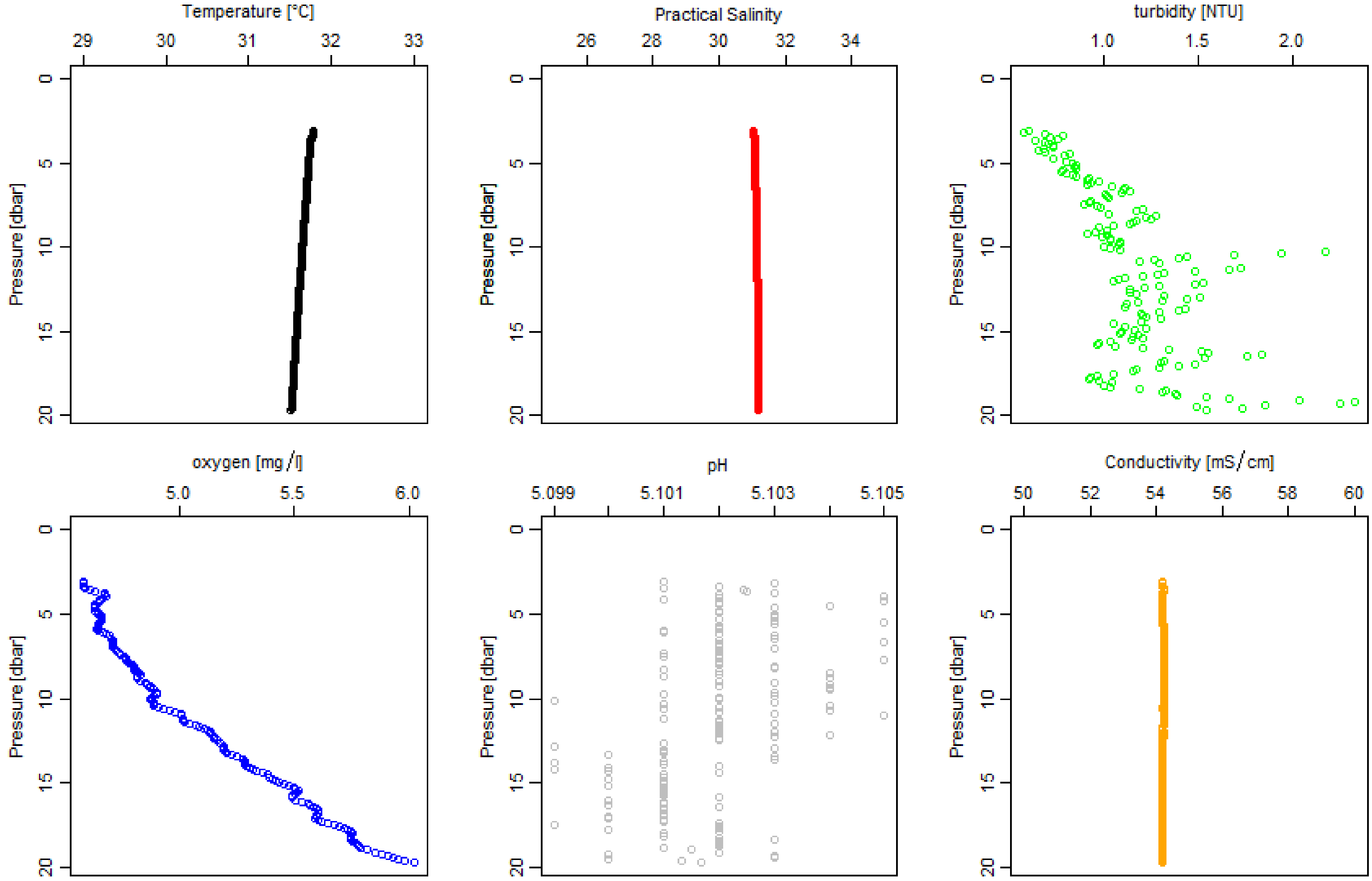


Figure 3-40: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG4

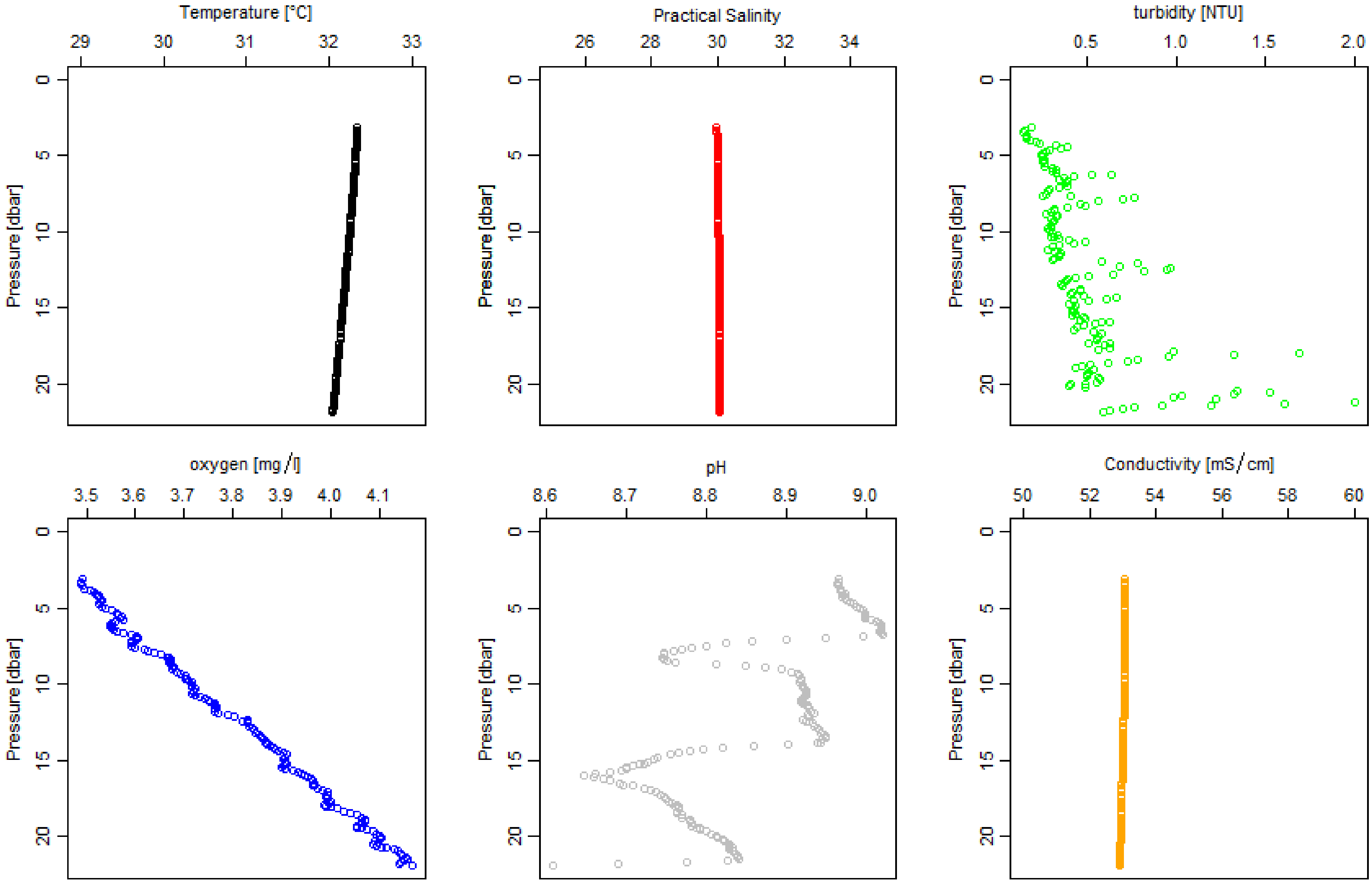


Figure 3-41: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG7

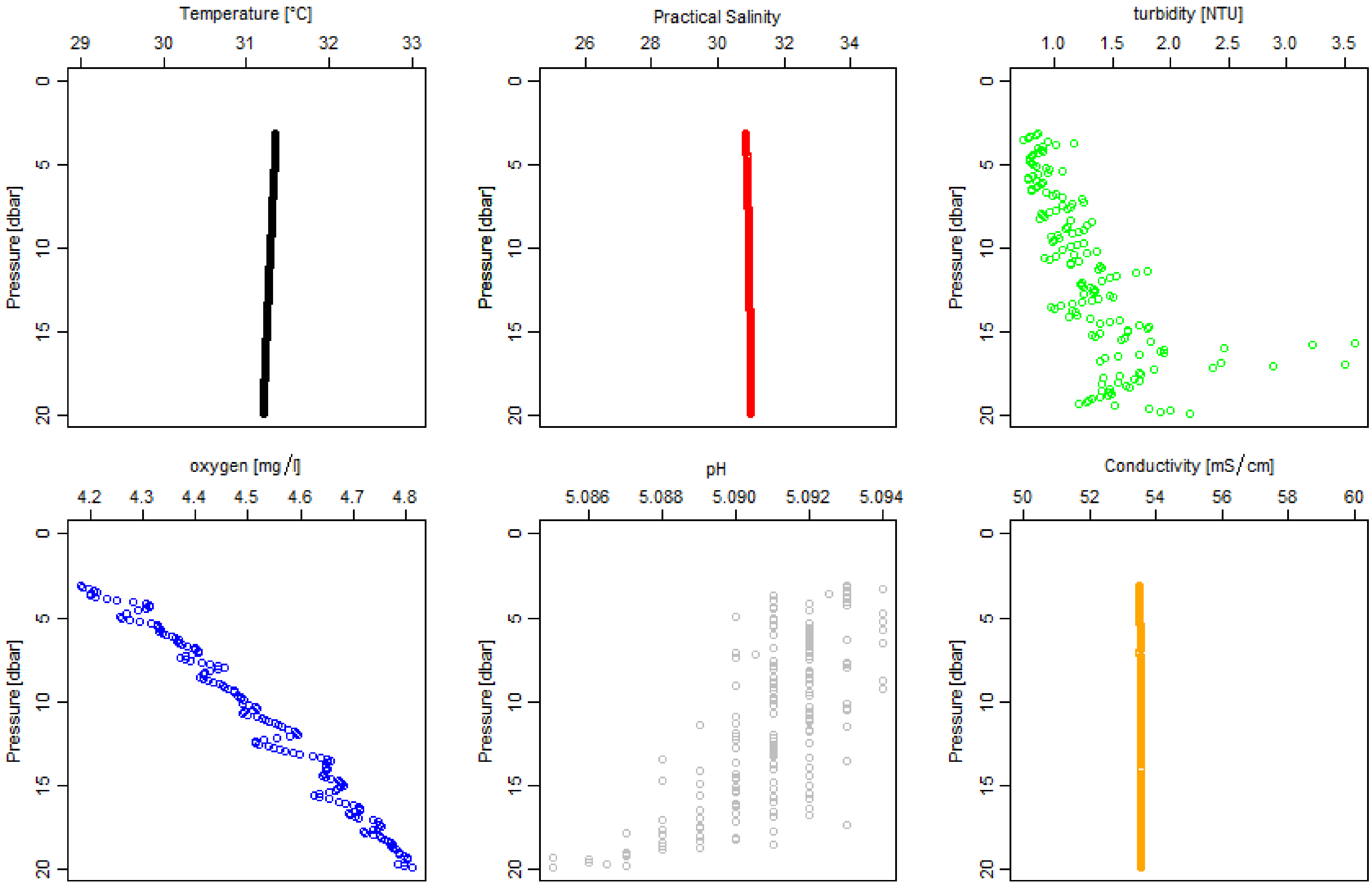


Figure 3-42: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG8

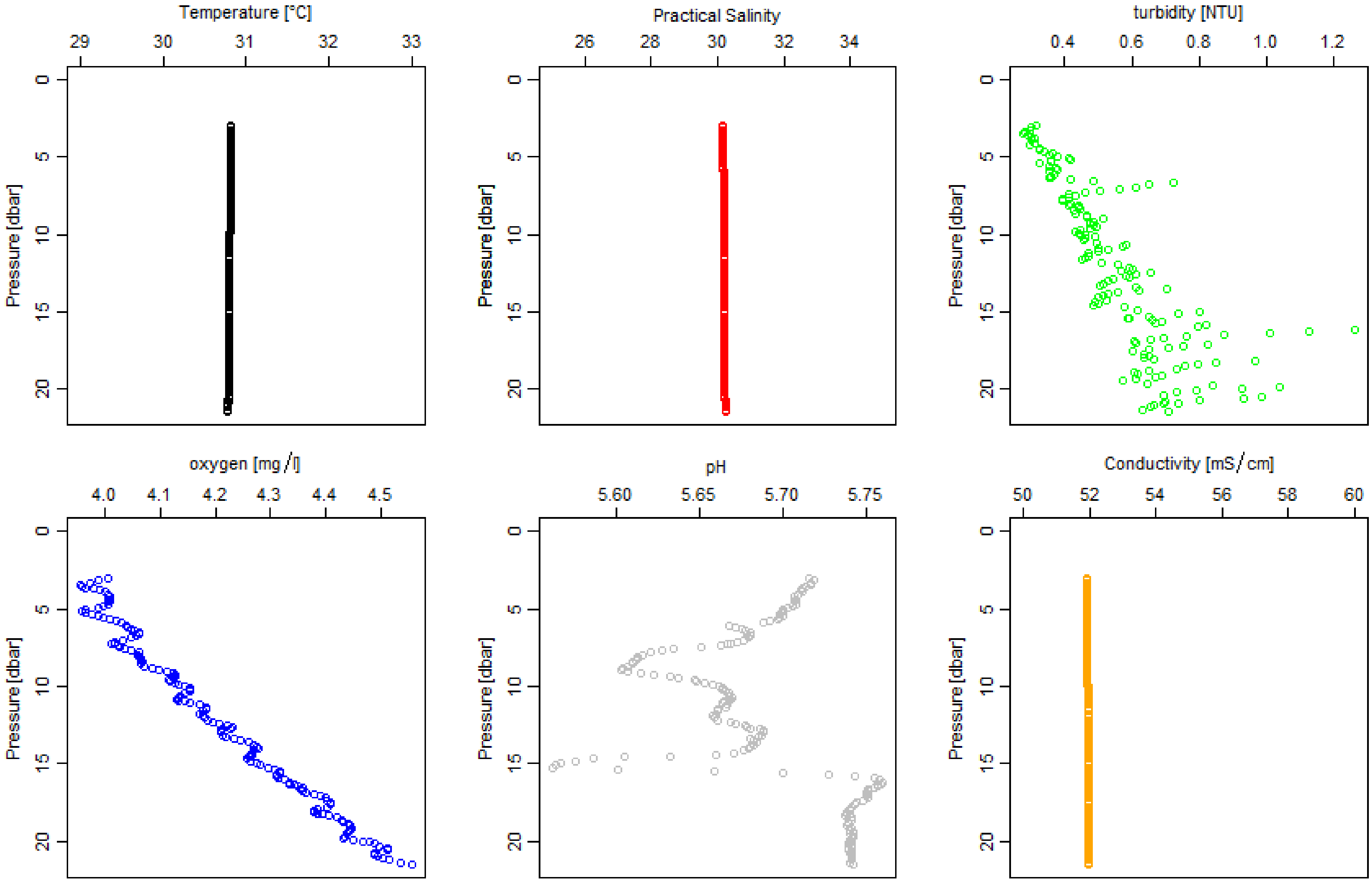


Figure 3-43: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG11

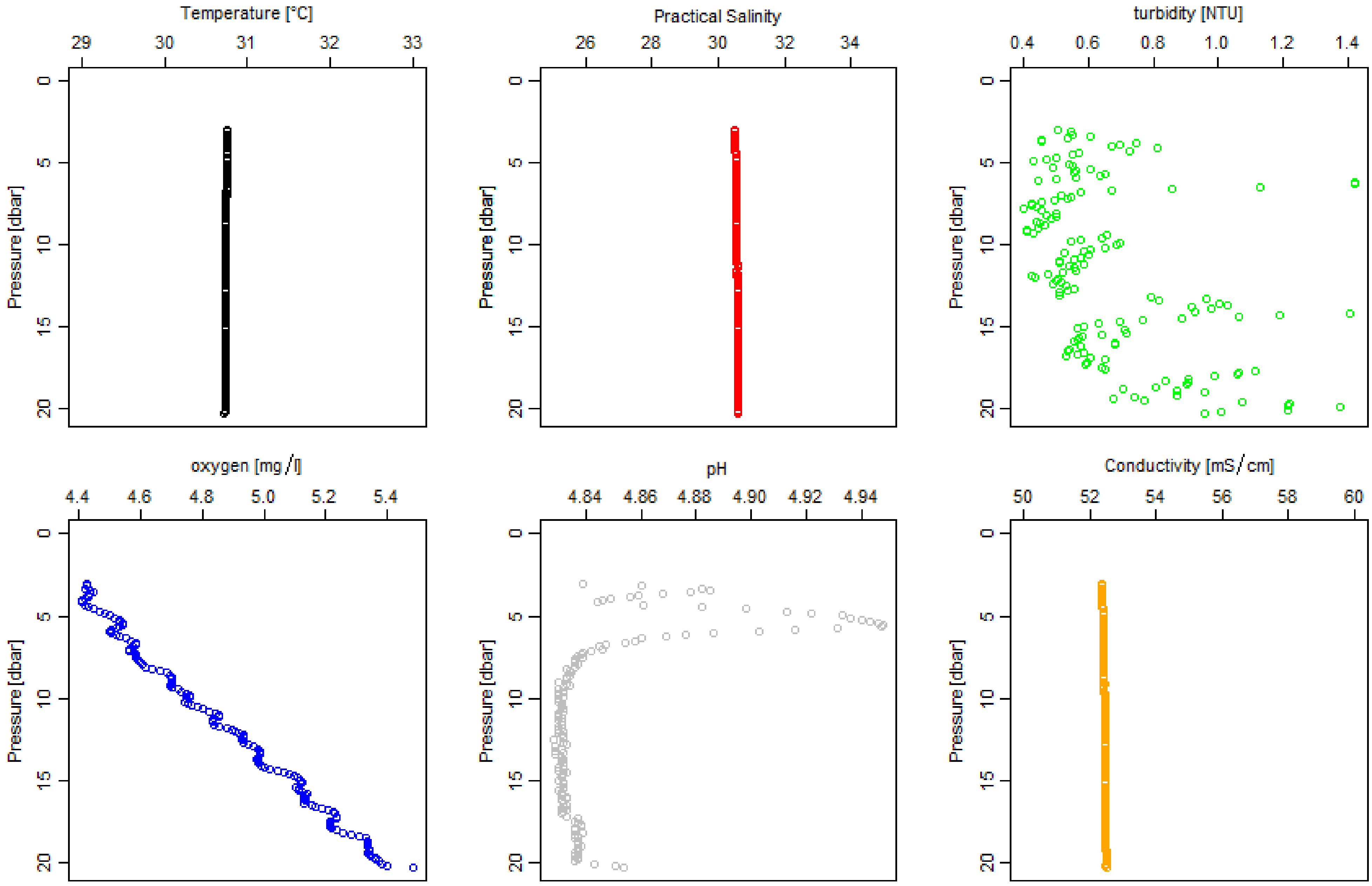


Figure 3-44: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG12

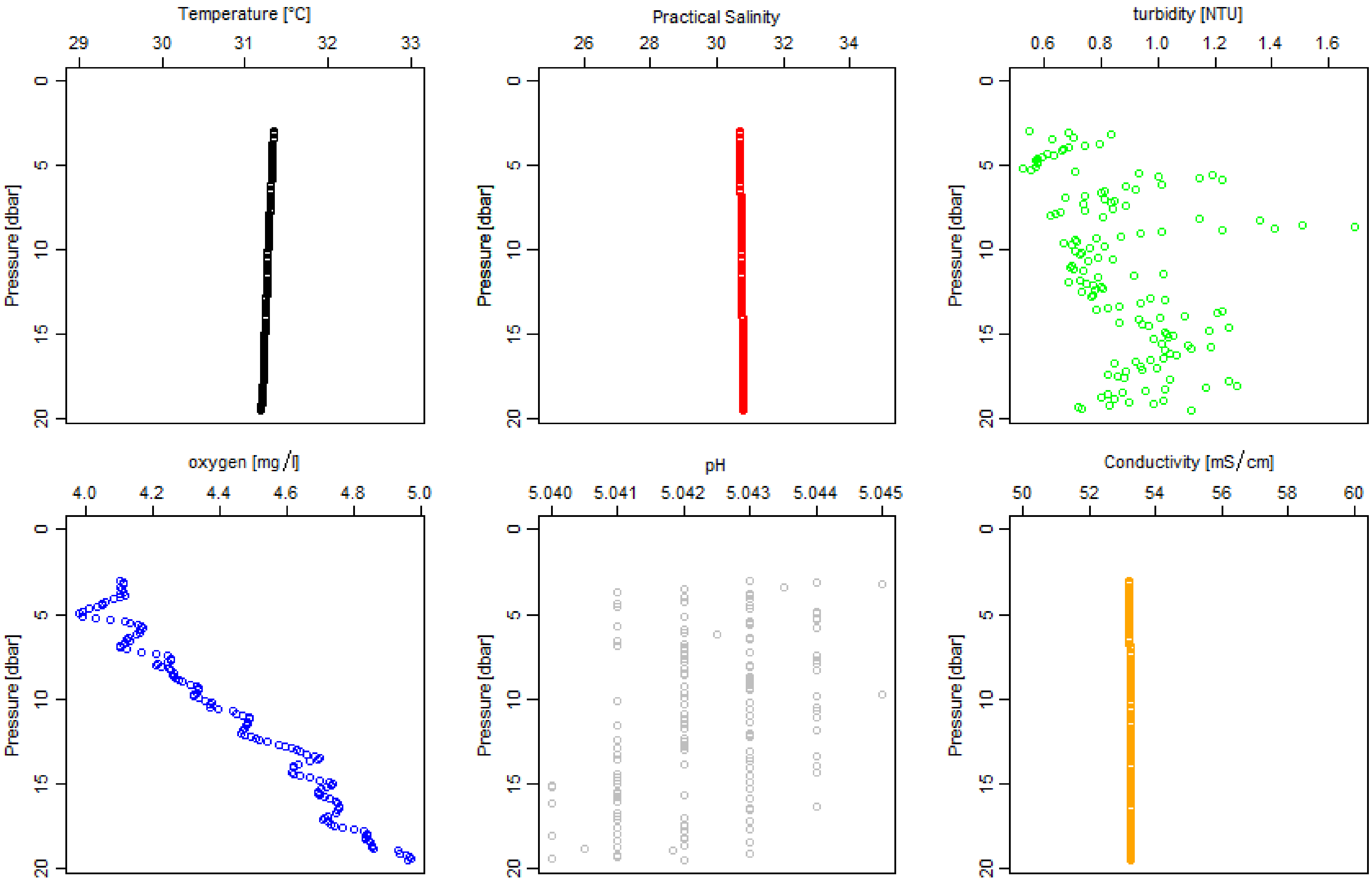


Figure 3-45: Seabird temperature, salinity, turbidity, oxygen, pH and conductivity (salinity) profiles from site SG13

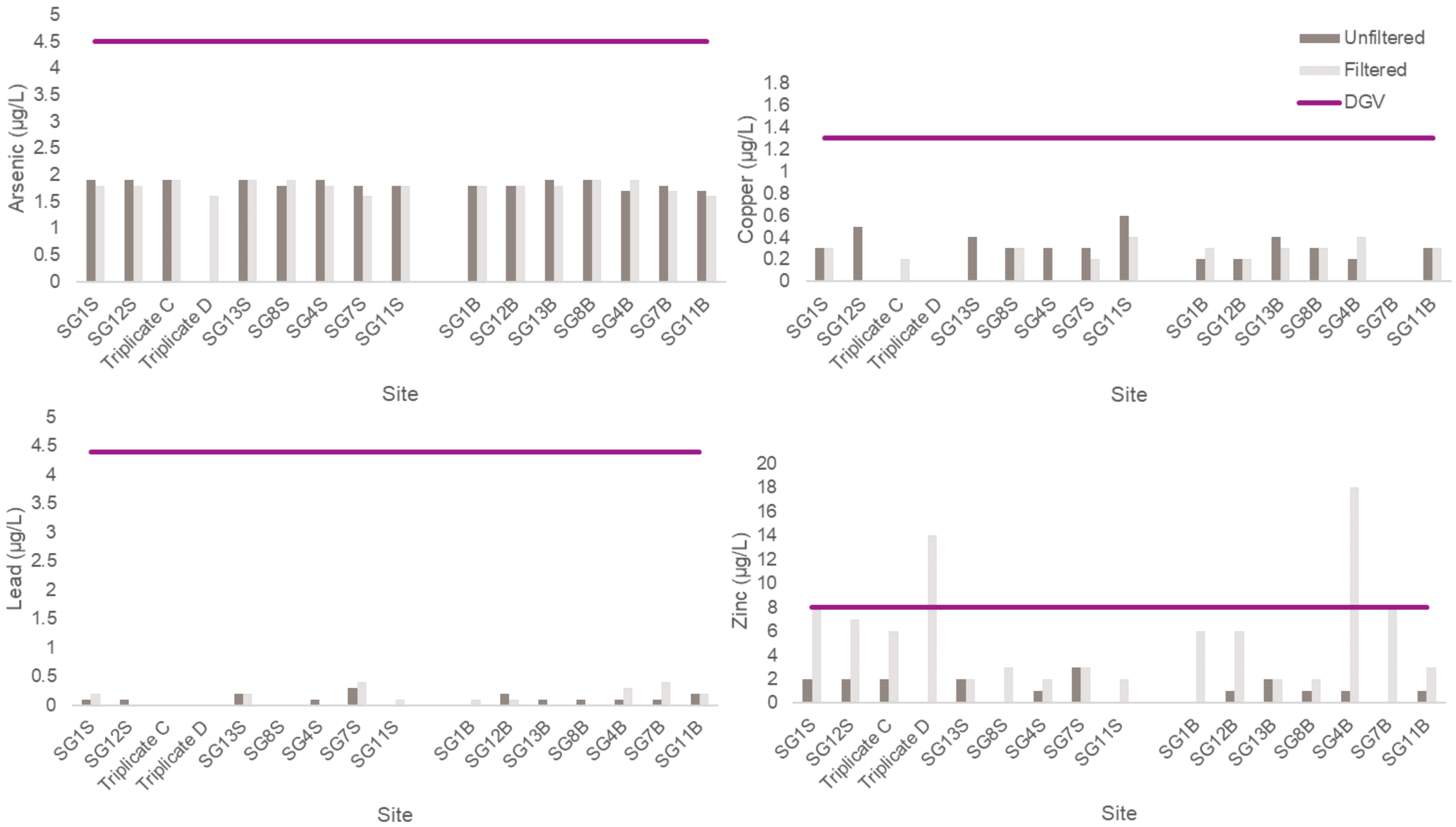


Figure 3-46: Filtered and unfiltered metal concentrations from the spoil ground

3.3.2.3 Nutrients and pigments

3.3.2.3.1 Nitrogen

Nitrite and nitrate were only recorded at concentrations above the LoR at two of the spoil ground sites, with both being bottom samples (Appendix G). These nitrate concentrations were 12 µg.N/L at SG12B and 4 µg.N/L at SG11B. All surface samples were below the LOR. These values are below the ANZG (2018) DGV for physical and chemical stressors in the Anson Beagle bioregion for nitrate in summer 1.717 µmol NO3-N/L (106.46 µg.N/L) in bottom waters.

Ammonia concentrations were below the LoR for all but three samples. Ammonia was only detected in near-seabed water samples (SG12B, SG4B and SG11B). The ammonia concentrations in these samples ranged from 3 µg.N/L to 13 µg.N/L. All samples were below the ANZG (2018) DGV (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) of 910 µg.N/L.

Total nitrogen concentrations indicated the presence of other organic nitrogen compounds, with no samples (excluding the field and transport blanks) being below the LoR of 50 µg.N/L. There is no ANZG (2018) default guideline value for total nitrogen. There is no ANZG (2018) default guideline value for total nitrogen.

3.3.2.3.2 Phosphorus

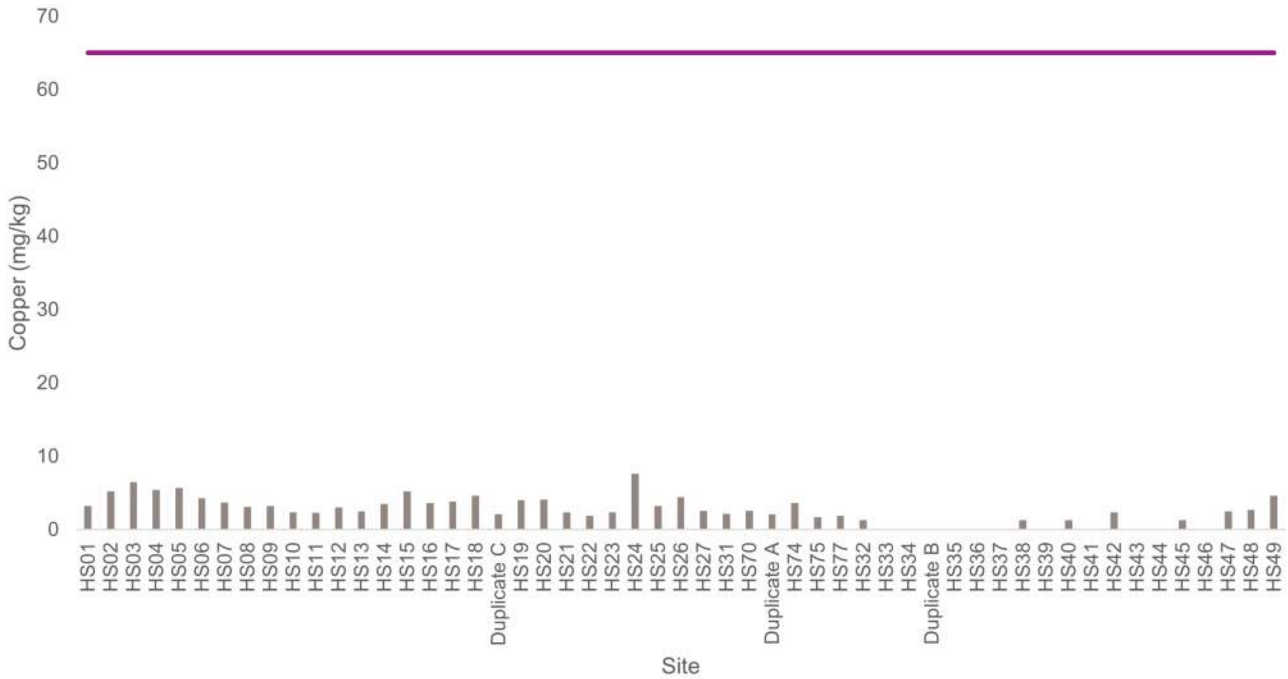
Orthophosphate (filterable reactive phosphorus) concentrations ranged from 4 to 9 µg.P/L (Appendix G). All samples were above the LoR. No samples exceeded the ANZG (2018) DGV for physical and chemical stressors in the Anson Beagle bioregion for phosphate of 0.209 µmol PO4-P/L (19.85 µg.P/L) in surface waters and 0.427 µmol PO4-P/L (40.55 µg.P/L) in bottom waters for summer.

TP concentrations ranged from 11 to 16 µg.P/L. There is no ANZG (2018) default guideline value for TP.

3.3.2.3.3 Pigments

Chlorophyll-a concentrations ranged from 0.2 to 0.5 µg/L at the spoil ground sites (Figure 3-47; Appendix G). All concentrations were below the ANZG (2018) DGV for physical and chemical stressors in the Anson Beagle bioregion value for chlorophyll-a of 2.568 µg/L in summer. Concentrations were variable across surface and bottom samples.

Phaeophytin-a was also sampled as this pigment is a breakdown product of chlorophyll-a and can be used to indicate if phytoplankton are blooming or declining. Phaeophytin-a was not detected above the LoR for any of the spoil ground sites.



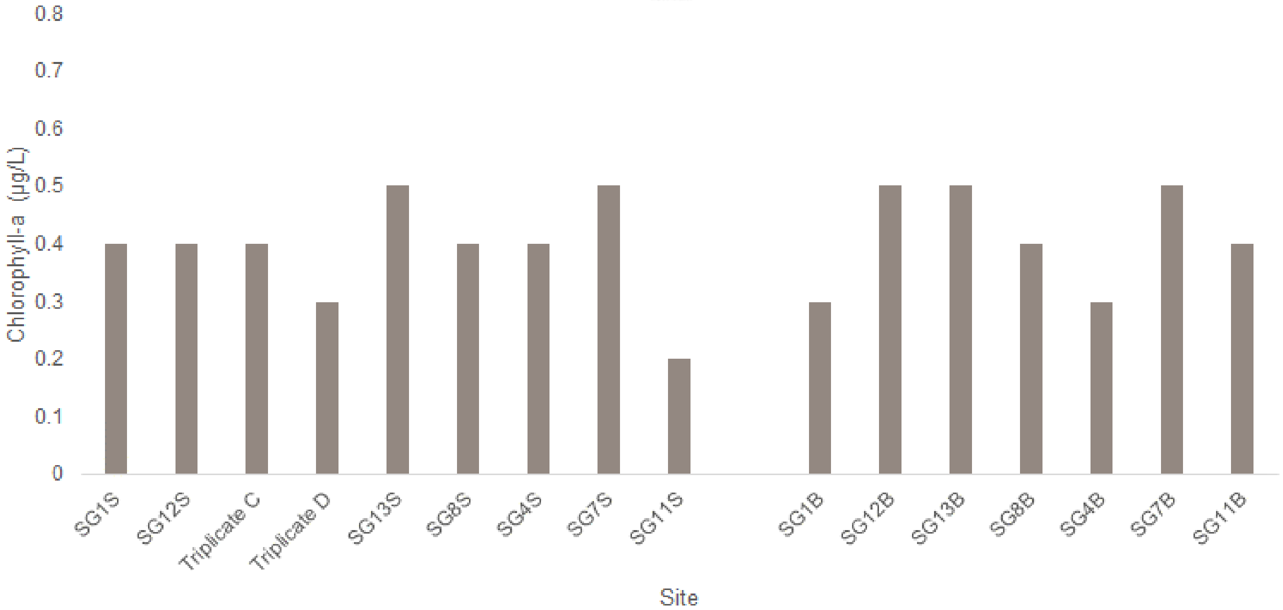


Figure 3-47: Surface and bottom chlorophyll-a concentrations at the spoil ground

3.3.2.3.4 Total suspended solids

Total suspended solid (TSS) concentrations were all above the LoR (0.5 mg/L) and ranged from 1.4 to 6.2 mg/L (Appendix G). There was no clear difference found in the TSS between surface and bottom samples.

3.3.2.4 Hydrocarbons

The spoil ground TRH and BTEXN concentrations were below the LoR for all samples (Appendix H). The offshore pipeline samples were, therefore, not tested for PAHs.

3.3.2.5 Naturally occurring radioactive materials

Naturally occurring radioactive materials (NORMS) were all below limits of detection in spoil ground water samples (Appendix F).

3.4 Quality control

3.4.1 Field quality control samples

Field QC samples were analysed to assess contamination of samples during sampling. The hydrocarbon concentrations for both water and sediment samples showed no difference between the triplicates and the original sample sites. All blank samples were below the limit of reporting for hydrocarbons. Therefore, there was no hydrocarbon contamination of samples during sampling. The equipment blank for sediment sampling indicated potential for contamination of nutrients (phosphorous and nitrogen) from the grab sampler, but analysis of the field samples showed that the contamination management processes had been effective and no notable cross-contamination was likely to have occurred. No other cross-contamination issues were identified.

3.4.2 Laboratory quality control compliance assessment

The laboratory quality control compliance assessments from all water and sediment samples identified the following:

- No method blank value outliers occurred
- Seven sediment sample duplicate, laboratory control and matrix spike outliers were recorded:
  - A total of four analytes (arsenic, chromium, manganese and monobutyltin) from three sediment samples were identified returned relative percentage differences which exceeded LOR-based limits or recovery was greater than the upper control limit.
  - Matrix spike recovery could not be determined for one analyte (TP) as background levels were ≥4 times the spike level.
  - Recovery was less than the lower data quality objective in one analyte test (TP) for one sample.
- Surrogate recovery outliers were identified for organotin surrogate tests for tripropyltin in eight sediment samples, where recovery was greater than the upper data quality objective.
- Holding time compliance – there were extraction/preparation holding time exceedances for seven water sample analytes from equipment blank samples (nutrients and hydrocarbons), though four of these were analysed within analysis holding times. None of the field test samples exceeded holding times.
- Parameter frequency compliance outliers were recorded for two analyte tests (TRH – semivolatile fraction and total metals by ORC-ICPMS) from water samples, where recovery rate was below expected values.

4 DISCUSSION

The surveys described herein provided data characterising benthic habitats and sediment quality (physico-chemical characteristics) in areas along the Barossa DPD pipeline route and proposed spoil disposal area. Water quality and infauna analysis were also undertaken at selected locations along the offshore pipeline and spoil ground. Water depths of sampling sites ranged from 8.5 m in Darwin Harbour to 59.9 m at the westernmost sites.

4.1 Benthic habitats

4.1.1 October 2021 survey

Eight high-level habitat types were identified along the Barossa DPD pipeline route and in the proposed spoil ground area. This comprised six soft substrate habitats and two hard substrate habitats. Soft sediment benthic habitats and communities were well represented across the whole survey area.

The offshore pipeline route was dominated by particulate silt/clay sediments with very sparse to sparse epibiota (1–5% cover), which mostly comprised soft corals and crinoids. Twenty-three video survey sites were characterised by this habitat type. Two other habitat types were also recorded towards the Darwin harbour end of the offshore pipeline route. These were: sand waves (~1 m) with silty sand in troughs and shelly sand at peaks and very sparse biota, and silt/clay with medium density biota (soft corals, algae and bryozoa). Conspicuous epibiota of soft sediment habitats included gorgonians, echinoderms, molluscs, crustaceans (including shrimp and the painted pebble crab, *Leucosia anatum*), with frequent bioturbation (burrows and polychaete tubes).

The benthic habitats in the spoil ground comprised silty/clay sediment with medium density biota (soft corals, algae and Bryozoa, 20–60% cover). Biota commonly associated with this habitat were soft corals (gorgonians, *Junceella* spp. and Alcyoniidae), branching and encrusting sponges, Bryozoa (lace corals), brown algae, bioturbation (invertebrate burrows and polychaete tubes) and occasional motile crinoids.

Darwin Harbour benthic habitats comprised soft sediment habitats and the only two hard substrate habitats were recorded during the surveys. Local fishers in Darwin target areas of the harbour identified as hard substrate. Hard substrates were recorded along the section of the pipeline route offshore from Fannie Bay (HS60 to HS68 and HS54 and HS55). Most of the hard substrate sites were consolidated rocks with a shelly coarse sediment veneer and sparse to medium conspicuous epibiota (mainly soft corals and bryozoans). Low profile reef was also recorded at sites HS61 and HSN2, with medium to high density epibiota. The epibiota associated with this habitat type included hydroids, soft corals (gorgonians, *Junceella* spp.), brown algae, bryozoans (lace corals), ascidians, and encrusting, digitate and globular sponges. The soft substrate habitat adjacent to hard substrate habitats in Darwin Harbour were generally silty, shelly sand with very sparse soft corals to no conspicuous epibiota. As this habitat was recorded both adjacent to and between hard substrate habitats, this soft substrate habitat is potentially a veneer overlying submerged geology. Other recorded soft sediment benthic habitats in Darwin Harbour included:

- Sand waves <1 m with coarse shelly sand and very sparse epibiota (HS78)
- Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids) (sites HS50, HS52 and HS53, at the southern end of the pipeline, near the shore crossing)
- Silty, shelly sand with sparse epibiota (soft corals) and scattered bombora (site HS51, at the southern end of the pipeline, near the shore crossing).

4.1.2 June 2022 survey

The June 2022 video transect survey was analysed and sorted into the same eight high-level habitat types that were used for the October 2021 (Table 3-1). Similar to the October 2021 study, soft sediment benthic habitats and communities were well represented across the entire survey area.

The June 2022 survey found that the outer offshore pipeline route was dominated by fine sand/silt with sparse epibiota and bioturbation with some sand waves (BACI_6C; <1 m high). Occasional sponges and soft corals were present with below 5% cover. However, a fish aggregation site, outside of the project area, ~2.6 km from the proposed pipeline route, was found to support a rocky reef with medium density epibiota and bioturbation. The proposed sand waves dredge area (Sand waves) was found to contain rippled coarse sand with very little epibiota (<1% abundance), consisting of some sparse soft corals and crinoids.

The habitat just outside Darwin Harbour consisted mainly of course rippled sand, with low overall epibiota but increasing towards the harbour opening and increasing rocky substrate. The habitat sites outside the harbour (Hab1–Hab5) ranged from rippled sand to medium sand with gravel toward the harbour opening. These sites had epibiota less than 1% coverage, consisting mainly of sparse anemone, soft corals and macroalgae (Hab1). INPHCMAN and INPHCMAN_1, closer to the western opening of the harbour, consisted of rocky/bedrock reefs with sediment veneer and medium to high density epibiota, consisting mainly of sponges and soft/hard corals. While epibiota increased towards the coast and opening of the harbour, the heritage sites (147, 031 and 241) did show some variety, as the dominant substrate was rocky/bedrock with sediment veneer and medium densities of epibiota (20–60% coverage), consisting mainly of sponges, soft corals, bryozoan turf with common fish sightings. This region represented a transition between the sand/silt low epibiota density habitats to the rocky high epibiota density habitats.

Epibiota continued to increase further into Darwin Harbour, as the majority of sites had medium to high epibiota density, with many also including reef habitats. The exceptions were the sites near Wickham point (Hab9, Hab10, BACI_1C/P and BACI_2C/P), as these consisted of only bedrock with a thin veneer of sediment unable to support large quantities of epibiota. Only sparse populations of sponges, soft corals and crinoids, though fish were often spotted in boroughs. The central portion of the harbour consisted of rocky/bedrock substrate with large patches of mobile sediment. Moderate density of epibiota was observed, consisting mainly of sponges, soft corals, hydroid/bryozoan turf, macroalgae and small quantities of hard coral (2–5% coverage). This central portion of Darwin Harbour had the greatest density and biodiversity of epibiota observed in the video transects within the project area.

Outside of the project area, INPHCWOD consisted of mainly rippled coarse sand with bioturbation and low-density seagrass. The other three sites (INPHCSSI, INPHCCHI and INPHCNEW) had moderate to high density epibiota with rocky/reef substrates. These sites were characterised by large soft corals and sponges, echinoderms, schools of fish and hard corals. These sites had the highest biodiversity and epibiota density observed in the video transect survey and were located in the shallower protected areas of the harbour, away from the project area.

4.1.3 Video transect surveys compared to AIMS 2021 habitat mapping

The Barossa DPD Darwin Harbour October 2021 and June 2022 benthic habitat data was overlaid on a composite habitat map of Darwin Harbour from AIMS (2021) (Figure 4-1, Figure 4-2 and Figure 4-3). The 2021 AIMS habitat map shows areas of seabed assigned by a predictive model to be suitable for the presence of different biota categories including seagrass, hard coral, macroalgae, filter feeders/octocorals and sponges. The comparison of datasets shows differences in habitat types, particularly with the level of information provided (approximate densities of biota, substrate types not available in AIMS data).

The Barossa DPD surveys recorded filter feeders at sparse densities across almost all soft substrate types whereas large areas of ‘sponges’ habitat with small patches of filter feeders/octocorals were predicted by AIMS only near the harbour entrance, which have been mapped based on emergent bedrock evident in geophysical (bathymetric) survey data (Figure 4-2). Barossa DPD video survey at the harbour entrance, however, identified habitat comprising consolidated rocks with a shell sediment veneer and sparse to medium density biota, mainly characterised by soft corals and bryozoa (though sponges were present). Moving north (in the AIMS predicted ‘sponges’ habitat), the seabed habitats were identified during the Barossa DPD survey as changing to silty, shelly sand, with very sparse to no conspicuous epibiota. This is potentially the area of transition from hard to soft substrates, as the soft sediment habitat continues in a northerly direction along the pipeline route.

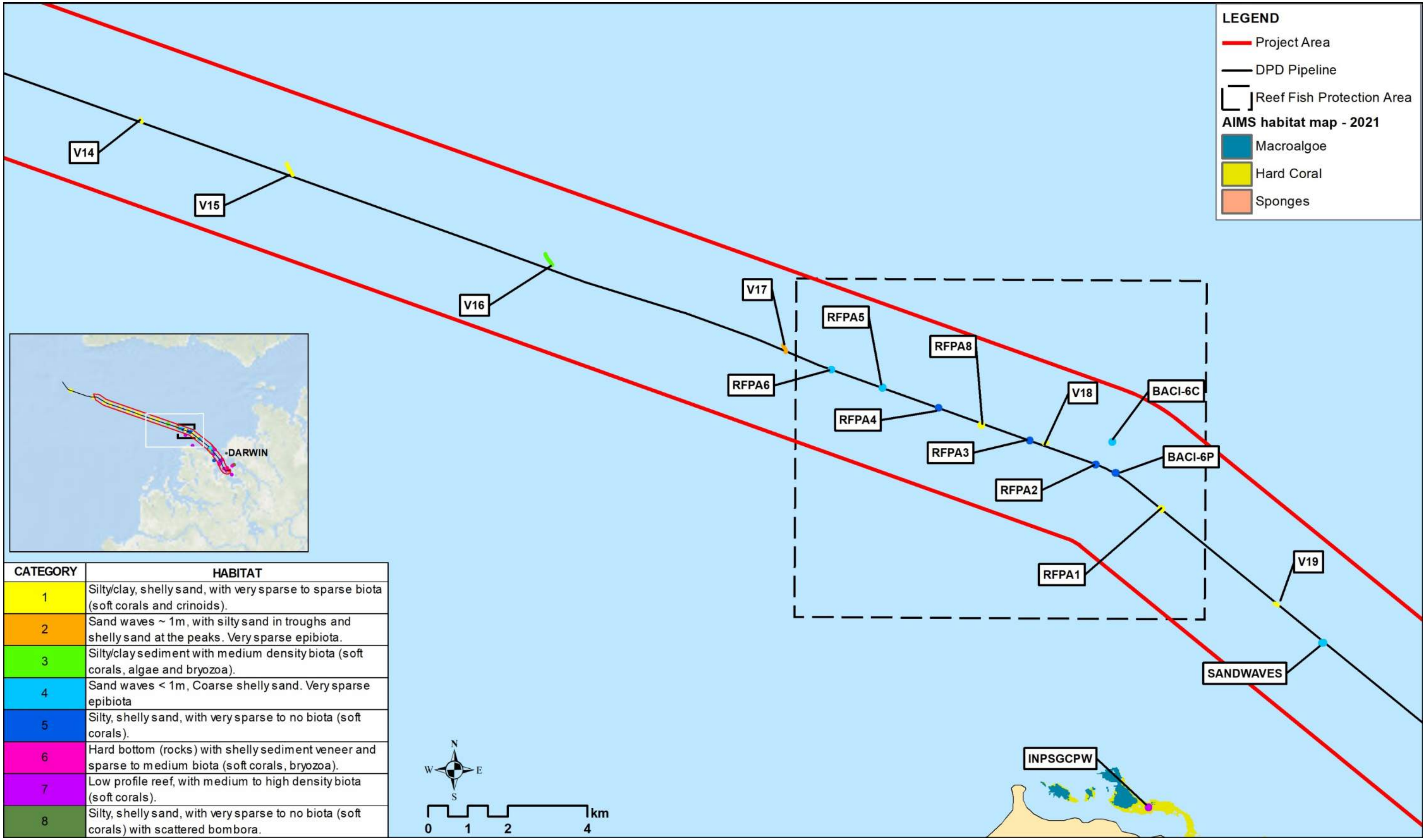
Nearer the shoreline crossing, large areas of the AIMS map show ‘bare ground’, whereas the Barossa DPD survey found a mosaic of habitats (Figure 4-3), comprising ‘silty, shelly sand with very sparse to no conspicuous epibiota’, ‘consolidated rocks with a shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)’, and ‘silt/clay and shelly sand with sparse to very sparse epibiota (soft corals and crinoids)’.

Overall, the benthic habitat and communities survey revealed that the Barossa DPD pipeline route is a transitional environment, with soft sediment habitats along the offshore pipeline route and spoil ground, and with areas of both soft and hard substrate habitat within Darwin Harbour. The soft sediment habitats support very sparse to sparse epibiota, and the rocky substrates support low to medium density filter-feeder communities.

Table 4-1: Comparison of habitat classifications of towed video surveys (October 2021 and June 2022) and AIMS habitat mapping (2021)

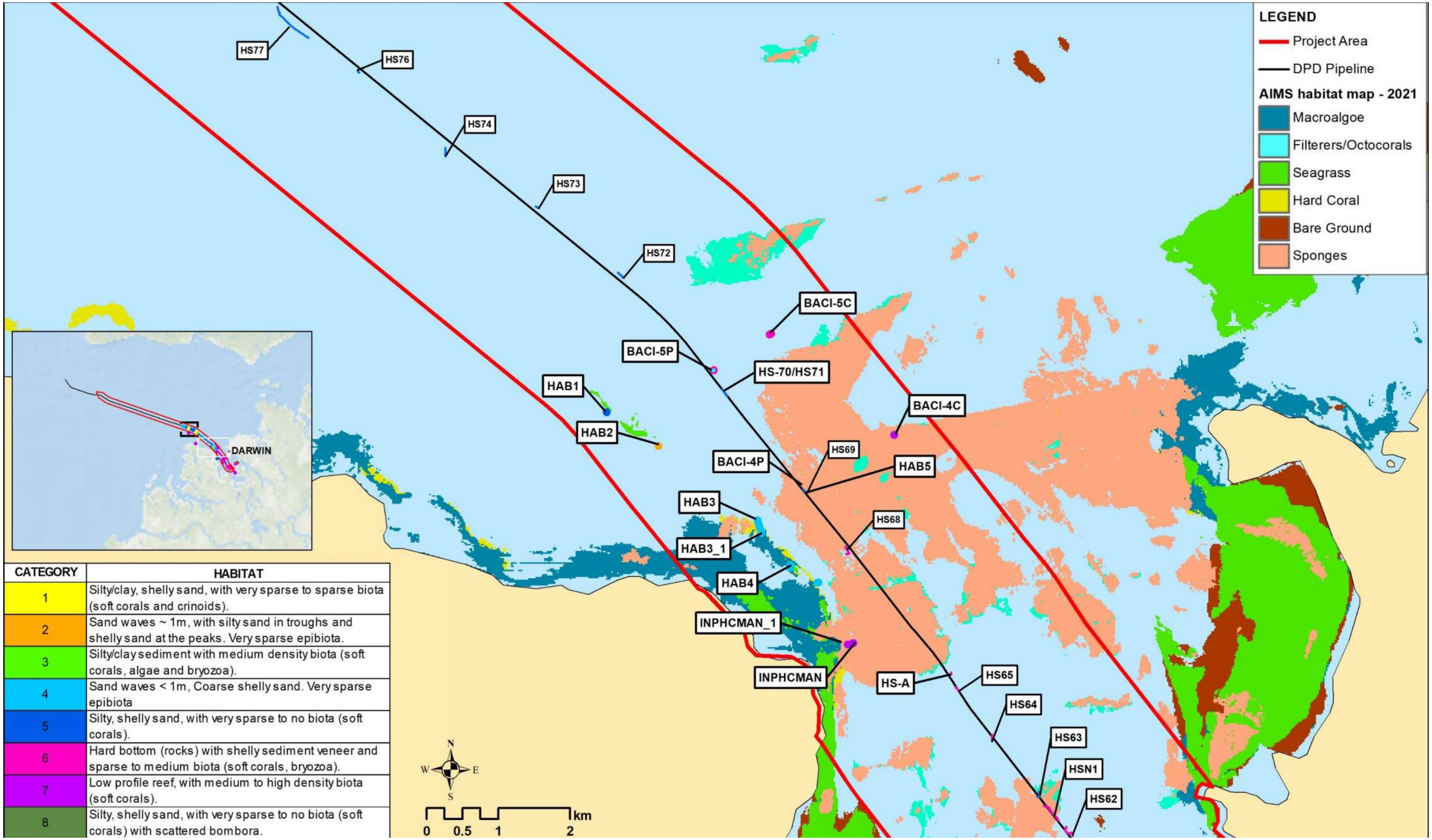
Site	AIMS habitat classification	Towed video habitat classification
Oct-21		
OP1	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP2	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP3	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP4	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP5	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP7	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP9	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP11	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
OP16	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
V3	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
V4	Not mapped	Silty, shelly sand, with sparse biota soft corals and crinoids).
V5	Not mapped	Silty, shelly sand, with sparse biota (soft corals and crinoids).
V6	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
V7	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V8	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
V9A	Not mapped	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
V10	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V11	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V12	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V13	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V14	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V15	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V16	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
V17	Not mapped	Sand waves ~ 1 m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota
V18	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
V19	Not mapped	Silty/clay sediment with sparse biota (soft corals and crinoids).
SG1	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG2a	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG3	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG4	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG5	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG6	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG7	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG8	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG9	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG10	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG11	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG12	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
SG13	Not mapped	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
HS79	Not mapped	Sand waves < 1 m, Coarse shelly sand. Very sparse epibiota
HS80	Not mapped	Sand waves < 1 m, Coarse shelly sand. Very sparse epibiota
HS78	Not mapped	Sand waves < 1 m, Coarse shelly sand. Very sparse epibiota
HS77	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
HS76/HS75	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
HS74	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
HS73	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
HS72	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
HS71/HS70	No data	Silty, shelly sand, with very sparse to no biota (soft corals).
HS69	Sponges	Silty, shelly sand, with very sparse to no biota (soft corals).
HS-A	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS68	Filter feeders/octocorals	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS65	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS64	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS63	Sponges	Silty, shelly sand, with very sparse to no biota (soft corals).
HS62	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)

Site	AIMS habitat classification	Towed video habitat classification
HS61	No data	Low profile reef, with medium to high density biota
HS60	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS-B/HS59	No data	Silty, shelly sand, with very sparse to no biota (soft corals).
HS58	No data	Silty, shelly sand, with very sparse to no biota (soft corals).
HS57	No data	Silty, shelly sand, with very sparse to no biota (soft corals).
HS56	Bare ground	Silty, shelly sand, with very sparse to no biota (soft corals).
HS55	Bare ground	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS54	Bare ground	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HS53	Bare ground	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
HS52	Bare ground	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
HS51	Bare ground	Silty, shelly sand, with very sparse to no biota (soft corals) with scattered bombora
HS50	Macroalgae	Silty, shelly sand, with very sparse biota (soft corals and crinoids).
HSN1	Sponges	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa)
HSN2	No data	Low profile reef, with medium to high density biota
Jun-22		
BACI_1C	Bare ground	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_1P	Bare ground	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_2C	Bare ground	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_2P	Bare ground	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_3C	No data	Low profile reef, with medium to high density biota.
BACI_3P	No data	Low profile reef, with medium to high density biota.
BACI_4C	Sponges	Low profile reef, with medium to high density biota.
BACI_4P	Sponges	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_5C	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_5P	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
BACI_6C	Not mapped	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.
BACI_6P	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
Fish aggregation site	Not mapped	Low profile reef, with medium to high density biota.
Hab1	Seagrasses	Silty, shelly sand, with very sparse to no biota (soft corals).
Hab2	No data	Sand waves ~ 1 m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
Hab3	Macroalgae	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.
Hab4	Macroalgae	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.
Hab5	Macroalgae	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.
Hab6	Hard corals	Silty, shelly sand, with very sparse biota (soft corals) with scattered bombora.
Hab7	Hard corals	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Hab8	Hard corals	Low profile reef, with medium to high density biota (soft corals).
Hab9	Macroalgae	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Hab10	Macroalgae	Sand waves ~ 1 m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
Heritage_147	No data	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Heritage_031	Sponges	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
Hertage_241	Sponges	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
INPHCCHI	Macroalgae	Low profile reef, with medium to high density biota.
INPHCNEW	Macroalgae	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
INPHCMAN	Sponges	Low profile reef, with medium to high density biota.
INPHCMAN_1	Sponges	Low profile reef, with medium to high density biota.
INPHCSSI	Sponges	Silty, shelly sand, with very sparse to no biota (soft corals) with bombora.
INPSGCPW	Hard corals	Low profile reef, with medium to high density biota.
INPHCWED2	Hard corals	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
INPHCWOD	Seagrasses	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA1	Not mapped	Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
RFPA2	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA3	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA4	Not mapped	Silty, shelly sand, with very sparse to no biota (soft corals).
RFPA5	Not mapped	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.
RFPA6	Not mapped	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.
RFPA8	Not mapped	Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
Sand waves	Not mapped	Sand waves < 1 m, Course shelly sand. Very sparse epibiota.



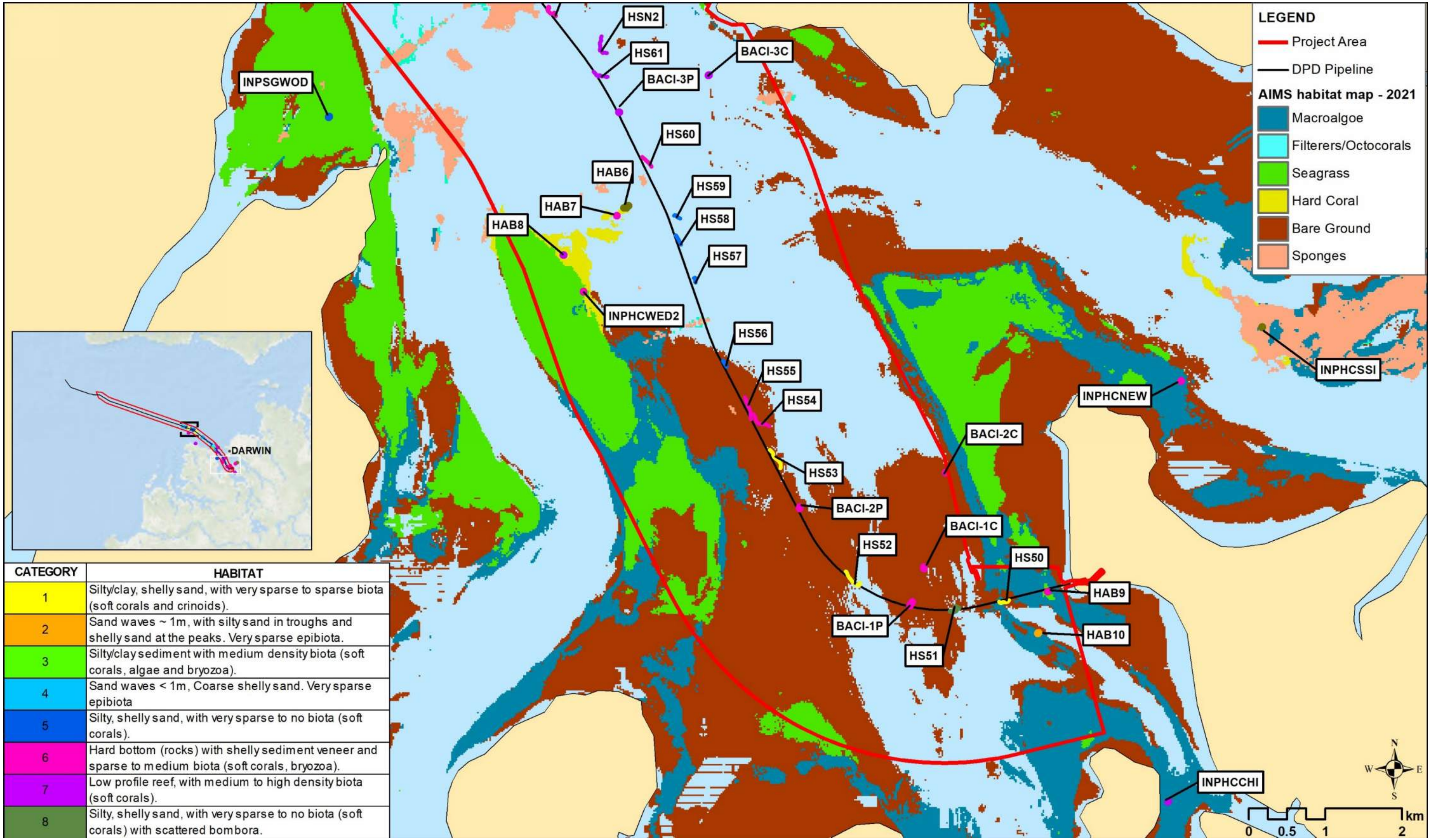
CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high density biota (soft corals).
8	Silty, shelly sand, with very sparse to no biota (soft corals) with scattered bombora.

Figure 4-1: Benthic habitat types identified along the offshore pipeline route overlayed on AIMS 2021 habitat map, including the Reef Fish Protection Area



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high density biota (soft corals).
8	Silty, shelly sand, with very sparse to no biota (soft corals) with scattered bombora.

Figure 4-2: Benthic habitat types identified along the pipeline route and outer Darwin Harbour overlayed on AIMS 2021 habitat map



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high density biota (soft corals).
8	Silty, shelly sand, with very sparse to no biota (soft corals) with scattered bombora.

Figure 4-3: Benthic habitat types identified along the pipeline route and inner Darwin Harbour overlayed on AIMS 2021 habitat map

4.2 Infauna assemblages

The infauna analysis revealed a total of 744 individuals from ten phyla were recorded from the 29 offshore pipeline samples analysed. Infaunal assemblages were dominated by crustaceans (350 individuals) and annelids (polychaete worms; 313 individuals). Crustaceans were most abundant at more than half of the sites sampled (55.2%), and Annelids most abundant at the other 13 sites (44.8%). The next most numerous phyla were an order of magnitude lower in abundance (Sipuncula, Echinodermata, Mollusca and Chordata). Multivariate analysis identified that there were three main infaunal assemblage types along the offshore pipeline route, interspersed with patchy or transitional (heterogeneous) habitats:

- The furthest offshore soft sediment habitats (OP1–OP10, OP12–OP19, OP22 and OP24) were characterised by a much more diverse community, with 30 taxa comprising the top 90% of taxa characterising the biological assemblage. The crustaceans (mainly amphipods, tanaids and isopods) and polychaetes (mainly deposit-feeding tube worms and free-living taxa) were the dominant taxa, with echinoderms (Ophiuroidea) and sipunculids also represented. This habitat was characterised by coarse sediments with the lowest silt/clay component, which would have provided a more complex substrate and potentially better sediment oxygenation in surficial sediments.
- This next group (sites OP21, OP23 and OP27) around the central and southern section of the offshore pipeline route was dominated by brittlestars (Ophiuroidea) and polychaetes (*Lumbrineris* sp., spionids, *Nephtys* sp. and *Axiothella* sp.). These taxa are generally surface deposit feeders and/or carnivores/ scavengers, with several capable of interface feeding (switching between, e.g. deposit feeding and suspension/filter feeding), which is a trait often associated with harsh or nutrient-poor environments, such as the fine or sandy sediments characterising this habitat. This infaunal assemblage was much less biodiverse than the first grouping, with only five taxa comprising the top 90% of taxa characterising the group. Diversity scores (Shannon-Weiner) were generally lower than recorded for the first group.
- The final group was generally the most shoreward group (OP26, OP28 and OP29), but was also recorded at the offshore end of the pipeline route (OP11). This group was dominated by Anthuridea (elongate isopod crustaceans) and polychaete worms (*Eunice* sp. *Axiothella* sp. and *Nepthys* sp.). The average abundance of these taxa is higher than the previous grouping, which is likely due to a greater range of particle sizes in the substrate. This aspect is indicated by the dominance of Anthuridea, which live in crevices, empty calcareous worm tubes or structurally complex epibiota. Sediments were characterised by a higher per cent gravel component and per cent silt component than the previous group.

A total of 185 individuals from five phyla were recorded from the 13 proposed spoil ground samples analysed. The dataset was dominated by crustaceans (107 individuals) and annelids (polychaete worms; 55 individuals), with the next most numerous phyla being Echinodermata, Sipuncula and Nematoda. Infaunal assemblages at the proposed spoil ground had fewer species and lower abundance, but both were greater than the infaunal assemblages recorded from previous studies in Darwin Harbour (INPEX Browse Ltd, 2010), most likely due to the different environmental conditions within the harbour (e.g. silt input, freshwater input, flushing rates). It is likely that other unmeasured factors, e.g. such as (but not limited to) current speeds/site energy, salinity profiles up the river and sediment chemistry, also contribute, and that there is likely to be seasonal variability in the distribution and composition of benthic faunal assemblages (Chalmers et al. 1976, Tweedley & Valesini 2008, Sheaves 2015, Silva & Barros 2015). No high conservation significant ecological values, habitats, communities of species were identified and the habitats and communities within the Barossa DPD survey area are very well represented in the region.

4.3 Sediment characteristics

Sediment sampling and analysis was conducted in line with the NAGD (CoA, 2009). Seabed sediment PSD data identified a transition in sediment grain sizes along the offshore pipeline route, with the per cent clay and silt contributions increasing from around 3% and 9%, respectively, at the offshore OP1 (slightly silty gravelly sands; near KP0) end of the survey area, to up to around 7% and 39%, respectively, at the OP30, near the Darwin Harbour limits (gravelly muddy sands; at ~KP90). The increase in silt from offshore (~KP0) to Darwin Harbour is likely due to the riverine input of fine material from the Darwin harbour catchment area and mudflats/mangrove areas. The PSD data for the spoil ground indicated some local heterogeneity in sediments but were generally gravelly sands and muddy gravelly sands (3–5% clay, 12–23% silt, 51–73% sand and 9–29% gravel). Darwin Harbour sediments ranged from sandy muds to muddy sandy gravels, with most sediments being muddy gravelly sands. There was also a sediment gradient from the harbour limits

(KP92) to near the shore crossing, with silty and slightly silty slightly gravelly sands at KP92 transitioning to silty sandy gravels from around KP102 to muddy sandy gravels and sandy muddy gravels near the shore crossing at KP120. Gravels in the study area comprise material from both geogenic (i.e. local rock formations) and biogenic (e.g. shell and potentially coral fragments) sources.

Comparison of the sediment composition of the offshore pipeline route, the spoil ground, the sand wave area in Darwin Harbour and the pipeline route south of the sand wave area to the shore crossing identified significant differences between all these areas. Sediments at the offshore sampling sites (offshore pipeline and spoil ground) were generally dominated by sands (average >50%), with pebbles (~27%), silt (11–15%) and clay (3–4%). There was no recorded hard substrate from subsea video survey, so the coarser fragments (pebble) are more likely to be of biogenic origin (e.g. shell fragments). The main difference between the offshore pipeline route and the spoil ground is the increased relative silt content and subsequent reduced sand content. This outcome may well be due to a combination of factor, such as the smaller survey area (relative to the offshore pipeline route) and hence reduced potential heterogeneity), the more eastern location of the spoil ground, and the greater potential for the influence of open ocean environmental conditions on seabed substrates at the western end of the offshore pipeline route (e.g. potentially greater energy and potential increased near-sed bed currents, increasing potential for winnowing of finer particle sizes).

The sediments inside the harbour were generally coarser and more characteristic of mixed sediments rather than the silty coarse sands recorded outside of Darwin Harbour. This is likely to be due to a combination of a range of factors, including the local geology and differences in hydrodynamic conditions of the semi-enclosed Darwin Harbour versus the more open ocean-influenced Beagle Gulf. However, the mobile sediments of the sand wave area were distinct with respect to the very low silt content. This is likely due to the sorting of sediment particle sizes during transport along the seabed and the winnowing (removal through resuspension) of the finer silt particles. It is also likely that the seabed underlying the mobile layer was more similar to nearby seabed substrates in Darwin Harbour.

Analysis of metals and metalloids in sediments along the pipeline route and at the spoil ground indicated arsenic concentrations in 74 samples greater than the relevant NAGD screening levels. Arsenic is considered to have become concentrated in sedimentary rocks through sedimentation processes. The fine-grained clastic sediments have higher arsenic concentrations than the coarse-grained sediments. Comparison of arsenic with iron showed strong positive results with spoil ground and Darwin Harbour surficial sediments. A weak result was identified with the offshore pipeline samples and Darwin Harbour core samples. The results indicate that the highest concentrations of arsenic and iron were recorded in the southerly section of the Darwin Harbour pipeline section, closest to the shore crossing. Geophysical data (both historic and contemporary), historic habitat mapping surveys and subsea video collected during the present study in Darwin Harbour have identified areas of emergent bedrock, often with a relatively thin veneer of sediment. The correlation between arsenic and iron in this area suggests that the underlying bedrock is likely the source of arsenic, which has previously been recorded in Darwin Harbour and is a well-known natural source in north-west Australia (e.g. INPEX Operations Australia Ltd 2014, DEC 2006). Arsenic in Darwin Harbour sediments is considered unlikely to be bioavailable to any significant extent, and therefore unlikely to cause toxic impacts to biota (INPEX Operations Australia Ltd 2014).

Despite a strong positive relationship between arsenic and iron in spoil ground samples, the concentrations of both analytes were much lower than recorded in the Harbour. This suggests that the source of the arsenic and iron is likely to be outside of the spoil ground, and spatial interpretation of arsenic concentrations at spoil ground sampling sites indicates that the source is likely to be to the north-north-west of the spoil ground (as there is an increasing transition in arsenic concentrations in this direction across the sampling array). The source is therefore unlikely to be dredged Darwin Harbour seabed material disposed of at the adjacent INPEX Ichthys spoil ground to the east of the proposed spoil ground location.

A general trend for many of the metals analysed was an increasing concentration towards and within Darwin Harbour, though with much lower concentrations (except manganese) recorded in the proposed sand wave dredging area towards the mouth of the harbour. This trend correlates with the silt content of sediments, which increased towards and within the harbour, except for the mobile sand waves from which the finer components were likely winnowed away by near seabed currents. Metals and metalloids are commonly associated with smaller particle sizes (Martincic et al*.* 1990).

TPH, TRH and BTEXN concentrations were below the laboratory LORs in sediment samples at all offshore pipeline and spoil ground sites. Consequently, no analysis of PAHs was required at these locations. TPH and TRH were detected at 35 of the Darwin Harbour sites at low levels. Normalised TPH and TRH concentrations were well below the Default Guideline Value (DGV) of 280 mg/kg across all sites, with the highest recorded concentration of C10–C36 (sum) being 45 mg/kg at site HS09. All PAH concentrations at these 35 sites were below the LoR.

NORMs were recorded above LoRs for all sediment samples long the offshore pipeline route. Levels of radium-226, radium-228 and thorium-228 were generally below 31, 33 and 37 Bq/kg, respectively, except at sites HS27 and HS31 in Darwin Harbour main channel between KP110 and KP112, where peak levels of 51.7–79.1, 46.8–59.5 and 43–63.8 Bq/kg were recorded, respectively. The combined value for radium-226, radium-228 and thorium-228 ('combined NORMs') were below the NAGD guideline value of 35,000 Bq/kg at all sites, even when considering upper confidence limits.

Pesticide concentration in all 27 of the Darwin Harbour sediment core samples retrieved were below the LoR.

TBT concentrations were below the limit of reporting in all samples from Darwin Harbour. No samples were analysed for TBT outside of the harbour.

There is low potential for acid sulfate soils as although inorganic sulfur is present in the sediments, there is significant ANC kinetically available to neutralise the oxidation products from the inorganic sulfur.

Overall, no contaminants of concern were found in the sediments along the pipeline route or at the potential spoil disposal ground, with elevated levels of arsenic considered to be naturally occurring. Therefore the sediments along the pipeline route are considered to be suitable for unconfined ocean disposal, as per the NAGD and NT EPA (2013) guidelines for dredging.

4.4 Water quality

Measurements of water quality profiles through the water column along the offshore pipeline route and at the proposed spoil ground indicated that water temperature was either consistent with depth or decreased slightly with depth. Salinity was either consistent or varied marginally over depth, except at the two westernmost offshore pipeline route sites, where an increase in salinity was recorded over the 0–10 m depth range. Turbidity at four sites along the offshore pipeline route decreased down to 15–20 m depth, then gradually increased with depth. Elsewhere along the pipeline route, turbidity was either relatively consistent with depth or increased with depth. At the proposed spoil ground turbidity generally increased with depth. Oxygen levels tended to increase with increasing depth in both study areas except at two sites along the offshore pipeline route. Oxygen levels decreased with depth below 20 m and at one and oxygen levels decreased down to ~10 m, then remained fairly consistent at the other site. pH decreased with increased depth at the majority of sites along the offshore pipeline route, increased with depth at two sites and at one site was consistent with depth except at ~15–20 m and ~35–>50 m where there was a relatively large drop from 11.5 to 9.5. The pH data from the spoil ground sites seemed to be inconsistent, and it was likely that the pH probe had developed a fault during these deployments. Overall, the CTD data indicate that there was no evidence of a halocline or thermocline and showed no indications of stratification of the water column.

Filtered and unfiltered cadmium (Cd), chromium (Cr), cobalt (Co), nickel (Ni) and mercury (Hg) were generally below LoRs at both offshore pipeline and spoil ground locations, except for one site, which had filtered nickel and unfiltered chromium concentrations that were above the LoR but well below the relevant guideline value. The filtered and unfiltered arsenic (As) concentrations were very similar in both offshore pipeline and spoil ground samples and were below the relevant ANZG (2018) DGV.

Filtered and unfiltered copper (Cu) concentrations at three sites were above the relevant ANZG (2018) DGV. The copper concentration in one sample OP2S was much higher than in other samples therefore it is likely that this sample is an outlier and sampled a potential contaminant. Filtered and unfiltered lead (Pb) concentrations ranged from <0.1 to 5.4 µg/L in the offshore pipeline samples but were much lower in the spoil ground samples (<0.1 to 0.4 µg/L). One sample had a filtered lead concentration above the relevant ANZG (2018) DGV. Unfiltered zinc (Zn) concentrations were at or above the relevant ANZG (2018) DGV of 8 µg/L in two samples, filtered zinc concentrations were at or above the DGV at six sites at the western end of the offshore pipeline route (between OP1 and OP5) and across the proposed spoil ground area (sites SG4, SG7 and SG12), with no clear trend in exceedances between surface and bottom waters.

The results of the analysis of metals and metalloids identified DGV exceedances in cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), nickel (Ni), mercury (Hg) and zinc (n) in the surface waters of site OP1, though the source was not identified.

Nitrite and nitrate were recorded at concentrations at or above LoRs in bottom water samples only, at concentrations of up to 15 µg.N/L. Ammonia was detected in 14 samples, with 13 of those being bottom (near seabed) samples and were below the relevant ANZG (2018) DGV. The peak concentration of ammonia was 13 µg.N/L at the proposed spoil ground. Total nitrogen concentrations ranged from 80 to 150 µg.N/L; 35 samples were at or exceeded the relevant ANZG (2018) DGV. Nineteen orthophosphate (filterable reactive phosphorus) concentrations samples exceeded the relevant ANZG (2018) and total phosphorous concentrations in 35 samples were at or exceeded the relevant ANZG (2018) DGV. Nutrients (nitrogen, phosphorus and organic carbon) are released in the decay of organic matter, and the increased concentrations of nutrients in near-seabed samples likely correlate with decaying organic matter on the seabed at those locations.

Chlorophyll-a concentrations were used as an indicator of the likely level of phytoplankton biomass across the offshore pipeline area. Chlorophyll-a concentrations ranged from 0.4 to 1.5 µg/L. All concentrations were below the relevant ANZG (2018). Phaeophytin-a is a breakdown product of chlorophyll-a and can be used to indicate if phytoplankton are blooming or declining. Phaeophytin-a was only detected in 10 samples of the offshore pipeline sites, the majority of which were surface samples.

TSS concentrations ranged from 1.7 to 8.6 mg/L. There was no correlation between depth and TSS, and no clear difference found in the TSS between surface and bottom samples. There is no ANZG (2018) default guideline value for TSS.

Hydrocarbon concentrations were below LoRs for all samples at all sites. Radium-226 was detected at above LoRs in near-seabed samples at two of the offshore pipeline sites but none of the spoil ground sites.

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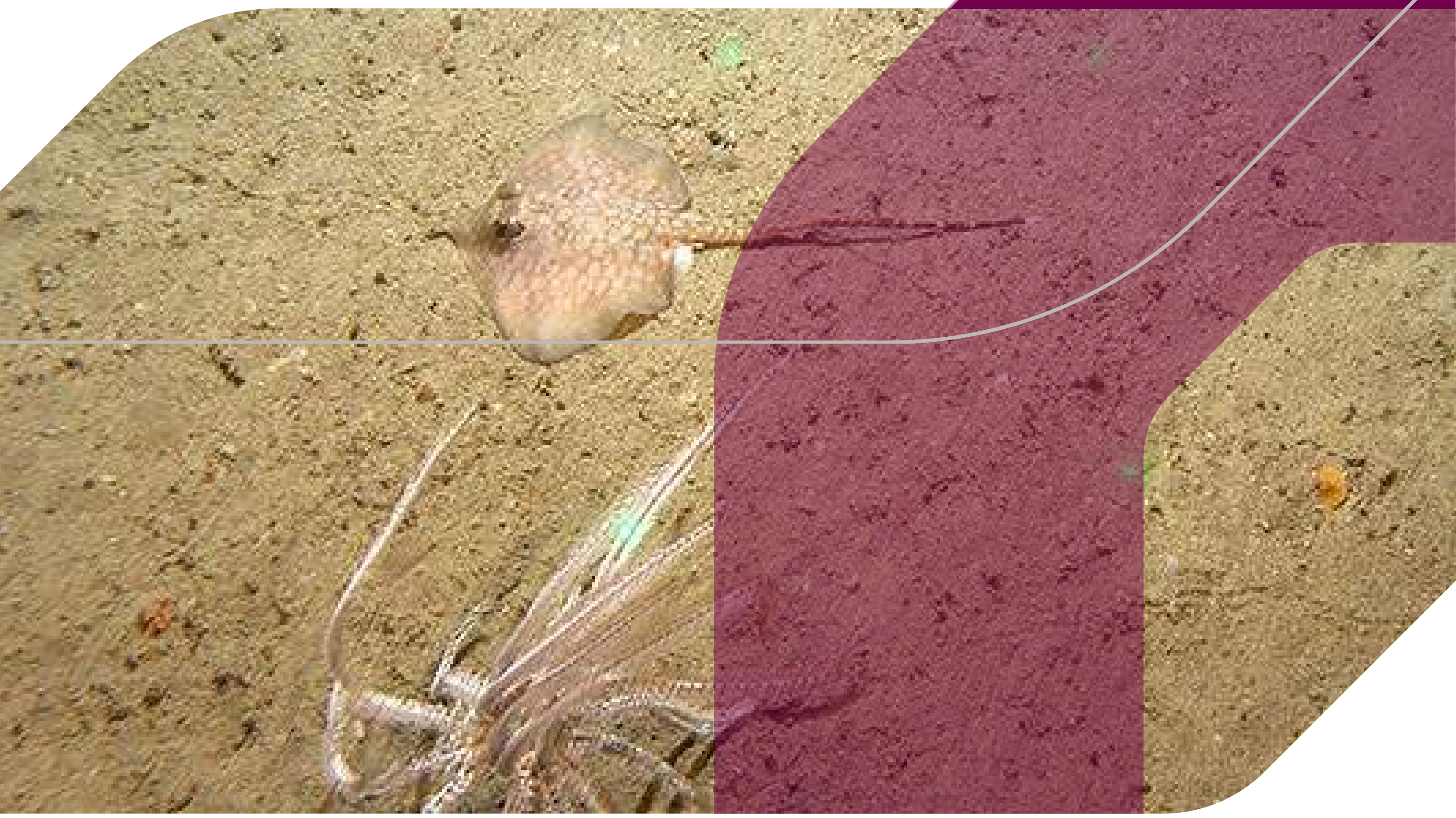
Appendix A
Survey sites



APPENDIX A: SURVEY SITES

Table A-1: Offshore pipeline sampling sites

Site	Sample ID	Latitude	Longitude	Video	Water quality	Water (NORMS)	Infauna	PSD[1]	Sediment (contaminants)	Sediment (NORMs)
KP -2.7	OP1	-12.0093	129.8887	Y			Y	Y	Y	Y
KP 0	OP1S	-12.0315	129.9137		Y					
	OP1B	-12.0315	129.9137		Y	Y				
KP 1	OP2	-12.0315	129.9138	Y			Y	Y	Y	Y
KP 6.8	OP3	-12.0691	129.949	Y			Y	Y	Y	Y
KP 8	V3	-12.0738	129.9594	Y						
	OP2S				Y					
	OP2B	-12.074	129.9594		Y	Y				
KP 11	OP4	-12.0826	129.9854	Y			Y	Y	Y	Y
KP 16	OP5	-12.0974	130.0287	Y			Y	Y	Y	Y
KP 20	OP3S	-12.1081	130.064		Y					
	OP3B	-12.1079	130.064		Y	Y				
KP 22	V4	-12.1091	130.0822	Y						
	OP6						Y	Y	Y	Y
KP 27	OP7	-12.1212	130.1247	Y			Y	Y	Y	Y
KP 30	V5	-12.1374	130.1479	Y						
	OP4S				Y					
	OP4B	-12.1373	130.148		Y	Y				
KP 31	OP9	-12.1409	130.1558	Y			Y	Y	Y	Y
KP 33.7	OP10	-12.15	130.1792				Y	Y	Y	Y
	V6			Y						
KP 36	OP11	-12.1571	130.1997	Y			Y	Y	Y	Y
	OP5S	-12.1573	130.199		Y					
	OP5B	-12.1577	130.1989		Y	Y				
KP 40	OP12	-12.1691	130.2339				Y	Y	Y	Y
	V7			Y						
KP 42	OP13	-12.1756	130.252				Y	Y	Y	Y
KP 45	OP6S	-12.1844	130.2772		Y					
	OP6B	-12.1848	130.2772		Y	Y				
KP 45.2	OP14	-12.1856	130.2795				Y	Y	Y	Y
	V8			Y						
KP 45.8	OP15	-12.1862	130.2855				Y	Y	Y	Y
	V9			Y						
KP 48	OP16	-12.1932	130.3039	Y			Y	Y	Y	Y
KP 50.5	OP17	-12.2012	130.3246				Y	Y	Y	Y
	V10			Y						
KP 51.3	OP18	-12.2025	130.3323				Y	Y	Y	Y
	V11			Y						
KP 52.5	OP19	-12.2069	130.3419				Y	Y	Y	Y
	V12			Y						
KP 54	OP20	-12.2114	130.3553				Y	Y	Y	Y
	V13			Y						
KP 55	OP7S	-12.2143	130.364		Y					
	OP7B	-12.2145	130.3636		Y	Y				
KP 56	OP21	-12.2172	130.3722	Y			Y	Y	Y	Y
KP 61	OP22	-12.2323	130.4149				Y	Y	Y	Y
	V14			Y						
KP 65	OP23	-12.2447	130.4503				Y	Y	Y	Y
	V15			Y						
	OP8S	-12.2444	130.4504		Y					
	OP8B	-12.2446	130.4502		Y	Y				
KP 71.5	OP24	-12.2639	130.5069				Y	Y	Y	Y
	V16			Y						
KP 75	OP25	-12.2743	130.5364	Y			Y	Y	Y	Y
	OP9S	-12.2742	130.5374		Y					
	OP9B	-12.2741	130.5376		Y	Y				
KP 78	OP26	-12.2831	130.5636				Y	Y	Y	Y
	V17			Y						
KP 80	OP27	-12.2894	130.5801	Y			Y	Y	Y	Y
KP 85	OP28	-12.3047	130.6252				Y	Y	Y	Y
	V18			Y						
	OP10S	-12.3043	130.6243		Y					
	OP10B	-12.3043	130.6245		Y	Y				
KP 86	OP29	-12.3081	130.6354	Y			Y	Y	Y	Y
KP 89	OP30	-12.3221	130.6555	Y			Y	Y	Y	Y
KP 91	V19	-12.3397	130.6776	Y						

[1] 29 samples were used for Offshore Pipeline PSD with three duplicates

Table A-2: Spoil Ground sampling sites

Site	Sample ID	Latitude	Longitude	Video	Water quality	Water (NORMS)	Infauna	PSD	Sediment (contaminants and nutrients)	Sediment (NORMs)
SG1 (NE)	SG1	-12.2144	130.8069	Y			Y	Y	Y	Y
	SG1S	-12.2129	130.8062		Y					
	SG1B	-12.2124	130.8063		Y	Y				
SG2	SG2	-12.2188	130.802	Y			Y	Y	Y	Y
	SG2S									
	SG2B									
SG3	SG3	-12.2252	130.7957	Y			Y	Y	Y	Y
	SG3S									
	SG3B					Y				
SG4 (centre)	SG4	-12.2304	130.7908	Y			Y	Y	Y	Y
	SG4S	-12.2291	130.7906		Y					
	SG4B	-12.2294	130.7907		Y					
SG5	SG5	-12.2336	130.7861	Y			Y	Y	Y	Y
	SG51									
	SG5S					Y				
SG6	SG6	-12.2382	130.78	Y			Y	Y	Y	Y
	SG6S									
	SG6B									
SG7 (SW)	SG7	-12.2436	130.7744	Y			Y	Y	Y	Y
	SG7S	-12.2448	130.7759		Y					
	SG7B	-12.2447	130.7766		Y	Y				
SG8 (NW)	SG8	-12.2254	130.787	Y			Y	Y	Y	Y
	SG8S	-12.2258	130.786		Y					
	SG8B	-12.2259	130.7868		Y					
SG9	SG9	-12.2269	130.7898	Y			Y	Y	Y	Y
	SG9S									
	SG9B					Y				
SG10	SG10	-12.2304	130.7933	Y			Y	Y	Y	Y
	SG10S									
	SG10B									
SG11 (SE)	SG11	-12.2325	130.7951	Y			Y	Y	Y	Y
	SG11S	-12.2327	130.7946		Y					
	SG11B	-12.2329	130.7948		Y					
SG12	SG12	-12.2147	130.7933	Y			Y	Y	Y	Y
	SG12S	-12.2125	130.7918		Y					
	SG12B	-12.2123	130.7923		Y	Y				
SG13	SG13	-12.2256	130.7723	Y			Y	Y	Y	Y
	SG13S	-12.2253	130.7714		Y					
	SG13B	-12.2259	130.7716		Y	Y				

Table A-3: Barossa Darwin Harbour sampling sites

Sample ID	Latitude	Longitude	Video	PSD[2]	Sediment (contaminants and nutrients)	Sediment (NORMs)	Sediment (PAH)[3]
HS01	-12.5278	130.8538		Y	Y	Y	Y
HS02	-12.5298	130.8515		Y	Y	Y	Y
HS03	-12.5312	130.8422		Y	Y	Y	Y
HS04	-12.5283	130.8366		Y	Y	Y	Y
HS05	-12.5259	130.832		Y	Y	Y	Y
HS06	-12.5187	130.8297		Y	Y	Y	Y
HS07	-12.5169	130.8274		Y	Y	Y	Y
HS08	-12.5138	130.8272		Y	Y	Y	Y
HS44	-12.3429	130.6958		Y	Y	Y	Y
HS10	-12.5063	130.823		Y	Y	Y	Y
HS11	-12.5048	130.8209		Y	Y	Y	Y
HS12	-12.5016	130.8183		Y	Y	Y	
HS13	-12.4992	130.8191		Y	Y	Y	Y
HS14	-12.4959	130.8169		Y	Y	Y	Y
HS15	-12.493	130.8169		Y	Y	Y	Y
HS16	-12.4912	130.8151		Y	Y	Y	Y
HS17	-12.487	130.8149		Y	Y	Y	Y
HS18	-12.484	130.8142		Y	Y	Y	Y
HS19	-12.4824	130.8116		Y	Y	Y	Y
HS20	-12.4792	130.8121		Y	Y	Y	Y
HS21	-12.4777	130.8112		Y	Y	Y	Y
HS22	-12.4774	130.8091		Y	Y	Y	Y
HS23	-12.4754	130.8094		Y	Y	Y	Y
HS24	-12.474	130.8088		Y	Y	Y	Y
HS25	-12.4727	130.8066		Y	Y	Y	
HS26	-12.4705	130.8052		Y	Y	Y	Y
HS27	-12.4674	130.8056		Y	Y	Y	
HS31	-12.4609	130.7974		Y	Y	Y	Y
HS32	-12.3476	130.7006		Y	Y	Y	
HS33	-12.3473	130.6992		Y	Y	Y	
HS34	-12.3481	130.6948		Y	Y	Y	
HS35	-12.3477	130.6928		Y	Y	Y	Y
HS36	-12.3489	130.6869		Y	Y	Y	
HS37	-12.3483	130.6816		Y	Y	Y	
HS38	-12.3454	130.6748		Y	Y	Y	Y
HS39	-12.3451	130.6809		Y	Y	Y	
HS40	-12.3461	130.6826		Y	Y	Y	
HS41	-12.3461	130.6879		Y	Y	Y	
HS42	-12.3448	130.6903		Y	Y	Y	Y
HS44a	-12.3429	130.6958		Y	Y	Y	
HS44b	-12.3429	130.6958		Y	Y	Y	
HS45	-12.3436	130.6844		Y	Y	Y	
HS46	-12.3399	130.685		Y	Y	Y	
HS47	-12.3372	130.6844		Y	Y	Y	Y
HS48	-12.3382	130.671		Y	Y	Y	Y
HS49	-12.337	130.6679		Y	Y	Y	Y
HS50	-12.5278	130.8531	Y				
HS51	-12.5287	130.8482	Y				
HS52	-12.5258	130.8363	Y				
HS53	-12.5101	130.8254	Y				
HS54	-12.5059	130.8234	Y				
HS55	-12.5040	130.8224	Y				
HS56	-12.5004	130.8202	Y				
HS57	-12.4899	130.8162	Y				
HS58	-12.4849	130.8139	Y				
HS59	-12.4825	130.8137	Y				
HS60	-12.4756	130.8098	Y				
HS61	-12.4656	130.8039	Y				
HSN2	-12.4634	130.8055	Y				
HS62	-12.4580	130.7985	Y				
HSN1	-12.4572	130.7975	Y				
HS63	-12.4535	130.7950	Y				
HS64	-12.4464	130.7889	Y				
HS65	-12.4409	130.7846	Y				
HS-A	-12.4388	130.7836	Y				
HS68	-12.4228	130.7699	Y				
HS69	-12.4156	130.7650	Y				
HS70	-12.4029	130.7542	Y	Y	Y	Y	Y
HS72	-12.3889	130.7411	Y				
HS73	-12.3802	130.7299	Y				
HS74	-12.3717	130.7184	Y	Y	Y	Y	Y
HS75	-12.3634	130.7075	Y	Y	Y	Y	Y
HS76	-12.3631	130.7070	Y				
HS77	-12.3548	130.6968	Y	Y	Y	Y	Y
HS78	-12.3479	130.6874	Y				

[2] 50 samples were used for Darwin Harbour PSD with three duplicates

[3] 35 samples were used for Darwin Harbour Sediment (PAH) with two duplicates

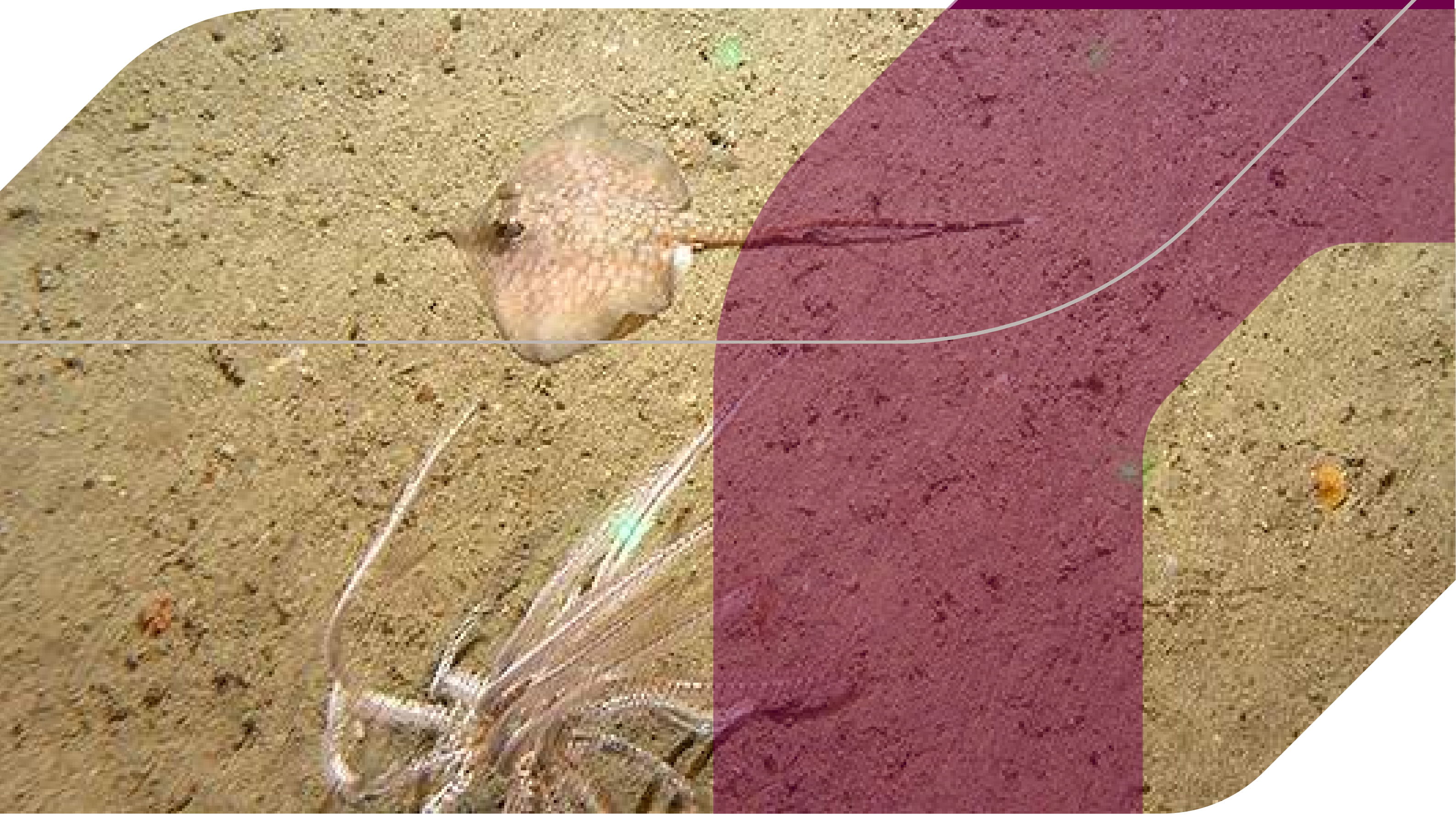
Table A-4: Geotechnical survey sampling sites

Sample ID	Depth interval	Latitude	Longitude	PSD	Sediment (contaminants and nutrients)	Sediment (PAH)
KP92.75_L	0.5–1.0 m	-12.342	130.6808	Y	Y	
KP92.75_U	0–0.5 m			Y	Y	Y
KP92.85_L	0.5–1.0 m	-12.3426	130.6815	Y	Y	
KP92.85_U	0–0.5 m			Y	Y	
KP92.95_U	0–0.5 m	-12.3431	130.6823	Y	Y	Y
KP93.23_U	0–0.5 m	-12.348	130.6884	Y	Y	
KP93.7_U	0–0.5 m	-12.3447	130.6843	Y	Y	
KP93.8_L	0.5–1.0 m	-12.3473	130.6877	Y	Y	Y
KP93.8_U	0–0.5 m			Y	Y	Y
KP102.7_L	0.5–1.0 m	-12.3995	130.7511	Y	Y	Y
KP102.7_U	0–0.5 m			Y	Y	Y
KP103.1_L	0.5–1.0 m	-12.4023	130.7534	Y	Y	Y
KP103.1_U	0–0.5 m			Y	Y	Y
KP103.5_U	0–0.5 m	-12.4051	130.7556	Y	Y	Y
KP104.9_U	0–0.5 m	-12.4149	130.7638	Y	Y	Y
KP106.0_L	0.5–1.0 m	-12.4226	130.7702	Y	Y	Y
KP106.0_U	0–0.5 m			Y	Y	Y
KP110.4_U	0–0.5 m	-12.4541	130.7949	Y	Y	Y
KP112.4_U	0–0.5 m	-12.4541	130.7949	Y	Y	
KP119.7_L	0.5–1.0 m	-12.5263	130.8369	Y	Y	Y
KP119.7_U	0–0.5 m			Y	Y	Y
KP119.8_U	0–0.5 m	-12.5263	130.8369	Y	Y	Y
KP120.5_U	0–0.5 m	-12.5287	130.8438	Y	Y	Y
KP120.6_U	0–0.5 m	-12.5288	130.8447	Y	Y	Y

Table A-5: June 2022 video transect sites

Sample ID	Latitude	Longitude	Video Transect
BACI_1C	130°50'38.495"E	12°31'26.461"S	Y
BACI_1P	130°50'32.347"E	12°31'42.246"S	Y
BACI_2C	130°50'47.455"E	12°30'45.598"S	Y
BACI_2P	130°49'44.420"E	12°31'1.153"S	Y
BACI_3C	130°49'4.068"E	12°27'57.263"S	Y
BACI_3P	130°48'25.361"E	12°28'13.464"S	Y
BACI_4C	130°46'33.883"E	12°24'31.296"S	Y
BACI_4P	130°45'51.573"E	12°24'54.006"S	Y
BACI_5C	130°45'36.170"E	12°23'46.150"S	Y
BACI_5P	130°45'10.407"E	12°24'2.428"S	Y
BACI_6C	130°38'23.665"E	12°18'11.888"S	Y
BACI_6P	130°38'10.108"E	12°18'30.388"S	Y
FishAgg	-	-	Y
Hab1	130°44'21.026"E	12°24'21.864"S	Y
Hab2	130°44'45.192"E	12°24'37.033"S	Y
Hab3	130°45'31.175"E	12°25'10.634"S	Y
Hab4	130°45'46.168"E	12°25'31.971"S	Y
Hab5	130°45'59.052"E	12°25'38.552"S	Y
Hab6	130°48'29.669"E	12°28'53.056"S	Y
Hab7	130°48'24.629"E	12°28'57.356"S	Y
Hab8	130°48'1.701"E	12°29'14.268"S	Y
Hab9	130°51'32.011"E	12°31'35.792"S	Y
Hab10	130°51'28.072"E	12°31'53.329"S	Y
Heritage_147	130°45'10.407"E	12°24'2.428"S	Y
Heritage_031	130°45'51.573"E	12°24'54.006"S	Y
Hertage_241	130°45'51.573"E	12°24'54.006"S	Y
INPHCCHI	130°52'24.661"E	12°33'4.623"S	Y
INPHCNEW	130°52'24.661"E	12°33'4.623"S	Y
INPHCMAN	130°46'15.600"E	12°26'6.019"S	Y
INPHCMAN_1	130°46'13.174"E	12°26'6.581"S	Y
INPHCSSI	130°53'3.741"E	12°29'42.839"S	Y
INPSGCPW	130°38'55.643"E	12°23'10.346"S	Y
INPHCWED2	130°48'10.492"E	12°29'29.812"S	Y
INPHCWOD	130°46'19.792"E	12°28'16.331"S	Y
RFPA1	130°37'14.803"E	12°18'11.254"S	Y
RFPA2	130°39'4.227"E	12°19'6.433"S	Y
RFPA3	130°38'26.235"E	12°18'37.210"S	Y
RFPA4	130°35'58.805"E	12°17'44.931"S	Y
RFPA5	130°35'12.359"E	12°17'28.386"S	Y
RFPA6	130°34'29.483"E	12°17'14.219"S	Y
RFPA8	130°36'34.496"E	12°17'58.787"S	Y
Sand waves	130°41'20.443"E	12°20'54.969"S	Y

Appendix B
Sediment survey log



APPENDIX B: SEDIMENT SURVEY LOG

Date	Site	Drop no.	Depth (m)	WP no.	Sample size (grab 1,2)	Successful	Sediment composition	Features	Conspicuous fauna	Metals/ nutrients/ TOC	Hydrocarbons	NORMs	PSD	Infauna	TBT	Leachates	ASS	Photo	Duplicate	Triplicate	Comments
15-Oct-21	OP1	1	56	1036	3/4, 3/4	Y	shelly sand (fine)	No	Algae- Caulerpa	Y	Y	Y	Y					Y			
15-Oct-21	OP1	2	56.5	1037	1/2	Y	Shelly sand (fine)	Slight odour	Algae					Y							
15-Oct-21	OP2	1	52.1	1038	1/2 3/4	Y	Shelly sand	No	Gastropods, algae	Y	Y	Y	Y								
15-Oct-21	OP2	2	52.1	1039	3/4 3/4	Y	Shelly sand	No	Worm, gastropods					Y							
15-Oct-21	OP3	1	59.9	1040	3/4 1/2	Y	Shelly sand (muddy)	No	No	Y	Y	Y	Y								
15-Oct-21	OP3	2	59.8	1041	3/4	Y	Shelly sand/muddy	No	Lace coral					Y							
15-Oct-21	OP4	1	49.4	1042	3/4, 3/4	Y	Shelly sand (muddy)	No	Algae, fish	Y	Y	Y	Y					Y			
15-Oct-21	OP4	2	49.4	1043	3/4	Y	Shelly sand, clumps of clay	No	Worms, starfish					Y				Y			
15-Oct-21	OP5	1	47.2	1044	3/4,3/4	Y	Shelly sand with clumps of clay	No	Algae	Y	Y	Y	Y					Y			
15-Oct-21	OP5	2	47	1045	0	N		No	No												Failed grab/misfire
15-Oct-21	OP5	3	47.2	1046	1/2	Y	Shelly sand with clumps of clay	No	No					Y				Y			
15-Oct-21	OP6	1	47	1047	1/2, 1/2	Y	Shelly sand with clumps of clay. Rocks caught in 1 grab	No	Bryozoa	Y	Y	Y	Y					Y			
15-Oct-21	OP6	2	48	1048	3/4	Y	Shelly sand with muddy/clay clumps	Tubes	Crabs, polychaete tubes					Y				Y			
15-Oct-21	OP7	1	48	1049	3/4, 3/4	Y	Shelly sand with clumps of clay	No	Algae	Y	Y	Y	Y					Y		Triplicate A	
15-Oct-21	OP7	2	47.3	1050	3/4	Y	Shelly sand with clay clumps	No	Brittle star					Y				Y			
15-Oct-21	OP9	1	48	1051	3/4	Y	Shelly sand with clumps of clay	No	No	Y	Y	Y	Y					Y			
15-Oct-21	OP9	2	47	1052		Y	Shelly sand with clumps of clay	No	No					Y				Y			
15-Oct-21	OP10	1	42.5	1053	Full	Y	Silty sand	No	No	Y	Y	Y	Y					Y			
15-Oct-21	OP11	1	44	1054	Full	Y	Silty mud	No	No	Y	Y	Y	Y								
15-Oct-21	OP11	2	46	1056	Full	Y	Sandy silt/mud. Lots of shells	No	No					Y							
15-Oct-21	OP12	1	39.9	1057	Full	Y	Sandy	No	Sea star	Y	Y	Y	Y								
15-Oct-21	OP12	2	42	1058	Full	Y	Sandy	No	No					Y							
15-Oct-21	OP13	1	38.7	1059	3/4, Full	Y	Silty sand/mud	No	No	Y	Y	Y	Y								
15-Oct-21	OP13	2	38.2	1060	1/2, 3/4	Y	Shelly silty sand	No	No					Y				Y			
15-Oct-21	OP14	1	38.4	1061	3/4	Y	Silty sand with lots of shells	No	No	Y	Y	Y	Y					Y			
15-Oct-21	OP14	2	38.5	1062	3/4	Y	Silty sand with lots of shells	No	No					Y							
15-Oct-21	OP15	1	40.4	1063	3/4	Y	Silty sand	No	Cauliflower species (photo)- Neptheidae)	Y	Y	Y	Y								
15-Oct-21	OP15	2	40.5	1064	3/4	Y	Silty sand	No	No					Y							
16-Oct-21	OP16	1	39.6	1065		Y	Silty sand	No	No	Y	Y	Y	Y								
16-Oct-21	OP16	2	39.9	1066	3/4	Y	Silty sand with lots of shells	No	No					Y							
16-Oct-21	OP17	1	38.2	1067	3/4	Y	Silty sand	No	Worms, starfish	Y	Y	Y	Y					Y			
16-Oct-21	OP17	2	38.1	1068	3/4	Y	Silty sand with lots of shells	No	Flat worm					Y							
16-Oct-21	OP18	1	38.8	1069	3/4	Y	Silty sand	No	Feather star	Y	Y	Y	Y								
16-Oct-21	OP18	2	39	1070	3/4	Y	Silty sand and shells	No	No					Y							
16-Oct-21	OP19	1	38.6	1072	3/4	Y	Silty sand	No	Hermit crab, brittle star	Y	Y	Y	Y								
16-Oct-21	OP19	2	38.8	1073	3/4	Y	Silty sediment and shells	No	No					Y				Y			
16-Oct-21	OP20	1	46	1074	Full	Y	Silty mud/sand	No	No	Y	Y	Y	Y					Y			

Date	Site	Drop no.	Depth (m)	WP no.	Sample size (grab 1,2)	Successful	Sediment composition	Features	Conspicuous fauna	Metals/ nutrients/ TOC	Hydrocarbons	NORMs	PSD	Infauna	TBT	Leachates	ASS	Photo	Duplicate	Triplicate	Comments
16-Oct-21	OP20	2	45.6	1075	Medium	Y	Silty mud/clay	No	No					Y							
16-Oct-21	OP21	1	45.3	1076	Full	Y	Silty sand/mud	No	No	Y	Y	Y	Y								
16-Oct-21	OP21	2	45.7	1077	Med	Y	Silty sand/mud	No	No					Y							
16-Oct-21	PTS-57.5-GS	1	39.8	1097	Full	Y	Silty sand	No	No				Y					N			
16-Oct-21	OP22	1	31.5	1098	7/8	Y	Silty sand, gritty mud	No	Coral, tube worm	Y	Y	Y	Y					Y			
16-Oct-21	OP22	2	31.7	1099		Y	Sandy gritty mud, clay clumps	No	Brittle star, urchin, murex					Y							
16-Oct-21	PTS-62.5-GS	1	34.9	1100	Full	Y	Silty sand	No	No				Y					Y			
16-Oct-21	PTS-64.0-GS	1	32.5	1101	Full	Y	Silty soft sediment, with sand and grit	No	No				Y								Not sure if PSD bag labelled correctly. Data sheet called this PTS-57.5-gs
16-Oct-21	OP23	2	32	1102		Y	Sandy mud, silty soft sediment	No	No	Y	Y	Y	Y								
16-Oct-21	OP24	1	26.4	1103	Full	Y	Sandy mud, rubble/gravel	No	Fireweed, tubeworms	Y	Y	Y	Y								Some fumes in air during sampling
17-Oct-21	OP24	2	26.5	1104	Full	Y	Sandy mud, rubble/gravel	No	Fireweed, spanner crab, worm					Y							
17-Oct-21	OP25	1	28	1105	Full	Y	Gravelly sandy mud	No	Tube worms	Y	Y	Y	Y								
17-Oct-21	OP25	2	28.4	1106	Full	Y	Gravelly mud	No	Blood worm, brittle star					Y							
17-Oct-21	OP26	1	27	1107	Full	Y	Gravelly, sandy mud	No	No	Y	Y	Y	Y								
17-Oct-21	OP26	1	27.2	1108	Full	Y	Gravely mud, clay clumps	No	Comb shells					Y							
17-Oct-21	OP27	1	28	1109		Y	Muddy sandy clay	No	Tube worms	Y	Y	Y	Y								
17-Oct-21	OP27	2	28	1110		Y	Gravelly mud, clay	No	Shells/worms					Y							
17-Oct-21	OP28	1	25.8	1111	Full	Y	Sandy clay	No	No	Y	Y	Y	Y					Y			
17-Oct-21	OP28	2	25.8	1112	Full	Y	Gritty mud/clay	No	No					Y				Y			
17-Oct-21	OP29	1	26.1	1113	Full	Y	Gritty mud	No	dead coral	Y	Y	Y	Y					Y			
17-Oct-21	OP29	2	26	1114		Y	Silty sand/mud	No	Lots of varieties of shells, bivalves					Y				Y			
17-Oct-21	OP30	1	21	1115	Full	Y	Silty sand/mud	Tubes	Polychaete tubers, worm (long)	Y	Y	Y	Y					Y			
17-Oct-21	OP30	2	21	1116		Y	Silty sand/mud	Tubes	No					Y				Y			
17-Oct-21	SG7	2	19.4	1136	Full	Y	Silty sand	No	No					Y							
17-Oct-21	SG6	1	18.3	1137	Full	Y	Silty sand	No	No	Y	Y	Y	Y								
17-Oct-21	SG6	2	18.2	1138		Y	NA	No	No					Y							
17-Oct-21	SG5	1	18	1139	Full	Y	NA	No	No	Y	Y	Y	Y								Photos have wrong label - says sg7
17-Oct-21	SG5	2	18	1140	NA	Y	NA	No	No					Y							
17-Oct-21	SG4	1	18.1	1141	1/3 1/2	Y	Sandy mud	No	No	Y	Y	Y	Y								
17-Oct-21	SG4	2	17.5	1142	NA	Y		No	No					Y							
17-Oct-21	SG3	1	19.1	1143	3/4	Y	go	No	No	Y	Y	Y	Y								
17-Oct-21	SG3	2	19.1	1144		Y	NA	No	No					Y						Triplicate B & C	
17-Oct-21	SG2	1	17.7	1145	1/4	Y	NA	No	No	Y	Y	Y	Y					Y			
17-Oct-21	SG2	2	17.8	1146	1/2	Y	Sandy mud + shells	NA	Lots of shell fragments, cone shell					Y				Y			
18-Oct-21	SG1	1	18.5	1147	1/2	Y	Sandy mud/gritty	No	No	Y	Y	Y	Y					Y			
18-Oct-21	SG1	2	19	1148	Full	Y	NA	No	No					Y							

Date	Site	Drop no.	Depth (m)	WP no.	Sample size (grab 1,2)	Successful	Sediment composition	Features	Conspicuous fauna	Metals/ nutrients/ TOC	Hydrocarbons	NORMs	PSD	Infauna	TBT	Leachates	ASS	Photo	Duplicate	Triplicate	Comments
18-Oct-21	SG12 (Control)	1	18.1	1149	1/2	Y	Sandy mud - doesn't look too shelly		Large cushion star in grab	Y	Y	Y	Y								
18-Oct-21	SG12 (Control)	2	19.7	1150	1/2	Y	Sandy mud	No	No					Y							
18-Oct-21	SG13 (Control)	1	21	1151	3/4	Y	Sandy mud	No	No	Y	Y	Y	Y								
18-Oct-21	SG13 (Control)	2	21	1152	3/4	Y	Gritty sandy mud, shell frags		Shrimp, spider crab, sponge, brittle star					Y							
18-Oct-21	SG8	1	22.4	1153	3/4	Y	Gritty mud	No	No	Y	Y	Y	Y								
18-Oct-21	SG8	2	22.5	1154	Full	Y	Sandy/gritty mud, shell frags	No	Coral, shells					Y							
18-Oct-21	SG9	1	22.7	1155	1/2 1/3	Y	Gritty mud, large coral pieces + rocks		Dead coral	Y	Y	Y	Y								
18-Oct-21	SG9	2	22.6	1156	3/4	Y	Gritty sandy mud, coral frags		Sponge, coral					Y							
18-Oct-21	SG10	1	21.7	1157	1/2 3/3	Y	Sandy mud		Coral, shells	Y	Y	Y	Y								
18-Oct-21	SG10	2	21.5	1158	2/3	Y	Sandy mud	No	No					Y							
18-Oct-21	SG11	1	21.1	1159		Y	Sandy mud	No	No	Y	Y	Y	Y								
18-Oct-21	SG11	2	21	1160		Y		No	No					Y							
19-Oct-21	HS49	1	20	1179	Full	Y	Clay	No	No	Y	Y	Y	Y		Y	Y	Y				
19-Oct-21	HS48	1	19.8	1180	Full	Y	Silty sandy clay	No	No	Y	Y	Y	Y		Y	Y	Y				
19-Oct-21	HS47	1	20.8	1181	Full	Y	Sandy mud		Tube worms	Y	Y	Y	Y		Y	Y	Y				
19-Oct-21	HS46	1	13.8	1182	1/4	N		No	No												One grab did not fire, other just 1/4 full. No sample taken
19-Oct-21	HS46	2	11	1183		N		No	No												Both grabs did not trigger
19-Oct-21	HS46	3	11	1184	1/2, 1/3	Y	Coarse sand, shell grit	No	Worm	Y	Y	Y	Y		Y	Y	Y				
19-Oct-21	HS45	1	11.2	1185		Y	Shell gravel/grit	No	No	Y	Y	Y	Y		Y	Y	Y				
19-Oct-21	HS38	1	16.9	1186		Y	Silty sand	No	No	Y	Y	Y	Y		Y	Y	Y				
19-Oct-21	HS39	1	11.4	1187	1/2, 0	N		No	No												One grab did not fire
20-Oct-21	HS39	2	11.4	1188	3/4, 3/4	Y	Sandy grit, shell fragments	No	No	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS40	1	16.1	1189	1/2, 2/3	Y	Medium coarse sand	No	Sea spider, feather star, worms	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS41	1	15.7	1190	1/4, 1/2	Y	Silty sand	No	Feather star	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS42	1	15.8	1191	1/2	Y	Silty sand/mud	Smell-Pungent (sour smell)	No	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS44	1	15.6	1192	3/4	Y	Sandy shell grit	No	Worm	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS43	1	17.4	1193	3/4	Y	Sandy grit with shell fragments	No	No	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS37	1	18	1194	3/4	Y	Sandy grit with shell fragments	No	No	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS36	1	19.1	1195		Y		No	No	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS35	1	15	1196	3/4, 3/4,	Y	Coarse shelly sand with clumps of clay	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
20-Oct-21	HS34	1	17	1197	Full	Y	Coarse shelly sand, with some mud	No	No	Y	Y	Y	Y		Y	Y	Y	Y	Duplicate B		
20-Oct-21	HS33	1	16	1198	Full	Y	Coarse shelly sand	No	100+ small hermit crabs (photo)	Y	Y	Y	Y		Y	Y	Y	Y			
20-Oct-21	HS32	1	16	1199	1/2, 3/4	Y	Coarse sand, with some mud	No	sand dollar (photo)	Y	Y	Y	Y		Y	Y	Y	Y			
20-Oct-21	HS77	1	15	1200	Full	Y	Muddy sand with some shells	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
20-Oct-21	HS75	1	13	1201	1/2, 3/4	Y	Muddy sand with some shells	No	Coral (photo)	Y	Y	Y	Y		Y	Y	Y	Y			
20-Oct-21	HS74	1	16	1202	1/2, 3/4	Y	Coarse sand with some silt	No	No	Y	Y	Y	Y		Y	Y	Y	Y			

Date	Site	Drop no.	Depth (m)	WP no.	Sample size (grab 1,2)	Successful	Sediment composition	Features	Conspicuous fauna	Metals/ nutrients/ TOC	Hydrocarbons	NORMs	PSD	Infauna	TBT	Leachates	ASS	Photo	Duplicate	Triplicate	Comments
20-Oct-21	HS70	1	24	1203	Full	Y	Coarse sand with small rocks and clumps of clay	No	Heart Urchin	Y	Y	Y	Y		Y	Y	Y	Y	Duplicate A		
20-Oct-21	HS31	1	15	1204	1/5	N		No	No									Y			Rocks caught in grab
20-Oct-21	HS31	2	15	1205	3/4, 1/2	Y	Muddy shelly sand	No	Algae, red sponge	Y	Y	Y	Y		Y	Y	Y	Y			Rock caught in grab- some fine sediments lost
20-Oct-21	HS31	3	15	1206	0	N		No	Algae, granite, sponges									Y			Rocks caught in grab
20-Oct-21	HS30	1	25	1207	1/5, 0	N		No	No									Y			Rocks caught in grab
20-Oct-21	HS30	2	25	1208	0, 1/8	N	Sandy shell	No	Heart Urchin (photo)									Y			Hard bottom- no grab
20-Oct-21	HS30	3	22	1209	0	N	Rocks	No	encrusting coral, polychaete tubes (photo)									Y			Moved 50 m s of hs30 ** site abandoned
20-Oct-21	HS29	1	20	1210	0	N	Rocks	No	Sponge, coral, Bryozoa, granite rocks, heart urchin									Y			Rocky bottom- no sediment in grab
20-Oct-21	HS29	2	20	1211	0	N	Rocks	No	No									N			Rocky bottom- no sediment in grab
20-Oct-21	HS29	3	25	1212	0	N	Rocks	No	No									Y			Rocks **site abandoned
20-Oct-21	HS28	1	18	1213	0	N	Rocks	No	No									Y			Rocks in grab- geophys shows hard bottom
20-Oct-21	HS28	2	18	1214	0	N	Rocks	No	Sponge, Bryozoa (lace coral), crabs x4									Y			**Site abandoned
20-Oct-21	HS27	1	25	1215	1/4	Y	Silty shelly sand with rocks	No	Gastropods				Y								
20-Oct-21	HS27	2	25	1216	3/4	Y	Silty shelly sand	Tubes	No	Y	Y	Y			Y	Y	Y	Y			
20-Oct-21	HS26	1	20	1217	1/2, 0	Y	Silty shelly sand	No	No	Y	Y		Y		Y	Y	Y	Y			No norms
20-Oct-21	HS26	2	20	1218	0	N	Rock and sponge	No	No									Y			No sample
20-Oct-21	HS26	3	20	1219	0	N	Rocks in grab	No	Gorgonian									Y			No sample
20-Oct-21	HS25	1	17.5	1220	1/3, 1/3	Y	Rocks, rubble, bit of silty sand		Crabs, worms, sponges, coral	Y	Y		Y				Y				Only 3 samples taken- small sample
20-Oct-21	HS25	2	17	1221	0	N	Coral, Rocks	No	Sponge, crabs, worms												No sample
20-Oct-21	HS25	3	17.5	1222	0	N	Coral, Rocks	No	sponges, crabs												No sample
20-Oct-21	HS24	1	17.2	1223	1/4	Y	Corals/Rocks	No	Sponge, gorgonian	Y	Y						Y				Small sample
20-Oct-21	HS24	2	16.2	1224	1/4	N	Rocks	No	Gorgonian, sponge												Fail
20-Oct-21	HS24	3	18.8	1225	1/5	N	Rocks	No	Fan coral												Fail
20-Oct-21	HS23	1	22.6	1226	1/4, 1/2	Y	Gravel/coarse sediment- silty with rocks	No	No	Y	Y	Y	Y		Y	Y	Y				
20-Oct-21	HS22	1	15.9	1227	1/4, 1/2	Y	Rock substrate	No	Coral and epibiota	Y	Y				Y						Partial sample
20-Oct-21	HS22	2	17	1229	1/4, 1/2	Y	Coarse sand, shell fragments	No	No			Y	Y		Y	Y	Y				
20-Oct-21	HS21	1	19.3	1230	1/5	N	Grainy sand	No	No												Whole sample touching bottom of grab- not used
20-Oct-21	HS21	2	19.1	1231	NA	Y	Silty sand/mud and rocks	No	Large sponge on rocks with epibiota, brittle star, tube worms	Y	Y		Y		Y	Y	Y				No norms
20-Oct-21	HS21	3	18.9	1232	0	N	Silty sand/mud and rocks	No	NA												Not enough
20-Oct-21	HS20	1	17.7	1233	1/5	N	NA		Coral/sponge									Y			
20-Oct-21	HS20	2	17.3	1234	1/2	Y	Silty sand/mud/gravel	No	Flat worm	Y	Y				Y	Y	Y				
20-Oct-21	HS20	3	17.5	1235	1/2	Y	Silty sand/mud/gravel	No	No			Y	Y		Y	Y					
20-Oct-21	HS14	1	14.3	1236	Full	Y	Silty grainy mud	No	Crab, coral	Y	Y	Y	Y		Y	Y	Y				
21-Oct-21	HS15	1	14.8	1237		Y	Silty mud with rocky rubble	No	No	Y	Y		Y		Y						

Date	Site	Drop no.	Depth (m)	WP no.	Sample size (grab 1,2)	Successful	Sediment composition	Features	Conspicuous fauna	Metals/ nutrients/ TOC	Hydrocarbons	NORMs	PSD	Infauna	TBT	Leachates	ASS	Photo	Duplicate	Triplicate	Comments
21-Oct-21	HS15	2	15.1	1238		Y	Silty sand	No	No			Y				Y	Y				
21-Oct-21	HS16	1	14.8	1239		Y	Silty sand/mud with rocky rubble	No	No	Y	Y		Y		Y	Y	Y				
21-Oct-21	HS16	2	15.3	1240	1/2, 1/4	Y	Silty sand/mud with rocky rubble	No	Coral			Y			Y	Y	Y				
21-Oct-21	HS17	1	16.6	1241	1/2, 1/2	Y	Gritty, silty mud	No	Coral, sponge	Y	Y	Y	Y		Y	Y	Y				
21-Oct-21	HS18	1	18.9	1242	3/4, 3/4	Y	Gritty mud	No	No	Y	Y	Y	Y		Y	Y	Y		Duplicate C		
21-Oct-21	HS19	1	19.8	1243		N	Large rocks	No	Coral, sponge												Large rocks caught in jaws, no sediment
21-Oct-21	HS19	2	21.5	1244		Y	Silty sand with pebbles/rubble	No	crab	Y	Y		Y		Y	Y	Y				
21-Oct-21	HS19	3	21.1	1245		N	Silty coarse sand/rubble and shell fragments	No	coral, feather star												
21-Oct-21	HS19	4	19.8	1246	1/2	Y	Silty coarse sand/rubble	No	No			Y					Y				
21-Jan-21	HS01	1	11	1247	Full	Y	Silty shelly sand	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS03	1	20	1248	1/4	N	Rock		Urchin- small									Y			Rock in grab
21-Oct-21	HS03	2	20	1249	1/2, 3/4	Y	Silty shelly sand with rocks	No	Lace coral, crab	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS02	1	15	1250	Full	Y	Silty sand with shells and rocks	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS04	1	18	1251	Full	Y	Muddy sand with some shells	No	Small octopus (photo)	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS05	1	13	1252	Full	Y	Muddy sand with some shells	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS06	1	10	1253	1, 3/4	Y	Silty shelly sand. Coarse sand on surface	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS07	1	10	1254	3/4	Y	Silty shelly sand	No	Worm	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS08	1	12	1255	Full	Y	Silty shelly sand	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS09	1	9	1256	1/2, 1/4	N		No	Corals									Y			Corals hanging out of grab, sample lost
21-Oct-21	HS09	2	9	1257	1/2, 1/2	N	Muddy, shelly sediment	No	No									Y			Grab partly open
21-Oct-21	HS09	3	9	1258	3/4, 3/4	Y	Muddy shelly sand	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS10	1	8.5	1259	3/4, 1/4	Y	Silty shelly sand	No	No	Y	Y	Y	Y		Y	Y	Y	Y			Rocks caught in one grab; sample taken from other grab
21-Oct-21	HS11	1	9	1260	3/4, 3/4	Y	Silty sand with shells and rocks	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS12	1	9	1261	Full	Y	Muddy/silty sand with shells and rocks	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
21-Oct-21	HS13	1	12	1262	Full	Y	Muddy/silty sand with shells and rocks	No	No	Y	Y	Y	Y		Y	Y	Y	Y			
15-Oct-21	OP10	2	42.8	NR	Full	Y	Silty sand	No	No					Y							
17-Oct-21	SG7	1	19.4	See note	Full	Y	NA	No	Crab	Y	Y	Y	Y								12°14.632's, 130°46.482'e
16-Oct-21	OP23	1	32.2	See note	Full	Y	Gravelly silty mud	No	No					Y							12°14.658's, 130°26.962'e

Job Name: Pipeline to Shore Marine Sediment Sampling						**Site ID:** KP92.75			
Job Number: 1001175						**Date:** 10/01/2022			
Coordinates (Attempt A): 682 764.090 m E, 8 635 053.557 m N						**Attempt B:**			
Attempt C:						**Attempt D:**			
Water depth LAT (m): 14.24				**Penetration (m):** 1.80 (A)				**Recovery (m):** 1.80 (A)	
Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	0930	1	0-100	M	M	10YR 5/4 (yellowish Brown)	Sand	~20% shell	Some clay/slit mixed in

Log notes:

- 1 m core sampled (upper and lower)
- Shelly sand throughout core
- Small amounts of silt and clay mixed in
- Only 1 attempt required
- Poor recovery at same site for Geotech samples

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP92.85
Job Number: 1001175		**Date:** 10/01/2022
Coordinates (Attempt A): 682 841.553 m E, 8 634 991.945 m N		**Attempt B:** 682 841.086 m E, 8 634 991.847 m N
Attempt C:		**Attempt D:**
Water depth LAT (m): 13.09	**Penetration (m):** 1 (A), 0.5 (B)	**Recovery (m):** 0.77 (A), 0.43 (B)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	0948	1	0-77	M	W	10 YR 5/3 Brown	Sand	~20% shell	
B (rep)	1005	1	0-43	M	W	10 YR 5/3 Brown	Sand	~20% shell	

Log notes:

- For attempt A core:
  - 0-0.5 m sampled with all jars full (upper)
  - 0.5-0.77m sampled with all but elutriate jars full (lower)
- For attempt B core:
  - 0-0.43 m core sampled as replicate (upper only)
- Shelly sand throughout (higher shell content at surface ~30%)
- Silt visible in water within liner
- Both cores were temporarily stored upright before processing due to a build-up of samples
- Lower part of sample appeared shellier

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP92.95
Job Number: 1001175		**Date:** 10/01/2022
Coordinates (Attempt A): 682 918.538 m E, 8 634 929.023 m N		**Attempt B:** 682 918.437 m E, 8 634 928.888 m N
Attempt C:		**Attempt D:**
Water depth LAT (m): 15.58	**Penetration (m):** 0.56 (A), 0.6 (B)	**Recovery (m):** 0.56 (A), 0.54 (B)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	1021	1	0-15	M	M	10 YR 4/1 Dark grey	Sand	~5% shells	
		2	15-56	VF-M	M	10 YR 4/2 Dark greyish brown	Sandy Clay	~5% shells	
B (rep)	1040	1	0-15	VF-M	M	2.5 Y 4/1 Dark grey	Clayey sand	~5% shells	
		2	15-40	VF-M	M	2.5 Y 4/1 Dark grey	Sandy Clay	~5% shells	
		3	40-54	VF-M	M	2.5 Y 4/1 Dark grey	Clayey sand	~5% shells	

Log notes:

- For attempt A core:
  - 0-0.5 m sampled with all jars full (upper)
- For attempt B core:
  - 0-0.5 m core sampled as replicate (upper only)
  - Clay layer in between two sandy layers
- Sample was stored in liner before processing

Job Name: Pipeline to Shore Marine Sediment Sampling	**Site ID:** KP93.23
Job Number: 1001175	**Date:** 08/01/2022
Coordinates (Attempt A): 683 134.336 m E, 8 634 752.961 m N	**Attempt B:** 683 137.628 m E, 8 634 749.041 m N
Attempt C: 683 134.857 m E, 8 634 752.218 m N	**Attempt D:** 683 133.776 m E, 8 634 750.419 m N

Water depth LAT (m): 12.94	**Penetration (m):** 0 (A), 0.2 (B), 0.1 (C), 0.4 (D)	**Recovery (m):** 0 (A), 0.18 (B), 0.05 (C), 0.4 (D)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
B	0421	1	0-18	M	W	10 YR 5/4 Yellowish brown	Sand	~10% shells	
D	0511	1	0-40	M	M	10 YR 5/4 Yellowish brown	Sand	~20% shells	Patches of clayey sand

Log notes:

- For attempt A core no sediment was collected and attempt 3 minimal sediment was collected
- Sample was collected from attempt B and D after homogenising (upper only)
- Samples were stored in liners before for several hours before processing

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP93.7
Job Number: 1001175		**Date:** 07/01/2022
Coordinates (Attempt A): 683 505.450 m E, 8 634 457.619 m N		**Attempt B:** 683 503.140 m E, 8 634 460.490 m N
Attempt C:		**Attempt D:**
Water depth LAT (m): 15.81	**Penetration (m):** 0 (A), 0.65 (B)	**Recovery (m):** 0 (A), 0.65 (B)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
B	2257	1	0-50	M	M	10 YR 5/4 Yellowish brown	Sand	~30% shells	Grey/blue clay band at 30cm and patches throughout

Log notes:

- For attempt A had no penetration or recovery
- Attempt B was sampled for 0-0.5m (upper only)

Job Name: Pipeline to Shore Marine Sediment Sampling						**Site ID:** KP93.8			
Job Number: 1001175						**Date:** 07/01/2022			
Coordinates (Attempt A): 683 578.871 m E, 8 634 392.984 m N						**Attempt B:** 683 578.584 m E, 8 634 390.045 m N			
Attempt C:						**Attempt D:**			
Water depth LAT (m): 12.47				**Penetration (m):** 0 (A), 1.57 (B)				**Recovery (m):** 0 (A), 1.57 (B)	
Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
B	2257	1	0-100	M	W	10 YR 6/4 Light yellowish brown	Sand	~30% shells	

Log notes:

- Attempt A was unsuccessful
- Attempt B was sampled for upper (0-0.5m) and lower (0.5-1m)
- Sandy ridge/crest

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP102.7	
Job Number: 1001175		**Date:** 07/01/2022	
Coordinates (Attempt A): 690 363.030 m E, 8 628 648.399 m N		**Attempt B:**	
Attempt C:		**Attempt D:**	
Water depth LAT (m): 27.09	**Penetration (m):** 2.65 (A)		**Recovery (m):** 1.6 (A)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	1704	1	0-25	F	P	5 Y 4/1 Dark grey	Sandy clay	Some shells	Fine-medium gravel
		2	25-100	VF	P	5 Y 5/1 Grey	Clay	Some shells	Fine-medium gravel

Log notes:

- Attempt A core was sampled for upper (0-0.5m) and lower (0.5-1m)
- Less large gravel compared with other gravelly sites
- Alive worm caught in liner

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP103.1
Job Number: 1001175		**Date:** 07/01/2022
Coordinates (Attempt A): 690 613.997 m E, 8 628 335.991 m N		**Attempt B:**
Attempt C:		**Attempt D:**
Water depth LAT (m): 25.23	**Penetration (m):** 2.3 (A)	**Recovery (m):** 1.73 (A)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	1603	1	0-11	VF	P	5 Y 5/1 Grey	Light clay	~30% shell	Medium-coarse gravel
		2	11-40	VF	P	5 Y 5/2 Olive grey	Sandy clay	Some shells	Medium-coarse gravel Patchy sand and clay
		3	40-100	VF	P	5 Y 4/2 Olive grey	Clay		Medium-coarse gravel Patchy sand and clay

Log notes:

- 1m core sampled from attempt A (upper and lower)
- Dense clay with patches of sandy clay

Job Name: Pipeline to Shore Marine Sediment Sampling	**Site ID:** KP103.5
Job Number: 1001175	**Date:** 07/01/2022
Coordinates (Attempt A): 690 850.349 m E, 8 628 017.285 m N	**Attempt B:** 690 851.951 m E, 8 628 020.097 m N
Attempt C:	**Attempt D:**

Water depth LAT (m): 20.42	**Penetration (m):** 0.28 (A), 0.23 (B)	**Recovery (m):** 0.28 (A), 0.23 (B)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	0934	1	0-18	VF-M	P	2.5 Y 5/3 Light olive brown	Clayey sand	~30% shell Coral and worm tubes	
		2	18-28	VF-M	P	5 Y 5/2 Olive grey	Sandy clay	Coral and worm tubes	Medium-coarse gravel
B	1011	1	0-13	VF-M	P	2.5 Y 5/2 Greyish brown	Clayed sand		Medium-coarse gravel
		2	13-23	VF-M	P	2.5 Y 5/2 Greyish brown	Clay		Medium-coarse gravel Red mottles (40%) Green mottles (10%)

Log notes:

- Upper sample collected from homogenised sediment from both attempts A and B
- Sample stored before homogenising and processing

Job Name: Pipeline to Shore Marine Sediment Sampling					**Site ID:** KP104.9				
Job Number: 1001175					**Date:** 06/01/2022				
Coordinates (Attempt A): 691 730.097 m E, 8 626 931.141 m N					**Attempt B:**				
Attempt C:					**Attempt D:**				
Water depth LAT (m): 22.08			**Penetration (m):** 0.7 (A)				**Recovery (m):** 0.59 (A)		
Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	2231	1	0-40	VF-M	P	5 Y 5/3 Olive	Sandy clay	Some shells in upper portion	Medium gravel
		2	40-59	VF-M	P	5 Y 5/3 Olive	Sandy clay		Medium-coarse gravel Orange mottles (25%) Grey/blue mottles (20%) Red mottles (2%)

Log notes:

- Upper sample collected from homogenised sediment from both attempts A and B
- Sample stored before homogenising and processing
- Orange, blue/grey and red mottles 0.4-0.59m

Job Name: Pipeline to Shore Marine Sediment Sampling	**Site ID:** KP106
Job Number: 1001175	**Date:** 06/01/2022
Coordinates (Attempt A): 692 426.006 m E, 8 626 073.362 m N	**Attempt B:** 692 420.161 m E, 8 626 076.814 m N
Attempt C:	**Attempt D:**

Water depth LAT (m): 21.92	**Penetration (m):** 1 (A), 0.53 (B)	**Recovery (m):** 1 (A), 0.53 (B)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	2024	1	0-100	F-M	P	5 Y 5/2 Olive Grey	Sandy clay	Some shells	
B (dupe)	2122	1	0-53	F-M	P	5 Y 5/2 Olive Grey	Sandy clay	Some shells	

Log notes:

- Upper 0.5m of attempt A core homogenised with upper 0.5m of attempt B core and sampled for KP106 upper and duplicate
- Lower 0.5m of attempt A core sampled

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP110.4	
Job Number: 1001175		**Date:** 06/01/2022 (Attempts A & B) & 10/01/2022 (Attempts C & D)	
Coordinates (Attempt A): 695 083.793 m E, 8 622 573.793 m N		**Attempt B:** 695 090.535 m E, 8 622 571.582 m N	
Attempt C: 695 085.691 m E, 8 622 571.271 m N		**Attempt D:** 695 085.769 m E, 8 622 575.183 m N	
Water depth LAT (m): 23.64	**Penetration (m):** 0.2 (A), 0.2 (B), 0.1 (C), 0.28 (D)		**Recovery (m):** 0.2 (A), 0.2 (B), 0.1 (C), 0.28 (D)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	1450 (6/1)	1	0-20	VF-F	P	2.5 Y 4/2 Dark greyish brown	Sandy clay	High shell content Green shell mesh at surface	Medium-coarse gravel
C	2229 (10/1)	1	0-10	M	P	2.5 Y 5/2 Greyish brown	Sand	Some shells	High medium-coarse gravel content
D	2253 (10/1)	1	0-19	VF-M	P	5 Y 5/2 Olive grey	Clayey sand	Some shells	High fine-coarse gravel content
		2	19-28	VF-M	P	5 Y 5/2 Olive grey	Sandy clay	Some shells	High fine-coarse gravel content

Log notes:

- Two attempts (A & B) conducted on the 6/1/22
- Attempt A core only enough sediment to fill:
    - 2x 250mL and 2x 150mL glass jars for ALS
    - 1x 150mL glass jars for MAFRL
- Attempt B core only gravel
- Several differing collection techniques trialled to maximise sample retention
- Two attempts (C & D) conducted on the 10/1/22 and homogenised to fill:
    - 3x 250mL jars, 1x 150mL jar and 1 bag for ALS
    - 1x 150mL jar and2 bags for MAFRL
    - Sample containers filled according to remaining requirements for missing containers from previous sample

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP112.4
Job Number: 1001175		**Date:** 06/01/2022 (Attempts A & B) & 10/01/2022 (Attempts C & D)
Coordinates (Attempt A): 696 267.828 m E, 8 620 958.932 m N		**Attempt B:** 696 267.058 m E, 8 620 956.578 m N
Attempt C: 696 265.258 m E, 8 620 960.969 m N		**Attempt D:** 696 264.954 m E, 8 620 963.672 m N
Water depth LAT (m): 19.74	**Penetration (m):** 0.1 (A), 0.25 (B), 0.2 (C), 0 (D)	**Recovery (m):** 0.1 (A), 0.25 (B), 0 (C), 0 (D)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	1609	1	0-10	VF	P	5 Y 5/1 Gray	Clay	Shells and corals present	Medium-coarse gravel
B	1644	1	0-25	VF	P	2.5 Y 8/1 White	Clay		Fine-medium gravel 30% mica

Log notes:

- Two attempts (A & B) conducted on the 6/1/22
- Attempt A core was predominantly gravel with some clay
- Attempt B core was a mix of mica, gravel and white clay (very different from first attempt)
- Sampled from attempt B however there was only enough sediment to fill some of the required jars/bags
- Two extra attempts (C & D) were conducted on the 10/1/22
- Attempt C had 0.2m penetration but only recovered gravel
- Attempt D was unsuccessful

Job Name: Pipeline to Shore Marine Sediment Sampling						**Site ID:** KP119.7			
Job Number: 1001175						**Date:** 06/01/2022 (Attempts A & B) & 8/01/2022 (Attempt C)			
Coordinates (Attempt A): 699 601.077 m E, 8 614 551.150 m N						**Attempt B:** 699 601.245 m E, 8 614 551.849 m N			
Attempt C: 699 601.148 m E, 8 614 550.346 m N						**Attempt D:**			
Water depth LAT (m): 19.89				**Penetration (m):** 1.5 (A), 1.5 (B), 1.06 (C)			**Recovery (m):** 0 (A), 0.05 (B), 1 (C)		
Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
C	1545	1	1-100	VF	P	5 Y 4/1 Dark grey	Clay	Some shells at surface	Fine-medium gravel

Log notes:

- Two attempts (A & B) conducted on the 6/1/22
- Attempt A and B had over a metre penetration but very little recovery and mostly only gravel collected
- Attempt C (conducted on 10/1/22) was sampled for upper and lower as a 1m was collected
- Liner had to be cut open using a grinder as clay was dense and stuck in liner and could not be tipped out
- The side of the sample along where the grinder was used was scrapped off before sampling
- Linear trend from coarser grains to finer from surface to bottom (slight sandiness at top)
- Heavy clay

Job Name: Pipeline to Shore Marine Sediment Sampling						**Site ID:** KP119.8			
Job Number: 1001175						**Date:** 06/01/2022 (Attempts A & B) & 11/01/2022 (Attempts C & D)			
Coordinates (Attempt A): 699 687.918 m E, 8 614 502.655 m N						**Attempt B:** 699 688.574 m E, 8 614 503.248 m N			
Attempt C: 699 688.317 m E, 8 614 500.820 m N						**Attempt D:** 699 686.599 m E, 8 614 500.582 m N			
Water depth LAT (m): 18.99				**Penetration (m):** 1.2 (A), 1 (B), 1 (C), 0.25 (D)				**Recovery (m):** 0 (A), 0.05 (B), 0.1 (C), 0.23 (D)	
Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
B	0813	1	-	VF	P	2.5 Y 5/3 Light olive brown	Clay	Some shells	Medium-coarse gravel
D	0101	1	0-10	VF-M	P	5 Y 4/2 Olive grey	Sandy clay	Some shells	Medium gravel
		2	10-18	VF-M	P	5 Y 4/1 Dark grey	Sandy clay	Some shells	Fine-medium gravel Sandy layer
		3	18-23	VF-F	P	5 Y 4/1 Dark grey	Sandy clay	Some shells	Fine-medium gravel Clay layer

Log notes:

- Penetration achieved however only gravel recovered on attempt A and B (06/01/2022)
- Sediment smear from attempt B used for colour and texture
- Attempt C and D conducted on the 11/01/2022
- From attempt D core only enough sediment recovered to fill the following:
  - 2x 250mL jars + 1x 150mL jar + 1x bag for ALS
  - 2x bags + 1x 150mL jar for MAFRL

Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP120.5
Job Number: 1001175		**Date:** 06/01/2022 (Attempts A & B) & 11/01/2022 (Attempts C & D)
Coordinates (Attempt A): 700 350.348 m E, 8 614 279.140 m N		**Attempt B:** 700 351.208 m E, 8 614 282.322 m N
Attempt C:		**Attempt D:**
Water depth LAT (m): 15.21	**Penetration (m):** 0.3 (A), 0.25 (B)	**Recovery (m):** 0.21 (A), 0.25 (B)

Attempt	Time (Local)	Horizon	Depth (cm)	Grainsize	Sorting	Colour (Munsell Soil Colour Charts)	Texture	Presence of shells/organics	Properties/comments/ inclusions
A	1426	1	0-21	VF-M	P	2.5 Y 4/1 Dark grey	Sandy clay	Some shells	Medium-coarse gravel
B	1453	1	0-25	VF-M	P	2.5 Y 4/1 Dark grey	Sandy clay	Some shells Coral and crab present	Medium-coarse gravel

Log notes:

- Two attempts taken and homogenised before filling sample jars and bags
- Coral and a crab pulled up in the core

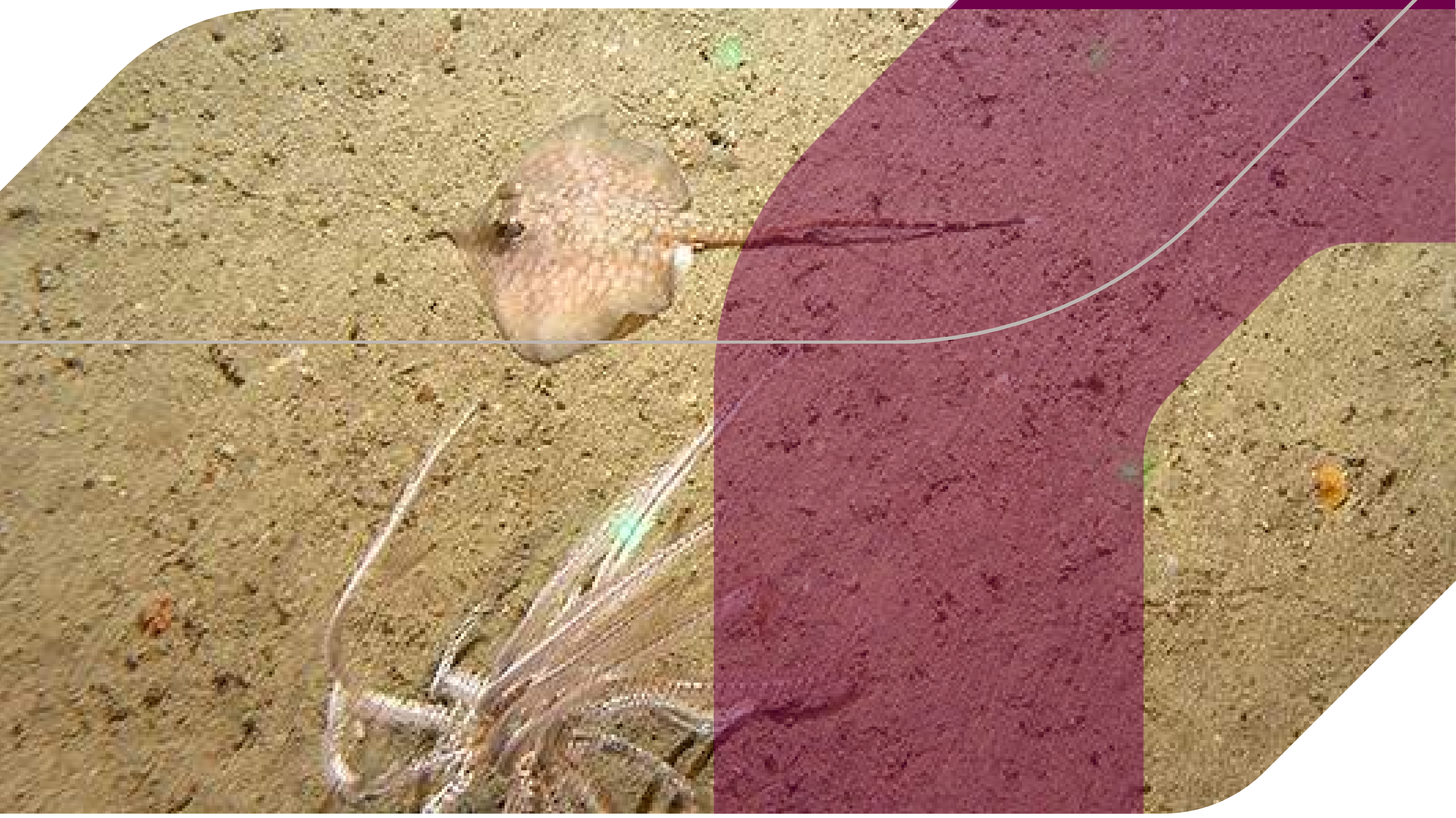
Job Name: Pipeline to Shore Marine Sediment Sampling		**Site ID:** KP120.6
Job Number: 1001175		**Date:** 08/01/2022
Coordinates (Attempt A): 700 449.348 m E, 8 614 269.568 m N		**Attempt B:** 700 447.842 m E, 8 614 272.682 m N
Attempt C: 700 448.914 m E, 8 614 273.365 m N		**Attempt D:**
Water depth LAT (m): 14.11	**Penetration (m):** 0.38 (A), 0 (B), 0.4 (C)	**Recovery (m):** 0.38 (A), 0 (B), 0.4 (C)

Attempt	**Time (Local)**	**Horizon**	**Depth (cm)**	**Grainsize**	**Sorting**	**Colour (Munsell Soil Colour Charts)**	**Texture**	**Presence of shells/organics**	**Properties/comments/ inclusions**
A	1307	1	0-10	VF	P	5 Y 4/2 Olive grey	Sandy clay	Some shell	
		2	10-30	VF	W	7.5 YR 4/3 Brown	Clay		Medium-coarse gravel 50% red mottles
		3	30-38	VF	P	5 Y 4/3 Olive	Clay		
C	1347	1	0-40	VF	P	2.5 Y 5/1 Grey	Clay	Some shell and coral	30% red mottles 15% orange mottles

Log notes:

- Two attempts taken and homogenised before filling sample jars and bags

Appendix C
Sediment sample photographs



APPENDIX C: SEDIMENT PHOTOGRAPHS

Offshore pipeline

Plate C-1: Sediment sample from OP1

Plate C-2: Sediment sample from OP2

Plate C-3: Sediment sample from OP3

Plate C-4: Sediment from site OP4

Plate C-5: Sediment from site OP5

Plate C-6: Sediment from site OP6

Plate C-7: Sediment from site OP7

Plate C-8: Sediment from site OP9

Plate C-9: Sediment from site OP10

Plate C-10: Sediment from site OP11

Plate C-11: Sediment from site OP12

Plate C-12: Sediment from site OP13

Plate C-13: Sediment from site OP14

Plate C-14: Sediment from site OP15

Plate C-15: Sediment from site OP16

Plate C-16: Sediment from site OP17

Plate C-17: Sediment from site OP18

Plate C-18: Sediment from OP19

Plate C-19: Sediment from site OP20

Plate C-20: Sediment from site OP21

Plate C-21: Sediment from site OP22

Plate C-22: Sediment from site OP23

Plate C-23: Sediment from site OP24

Plate C-24: Sediment from site OP25

Plate C-25: Sediment from site OP26

Plate C-26: Sediment from site OP27

Plate C-27: Sediment from site OP28

Plate C-28: Sediment from site OP29

Plate C-29: Sediment from site OP30

Spoil ground

Plate C-30: Sediment from site SG1

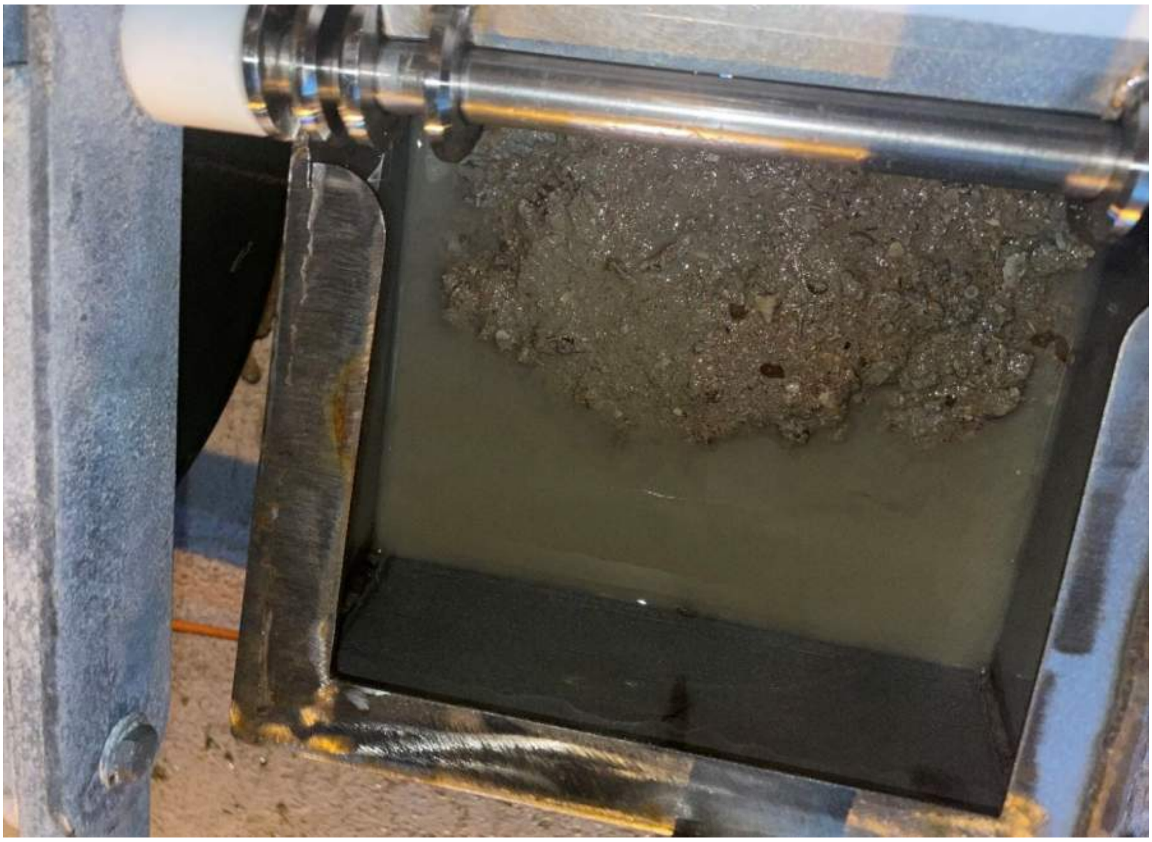


Plate C-31: Sediment from site SG2

Plate C-32: Sediment from site SG3

Plate C-33: Sediment from site SG4

Plate C-34: Sediment from site SG5

Plate C-35: Sediment from site SG6

Plate C-36: Sediment from site SG7

January 2022 core samples

Plate C-37: Sediment from site KP92.75 A1

Plate C-38: Sediment from site KP92.75 A2

Plate C-39: Sediment from site KP92.85 A1

Plate C-40: Sediment from site KP92.85 A2

Plate C-41: Sediment from site KP92.85 B1

Plate C-42: Sediment from site KP92. 85 B2

Plate C-43: Sediment from site KP92.95 A1

Plate C-44: Sediment from site KP92. 95 A2

Plate C-45: Sediment from site KP92.95 B1

Plate C-46: Sediment from site KP92.95 B2

Plate C-47: Sediment from site KP92.95 B3

Plate C-48: Sediment from site KP93.7 A1

Plate C-49: Sediment from site KP93.7 A2

Plate C-50: Sediment from site KP93.7 B1

Plate C-51: Sediment from site KP93.7 B2

Plate C-52: Sediment from site KP93.7 B3

Plate C-53: Sediment from site KP93.7 B4

Plate C-54: Sediment from site KP93.8 A1

Plate C-55: Sediment from site KP93.8 A2

Plate C-56: Sediment from site KP93.8 A3

Plate C-57: Sediment from site KP93.8 A4

Plate C-58: Sediment from site KP93.23 A1

Plate C-59: Sediment from site KP93.23 B1

Plate C-60: Sediment from site KP93.23 B2

Plate C-61: Sediment from site KP93.23 B3

Plate C-62: Sediment from site KP93.23 D1

Plate C-63: Sediment from site KP93.23 D2

Plate C-64: Sediment from site KP102.7 A1

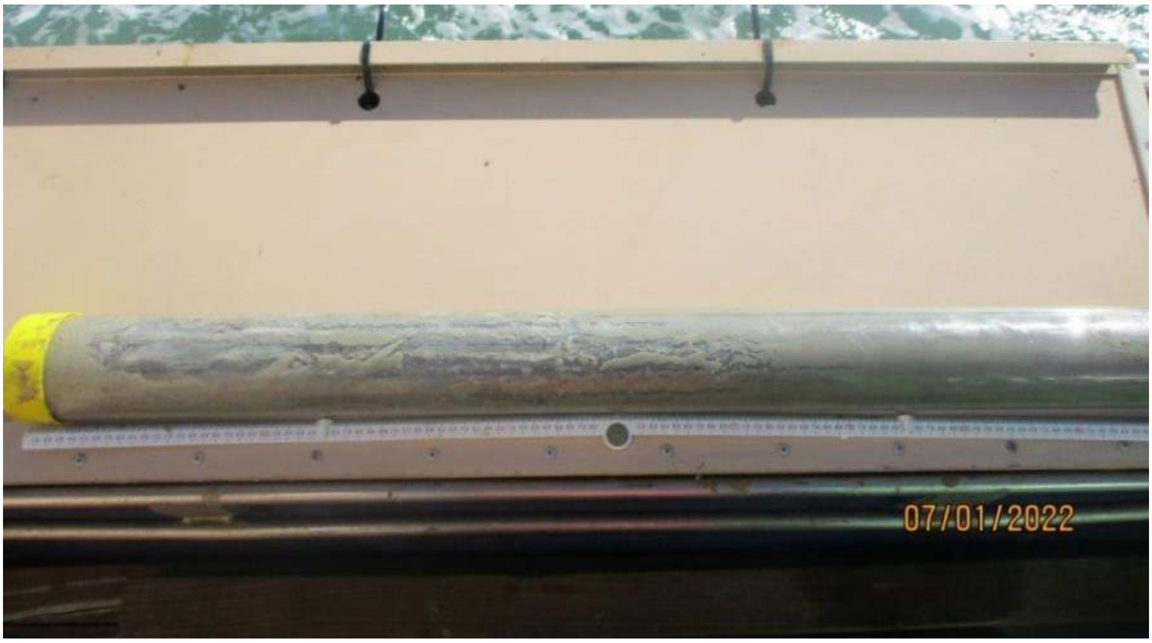


Plate C-65: Sediment from site KP102.7 A2

Plate C-66: Sediment from site KP102.7 A3

Plate C-67: Sediment from site KP102.7 A4

Plate C-68: Sediment from site KP103.1 A1

Plate C-69: Sediment from site KP103.1 A2

Plate C-70: Sediment from site KP103.1 A3

Plate C-71: Sediment from site KP103.1 A4

Plate C-72: Sediment from site KP103.1 A5

Plate C-73: Sediment from site KP103.1 A6

Plate C-74: Sediment from site KP103.1 A7

Plate C-75: Sediment from site KP103.1 A8

Plate C-76: Sediment from site KP103.1 A1

Plate C-77: Sediment from site KP103.5 A1

Plate C-78: Sediment from site KP103.5 A2

Plate C-79: Sediment from site KP103.5 A3

Plate C-80: Sediment from site KP103.5 B1

Plate C-81: Sediment from site KP104.9 A1

Plate C-82: Sediment from site KP104.9 A2

Plate C-83: Sediment from site KP106 A1

Plate C-84: Sediment from site KP106 A2

Plate C-85: Sediment from site KP110.4 A1

Plate C-86: Sediment from site KP110.4 A2

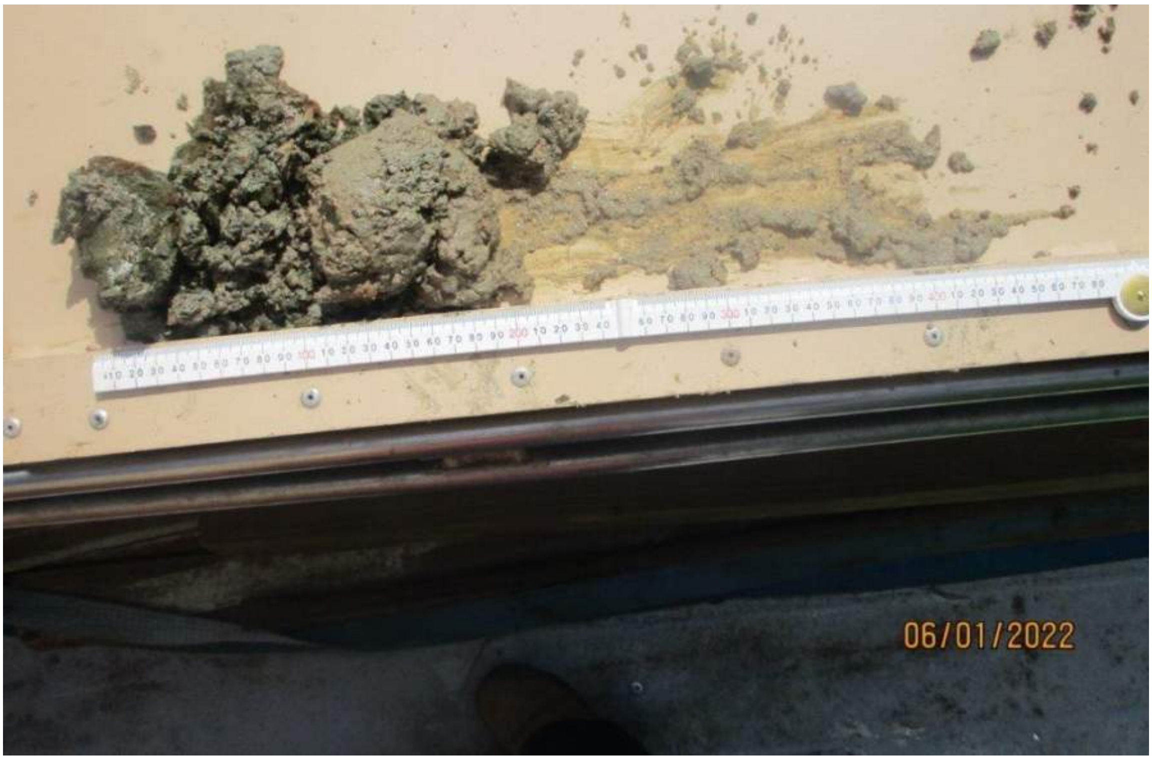


Plate C-87: Sediment from site KP110.4 A3

Plate C-88: Sediment from site KP110.4 A4

Plate C-89: Sediment from site KP110.4 B1

Plate C-90: Sediment from site KP110.4 C1

Plate C-91: Sediment from site KP110.4 C2

Plate C-92: Sediment from site KP110.4 D1

Plate C-93: Sediment from site KP110.4 a1D2

Plate C-94: Sediment from site KP112.4 A1

Plate C-95: Sediment from site KP112.4 A2

Plate C-96: Sediment from site KP112.4 B1

Plate C-97: Sediment from site KP112.4 B2

Plate C-98: Sediment from site KP112.4 B3

Plate C-99: Sediment from site KP112.4 B4

Plate C-100: Sediment from site KP112.4 C1

Plate C-101: Sediment from site KP112.4 C2

Plate C-102: Sediment from site KP112.4 C3

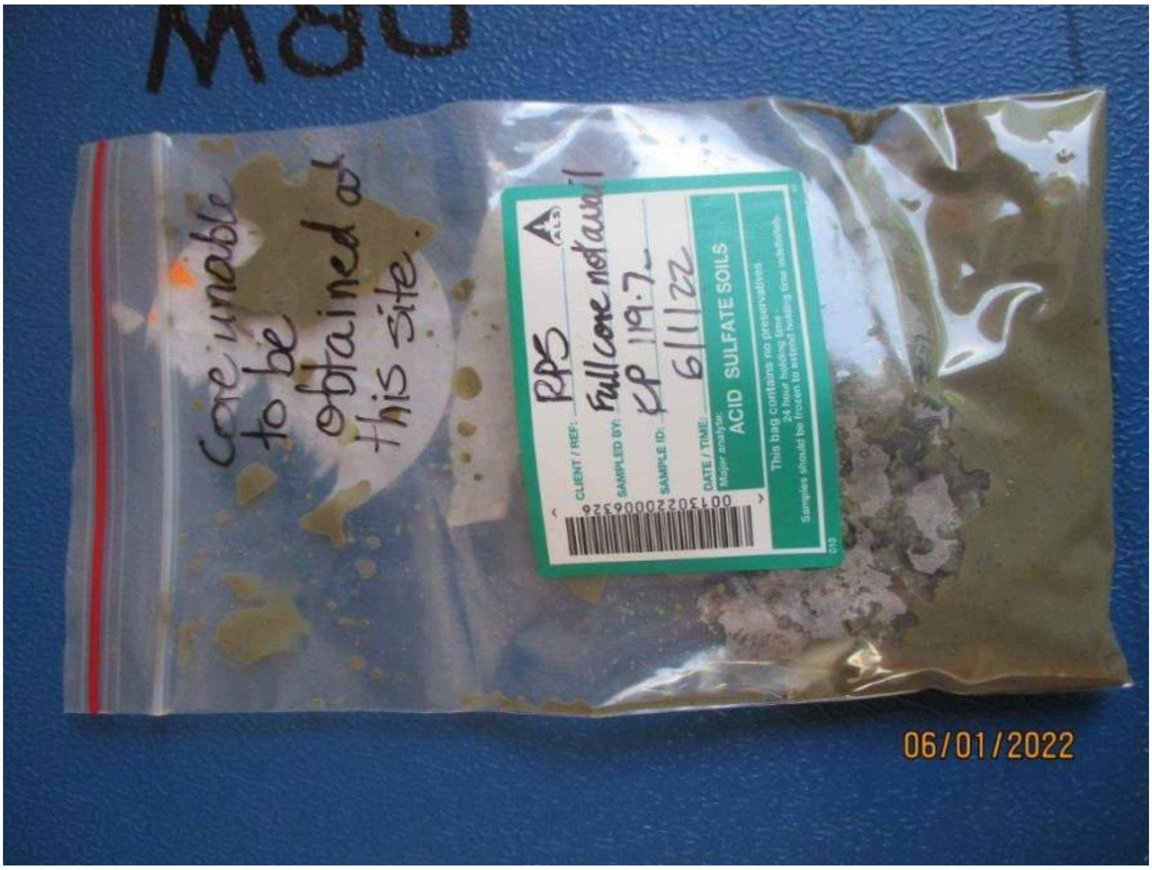


Plate C-103: Sediment from site KP119.7 A1

Plate C-104: Sediment from site KP119.7 C1

Plate C-105: Sediment from site KP119.7 C2

Plate C-106: Sediment from site KP110.8 B1

Plate C-107: Sediment from site KP119.8 B2

Plate C-108: Sediment from site KP119.8 C1

Plate C-109: Sediment from site KP119.8 C2

Plate C-110: Sediment from site KP119.8 D1

Plate C-111: Sediment from site KP120.5 A1

Plate C-112: Sediment from site KP120.5 B1

Plate C-113: Sediment from site KP120.6 A1

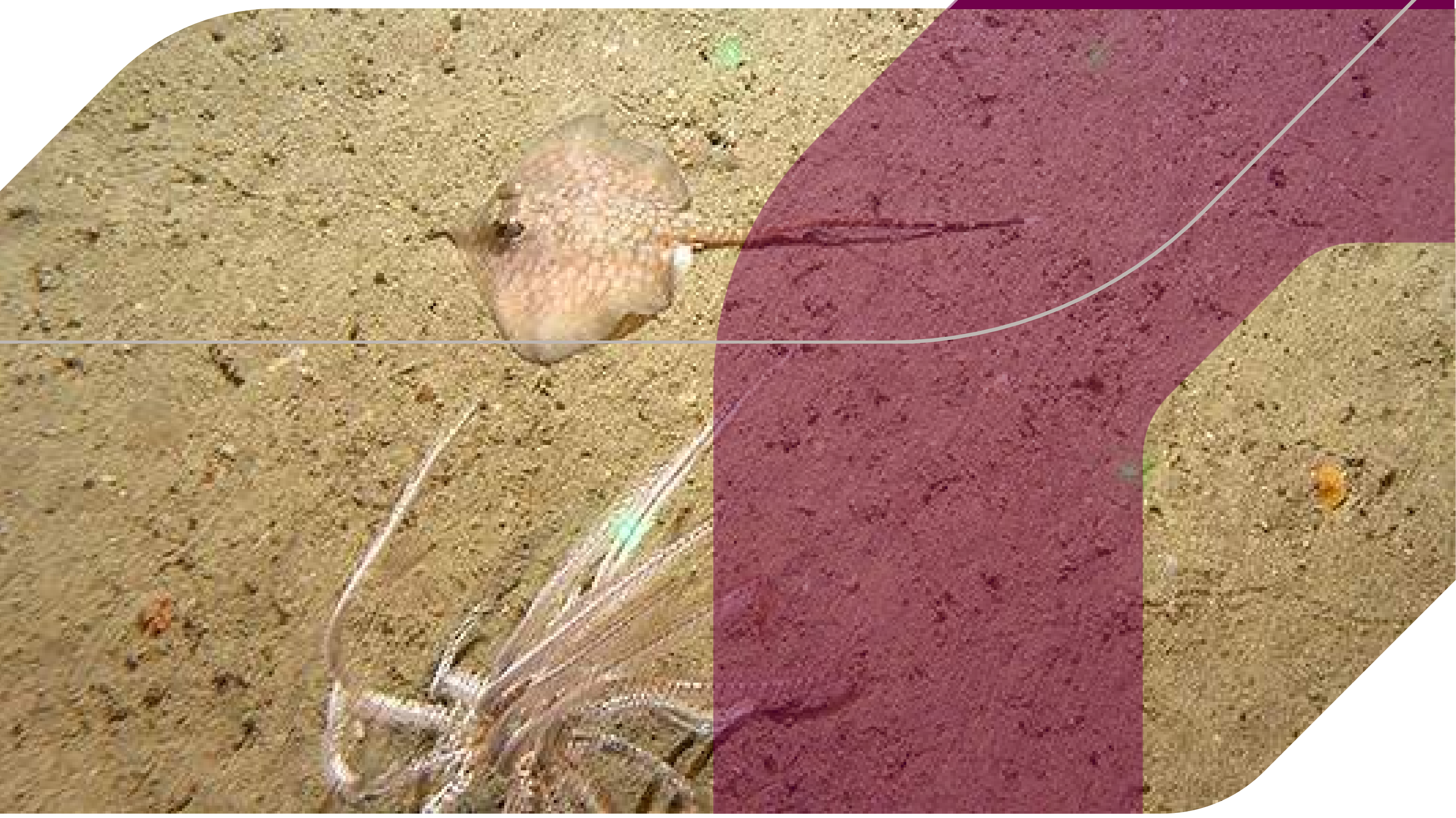
Plate C-114: Sediment from site KP120.6 A2

Plate C-115: Sediment from site KP120.6 A3

Plate C-116: Sediment from site KP120.6 B1

Plate C-117: Sediment from site KP120.6 B2

Appendix D
Laboratory sediment particle size data



Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP1
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.92**
Very Fine Silt % (4-8µm)	1.56
Fine Silt % (8-16µm)	1.72
Medium Silt % (16-31µm)	2.24
Course Silt % (31-63µm)	3.77
Total Silt (4-63µm)	**9.29**
Very Fine sand % (63-125µm)	3.13
Fine sand % (125-250µm)	18.33
Medium sand % (250-500µm)	31.01
Coarse sand % (500-1000µm)	10.35
Very Coarse sand % (1000-2000µm)	8.76
Total Sand (63-2000µm)	**71.59**
Total Gravels (>2000µm)	**16.20**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.35
1000	8.76
2000	11.35
4000	4.85
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	349.88
Minimum settling velocity of 50% of particles (mm s^1)	100.94
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	42.11
Minimum settling velocity of 90% of particles (mm s^1)	1.46
Time for 90% of particles to settle over 1 m (hours)	0.190

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP2
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.99**
Very Fine Silt % (4-8µm)	1.08
Fine Silt % (8-16µm)	1.20
Medium Silt % (16-31µm)	1.57
Course Silt % (31-63µm)	2.72
Total Silt (4-63µm)	**6.57**
Very Fine sand % (63-125µm)	2.20
Fine sand % (125-250µm)	13.57
Medium sand % (250-500µm)	25.41
Coarse sand % (500-1000µm)	11.77
Very Coarse sand % (1000-2000µm)	9.90
Total Sand (63-2000µm)	**62.85**
Total Gravels (>2000µm)	**28.58**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.77
1000	9.90
2000	13.09
4000	8.10
8000	7.39
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	510.60
Minimum settling velocity of 50% of particles (mm s^1)	214.99
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	104.54
Minimum settling velocity of 90% of particles (mm s^1)	9.01
Time for 90% of particles to settle over 1 m (hours)	0.031

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell, mud and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP3
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.45**
Very Fine Silt % (4-8µm)	1.79
Fine Silt % (8-16µm)	2.06
Medium Silt % (16-31µm)	2.96
Course Silt % (31-63µm)	4.78
Total Silt (4-63µm)	**11.58**
Very Fine sand % (63-125µm)	4.87
Fine sand % (125-250µm)	9.46
Medium sand % (250-500µm)	12.47
Coarse sand % (500-1000µm)	8.21
Very Coarse sand % (1000-2000µm)	8.23
Total Sand (63-2000µm)	**43.23**
Total Gravels (>2000µm)	**41.73**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.21
1000	8.23
2000	12.37
4000	11.53
8000	17.83
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	997.18
Minimum settling velocity of 50% of particles (mm s^1)	819.97
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	29.63
Minimum settling velocity of 90% of particles (mm s^1)	0.72
Time for 90% of particles to settle over 1 m (hours)	0.384

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP4
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.87**
Very Fine Silt % (4-8µm)	1.05
Fine Silt % (8-16µm)	1.13
Medium Silt % (16-31µm)	1.50
Course Silt % (31-63µm)	2.77
Total Silt (4-63µm)	**6.46**
Very Fine sand % (63-125µm)	3.31
Fine sand % (125-250µm)	17.96
Medium sand % (250-500µm)	27.98
Coarse sand % (500-1000µm)	13.85
Very Coarse sand % (1000-2000µm)	11.41
Total Sand (63-2000µm)	**74.52**
Total Gravels (>2000µm)	**17.15**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.85
1000	11.41
2000	11.80
4000	5.35
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	399.46
Minimum settling velocity of 50% of particles (mm s^1)	131.58
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	98.61
Minimum settling velocity of 90% of particles (mm s^1)	8.02
Time for 90% of particles to settle over 1 m (hours)	0.035

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell, mud, coral and plant material present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP5
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.23**
Very Fine Silt % (4-8µm)	1.19
Fine Silt % (8-16µm)	1.31
Medium Silt % (16-31µm)	1.76
Course Silt % (31-63µm)	3.04
Total Silt (4-63µm)	**7.30**
Very Fine sand % (63-125µm)	3.39
Fine sand % (125-250µm)	12.74
Medium sand % (250-500µm)	20.21
Coarse sand % (500-1000µm)	13.32
Very Coarse sand % (1000-2000µm)	13.55
Total Sand (63-2000µm)	**63.21**
Total Gravels (>2000µm)	**27.27**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.32
1000	13.55
2000	17.34
4000	9.93
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	655.43
Minimum settling velocity of 50% of particles (mm s^1)	354.24
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	70.38
Minimum settling velocity of 90% of particles (mm s^1)	4.08
Time for 90% of particles to settle over 1 m (hours)	0.068

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP6
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.30**
Very Fine Silt % (4-8µm)	1.25
Fine Silt % (8-16µm)	1.38
Medium Silt % (16-31µm)	1.84
Course Silt % (31-63µm)	3.04
Total Silt (4-63µm)	**7.50**
Very Fine sand % (63-125µm)	3.42
Fine sand % (125-250µm)	9.79
Medium sand % (250-500µm)	15.77
Coarse sand % (500-1000µm)	10.37
Very Coarse sand % (1000-2000µm)	11.54
Total Sand (63-2000µm)	**50.88**
Total Gravels (>2000µm)	**39.32**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.37
1000	11.54
2000	15.77
4000	13.93
8000	9.62
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1074.24
Minimum settling velocity of 50% of particles (mm s^1)	951.59
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	65.88
Minimum settling velocity of 90% of particles (mm s^1)	3.58
Time for 90% of particles to settle over 1 m (hours)	0.078

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP7
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.56**
Very Fine Silt % (4-8µm)	1.38
Fine Silt % (8-16µm)	1.52
Medium Silt % (16-31µm)	2.05
Course Silt % (31-63µm)	3.65
Total Silt (4-63µm)	**8.60**
Very Fine sand % (63-125µm)	4.85
Fine sand % (125-250µm)	13.12
Medium sand % (250-500µm)	20.28
Coarse sand % (500-1000µm)	18.29
Very Coarse sand % (1000-2000µm)	17.05
Total Sand (63-2000µm)	**73.60**
Total Gravels (>2000µm)	**15.24**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	18.29
1000	17.05
2000	12.38
4000	2.86
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	515.84
Minimum settling velocity of 50% of particles (mm s^1)	219.42
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	51.51
Minimum settling velocity of 90% of particles (mm s^1)	2.19
Time for 90% of particles to settle over 1 m (hours)	0.127

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP9
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.86**
Very Fine Silt % (4-8µm)	1.02
Fine Silt % (8-16µm)	1.11
Medium Silt % (16-31µm)	1.57
Course Silt % (31-63µm)	2.84
Total Silt (4-63µm)	**6.55**
Very Fine sand % (63-125µm)	4.60
Fine sand % (125-250µm)	14.90
Medium sand % (250-500µm)	19.35
Coarse sand % (500-1000µm)	10.02
Very Coarse sand % (1000-2000µm)	13.16
Total Sand (63-2000µm)	**62.04**
Total Gravels (>2000µm)	**29.55**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.02
1000	13.16
2000	19.05
4000	8.85
8000	1.65
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	636.62
Minimum settling velocity of 50% of particles (mm s^1)	334.20
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	86.50
Minimum settling velocity of 90% of particles (mm s^1)	6.17
Time for 90% of particles to settle over 1 m (hours)	0.045

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell, mud and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP10
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	24/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.51**
Very Fine Silt % (4-8µm)	1.30
Fine Silt % (8-16µm)	1.46
Medium Silt % (16-31µm)	2.03
Course Silt % (31-63µm)	3.46
Total Silt (4-63µm)	**8.25**
Very Fine sand % (63-125µm)	5.19
Fine sand % (125-250µm)	16.78
Medium sand % (250-500µm)	20.58
Coarse sand % (500-1000µm)	13.95
Very Coarse sand % (1000-2000µm)	13.45
Total Sand (63-2000µm)	**69.95**
Total Gravels (>2000µm)	**19.29**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.95
1000	13.45
2000	14.75
4000	4.54
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	432.70
Minimum settling velocity of 50% of particles (mm s^1)	154.39
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	54.53
Minimum settling velocity of 90% of particles (mm s^1)	2.45
Time for 90% of particles to settle over 1 m (hours)	0.113

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP11
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.73**
Very Fine Silt % (4-8µm)	1.39
Fine Silt % (8-16µm)	1.56
Medium Silt % (16-31µm)	2.13
Course Silt % (31-63µm)	3.58
Total Silt (4-63µm)	**8.68**
Very Fine sand % (63-125µm)	4.63
Fine sand % (125-250µm)	15.27
Medium sand % (250-500µm)	19.42
Coarse sand % (500-1000µm)	11.60
Very Coarse sand % (1000-2000µm)	13.33
Total Sand (63-2000µm)	**64.24**
Total Gravels (>2000µm)	**24.36**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.60
1000	13.33
2000	15.34
4000	6.59
8000	2.42
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	483.19
Minimum settling velocity of 50% of particles (mm s^1)	192.52
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	48.43
Minimum settling velocity of 90% of particles (mm s^1)	1.93
Time for 90% of particles to settle over 1 m (hours)	0.144

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP12
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.48**
Very Fine Silt % (4-8µm)	1.32
Fine Silt % (8-16µm)	1.47
Medium Silt % (16-31µm)	2.03
Course Silt % (31-63µm)	3.60
Total Silt (4-63µm)	**8.41**
Very Fine sand % (63-125µm)	5.06
Fine sand % (125-250µm)	8.94
Medium sand % (250-500µm)	9.98
Coarse sand % (500-1000µm)	8.96
Very Coarse sand % (1000-2000µm)	10.62
Total Sand (63-2000µm)	**43.57**
Total Gravels (>2000µm)	**45.53**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.96
1000	10.62
2000	17.11
4000	19.41
8000	9.01
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1579.68
Minimum settling velocity of 50% of particles (mm s^1)	2057.71
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	54.19
Minimum settling velocity of 90% of particles (mm s^1)	2.42
Time for 90% of particles to settle over 1 m (hours)	0.115

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP13
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.37**
Very Fine Silt % (4-8µm)	1.24
Fine Silt % (8-16µm)	1.33
Medium Silt % (16-31µm)	1.77
Course Silt % (31-63µm)	3.09
Total Silt (4-63µm)	**7.43**
Very Fine sand % (63-125µm)	4.06
Fine sand % (125-250µm)	17.75
Medium sand % (250-500µm)	22.26
Coarse sand % (500-1000µm)	11.43
Very Coarse sand % (1000-2000µm)	12.30
Total Sand (63-2000µm)	**67.80**
Total Gravels (>2000µm)	**22.40**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.43
1000	12.30
2000	15.78
4000	6.62
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	424.16
Minimum settling velocity of 50% of particles (mm s^1)	148.36
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	66.17
Minimum settling velocity of 90% of particles (mm s^1)	3.61
Time for 90% of particles to settle over 1 m (hours)	0.077

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP14
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.83**
Very Fine Silt % (4-8µm)	1.43
Fine Silt % (8-16µm)	1.54
Medium Silt % (16-31µm)	1.94
Course Silt % (31-63µm)	3.38
Total Silt (4-63µm)	**8.30**
Very Fine sand % (63-125µm)	3.88
Fine sand % (125-250µm)	19.68
Medium sand % (250-500µm)	26.69
Coarse sand % (500-1000µm)	10.36
Very Coarse sand % (1000-2000µm)	10.73
Total Sand (63-2000µm)	**71.35**
Total Gravels (>2000µm)	**17.53**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.36
1000	10.73
2000	12.27
4000	5.26
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	352.89
Minimum settling velocity of 50% of particles (mm s^1)	102.69
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	50.04
Minimum settling velocity of 90% of particles (mm s^1)	2.06
Time for 90% of particles to settle over 1 m (hours)	0.135

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP15
Sampling Date:	15/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.57**
Very Fine Silt % (4-8µm)	1.33
Fine Silt % (8-16µm)	1.42
Medium Silt % (16-31µm)	1.87
Course Silt % (31-63µm)	3.42
Total Silt (4-63µm)	**8.04**
Very Fine sand % (63-125µm)	5.07
Fine sand % (125-250µm)	23.78
Medium sand % (250-500µm)	30.47
Coarse sand % (500-1000µm)	7.87
Very Coarse sand % (1000-2000µm)	6.44
Total Sand (63-2000µm)	**73.63**
Total Gravels (>2000µm)	**15.76**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.87
1000	6.44
2000	9.62
4000	6.14
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	307.49
Minimum settling velocity of 50% of particles (mm s^1)	77.97
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	55.66
Minimum settling velocity of 90% of particles (mm s^1)	2.56
Time for 90% of particles to settle over 1 m (hours)	0.109

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP16
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.54**
Very Fine Silt % (4-8µm)	1.79
Fine Silt % (8-16µm)	1.91
Medium Silt % (16-31µm)	2.50
Course Silt % (31-63µm)	4.07
Total Silt (4-63µm)	**10.26**
Very Fine sand % (63-125µm)	6.23
Fine sand % (125-250µm)	23.17
Medium sand % (250-500µm)	24.47
Coarse sand % (500-1000µm)	5.84
Very Coarse sand % (1000-2000µm)	5.22
Total Sand (63-2000µm)	**64.94**
Total Gravels (>2000µm)	**21.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.84
1000	5.22
2000	9.22
4000	10.32
8000	1.72
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	292.05
Minimum settling velocity of 50% of particles (mm s^1)	70.33
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	32.68
Minimum settling velocity of 90% of particles (mm s^1)	0.88
Time for 90% of particles to settle over 1 m (hours)	0.315

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP17
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.19**
Very Fine Silt % (4-8µm)	1.12
Fine Silt % (8-16µm)	1.13
Medium Silt % (16-31µm)	1.56
Course Silt % (31-63µm)	2.60
Total Silt (4-63µm)	**6.41**
Very Fine sand % (63-125µm)	5.73
Fine sand % (125-250µm)	26.08
Medium sand % (250-500µm)	29.02
Coarse sand % (500-1000µm)	8.74
Very Coarse sand % (1000-2000µm)	7.72
Total Sand (63-2000µm)	**77.29**
Total Gravels (>2000µm)	**14.12**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.74
1000	7.72
2000	7.78
4000	4.17
8000	2.17
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	302.82
Minimum settling velocity of 50% of particles (mm s^1)	75.62
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	85.94
Minimum settling velocity of 90% of particles (mm s^1)	6.09
Time for 90% of particles to settle over 1 m (hours)	0.046

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP18
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.43**
Very Fine Silt % (4-8µm)	2.13
Fine Silt % (8-16µm)	2.24
Medium Silt % (16-31µm)	2.79
Course Silt % (31-63µm)	4.51
Total Silt (4-63µm)	**11.67**
Very Fine sand % (63-125µm)	7.16
Fine sand % (125-250µm)	24.03
Medium sand % (250-500µm)	32.20
Coarse sand % (500-1000µm)	6.04
Very Coarse sand % (1000-2000µm)	3.92
Total Sand (63-2000µm)	**73.36**
Total Gravels (>2000µm)	**10.54**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.04
1000	3.92
2000	5.88
4000	3.83
8000	0.83
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	264.32
Minimum settling velocity of 50% of particles (mm s^1)	57.61
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	22.04
Minimum settling velocity of 90% of particles (mm s^1)	0.40
Time for 90% of particles to settle over 1 m (hours)	0.693

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell, coral and plant material present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP19
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	25/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.34**
Very Fine Silt % (4-8µm)	1.20
Fine Silt % (8-16µm)	1.22
Medium Silt % (16-31µm)	1.63
Course Silt % (31-63µm)	2.84
Total Silt (4-63µm)	**6.88**
Very Fine sand % (63-125µm)	6.47
Fine sand % (125-250µm)	26.56
Medium sand % (250-500µm)	31.30
Coarse sand % (500-1000µm)	7.97
Very Coarse sand % (1000-2000µm)	5.98
Total Sand (63-2000µm)	**78.28**
Total Gravels (>2000µm)	**12.49**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.97
1000	5.98
2000	6.57
4000	3.61
8000	2.31
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	290.19
Minimum settling velocity of 50% of particles (mm s^1)	69.44
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	73.99
Minimum settling velocity of 90% of particles (mm s^1)	4.51
Time for 90% of particles to settle over 1 m (hours)	0.062

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP20
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	26/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.95**
Very Fine Silt % (4-8µm)	1.94
Fine Silt % (8-16µm)	2.03
Medium Silt % (16-31µm)	2.93
Course Silt % (31-63µm)	4.88
Total Silt (4-63µm)	**11.77**
Very Fine sand % (63-125µm)	12.94
Fine sand % (125-250µm)	33.01
Medium sand % (250-500µm)	24.69
Coarse sand % (500-1000µm)	4.36
Very Coarse sand % (1000-2000µm)	4.06
Total Sand (63-2000µm)	**79.06**
Total Gravels (>2000µm)	**5.22**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	4.36
1000	4.06
2000	2.80
4000	2.42
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	200.03
Minimum settling velocity of 50% of particles (mm s^1)	33.00
Time for 50% of particles to settle over 1 m (hours)	0.008
D10 (µm)	26.51
Minimum settling velocity of 90% of particles (mm s^1)	0.58
Time for 90% of particles to settle over 1 m (hours)	0.479

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP21
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	26/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.95**
Very Fine Silt % (4-8µm)	1.52
Fine Silt % (8-16µm)	1.60
Medium Silt % (16-31µm)	2.51
Course Silt % (31-63µm)	4.47
Total Silt (4-63µm)	**10.10**
Very Fine sand % (63-125µm)	15.65
Fine sand % (125-250µm)	34.96
Medium sand % (250-500µm)	21.12
Coarse sand % (500-1000µm)	4.23
Very Coarse sand % (1000-2000µm)	3.83
Total Sand (63-2000µm)	**79.79**
Total Gravels (>2000µm)	**7.16**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	4.23
1000	3.83
2000	4.16
4000	3.01
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	192.64
Minimum settling velocity of 50% of particles (mm s^1)	30.60
Time for 50% of particles to settle over 1 m (hours)	0.009
D10 (µm)	40.76
Minimum settling velocity of 90% of particles (mm s^1)	1.37
Time for 90% of particles to settle over 1 m (hours)	0.203

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP22
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	26/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.07**
Very Fine Silt % (4-8µm)	1.52
Fine Silt % (8-16µm)	1.65
Medium Silt % (16-31µm)	2.20
Course Silt % (31-63µm)	4.13
Total Silt (4-63µm)	**9.49**
Very Fine sand % (63-125µm)	8.89
Fine sand % (125-250µm)	15.50
Medium sand % (250-500µm)	14.58
Coarse sand % (500-1000µm)	15.51
Very Coarse sand % (1000-2000µm)	12.22
Total Sand (63-2000µm)	**66.71**
Total Gravels (>2000µm)	**20.72**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.51
1000	12.22
2000	11.50
4000	9.22
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	453.86
Minimum settling velocity of 50% of particles (mm s^1)	169.86
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	43.08
Minimum settling velocity of 90% of particles (mm s^1)	1.53
Time for 90% of particles to settle over 1 m (hours)	0.181

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP23
Sampling Date:	16/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	26/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**5.32**
Very Fine Silt % (4-8µm)	2.60
Fine Silt % (8-16µm)	2.78
Medium Silt % (16-31µm)	3.31
Course Silt % (31-63µm)	5.42
Total Silt (4-63µm)	**14.11**
Very Fine sand % (63-125µm)	10.37
Fine sand % (125-250µm)	17.68
Medium sand % (250-500µm)	16.39
Coarse sand % (500-1000µm)	9.95
Very Coarse sand % (1000-2000µm)	6.79
Total Sand (63-2000µm)	**61.18**
Total Gravels (>2000µm)	**19.38**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.95
1000	6.79
2000	8.64
4000	8.30
8000	2.44
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	274.07
Minimum settling velocity of 50% of particles (mm s^1)	61.94
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	13.57
Minimum settling velocity of 90% of particles (mm s^1)	0.15
Time for 90% of particles to settle over 1 m (hours)	1.830

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP24
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	26/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.33**
Very Fine Silt % (4-8µm)	1.23
Fine Silt % (8-16µm)	1.34
Medium Silt % (16-31µm)	1.72
Course Silt % (31-63µm)	3.37
Total Silt (4-63µm)	**7.66**
Very Fine sand % (63-125µm)	7.62
Fine sand % (125-250µm)	13.21
Medium sand % (250-500µm)	14.11
Coarse sand % (500-1000µm)	9.67
Very Coarse sand % (1000-2000µm)	10.22
Total Sand (63-2000µm)	**54.83**
Total Gravels (>2000µm)	**35.19**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.67
1000	10.22
2000	12.04
4000	16.03
8000	7.11
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	762.30
Minimum settling velocity of 50% of particles (mm s^1)	479.18
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	63.14
Minimum settling velocity of 90% of particles (mm s^1)	3.29
Time for 90% of particles to settle over 1 m (hours)	0.084

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some mud, rock, shell, coral and plant material present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP25
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**5.42**
Very Fine Silt % (4-8µm)	2.73
Fine Silt % (8-16µm)	3.18
Medium Silt % (16-31µm)	3.95
Course Silt % (31-63µm)	6.93
Total Silt (4-63µm)	**16.78**
Very Fine sand % (63-125µm)	14.07
Fine sand % (125-250µm)	21.36
Medium sand % (250-500µm)	17.52
Coarse sand % (500-1000µm)	11.15
Very Coarse sand % (1000-2000µm)	8.25
Total Sand (63-2000µm)	**72.35**
Total Gravels (>2000µm)	**5.45**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.15
1000	8.25
2000	5.45
4000	0.00
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	196.77
Minimum settling velocity of 50% of particles (mm s^1)	31.93
Time for 50% of particles to settle over 1 m (hours)	0.009
D10 (µm)	12.23
Minimum settling velocity of 90% of particles (mm s^1)	0.12
Time for 90% of particles to settle over 1 m (hours)	2.252

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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WORLD RECOGNISED ACCREDITATION

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP26
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**5.03**
Very Fine Silt % (4-8µm)	2.56
Fine Silt % (8-16µm)	3.10
Medium Silt % (16-31µm)	3.95
Course Silt % (31-63µm)	7.54
Total Silt (4-63µm)	**17.16**
Very Fine sand % (63-125µm)	15.34
Fine sand % (125-250µm)	21.17
Medium sand % (250-500µm)	17.71
Coarse sand % (500-1000µm)	12.16
Very Coarse sand % (1000-2000µm)	7.01
Total Sand (63-2000µm)	**73.39**
Total Gravels (>2000µm)	**4.42**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.16
1000	7.01
2000	3.32
4000	1.10
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	188.79
Minimum settling velocity of 50% of particles (mm s^1)	29.39
Time for 50% of particles to settle over 1 m (hours)	0.009
D10 (µm)	13.93
Minimum settling velocity of 90% of particles (mm s^1)	0.16
Time for 90% of particles to settle over 1 m (hours)	1.737

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP27
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.77**
Very Fine Silt % (4-8µm)	3.56
Fine Silt % (8-16µm)	4.44
Medium Silt % (16-31µm)	5.52
Course Silt % (31-63µm)	9.36
Total Silt (4-63µm)	**22.88**
Very Fine sand % (63-125µm)	15.57
Fine sand % (125-250µm)	18.99
Medium sand % (250-500µm)	13.65
Coarse sand % (500-1000µm)	7.67
Very Coarse sand % (1000-2000µm)	5.60
Total Sand (63-2000µm)	**61.48**
Total Gravels (>2000µm)	**8.88**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.67
1000	5.60
2000	5.64
4000	3.23
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	148.96
Minimum settling velocity of 50% of particles (mm s^1)	18.30
Time for 50% of particles to settle over 1 m (hours)	0.015
D10 (µm)	7.55
Minimum settling velocity of 90% of particles (mm s^1)	0.05
Time for 90% of particles to settle over 1 m (hours)	5.911

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some sand, rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP28
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**5.86**
Very Fine Silt % (4-8µm)	3.14
Fine Silt % (8-16µm)	4.26
Medium Silt % (16-31µm)	5.40
Course Silt % (31-63µm)	9.59
Total Silt (4-63µm)	**22.38**
Very Fine sand % (63-125µm)	14.57
Fine sand % (125-250µm)	14.00
Medium sand % (250-500µm)	12.02
Coarse sand % (500-1000µm)	11.46
Very Coarse sand % (1000-2000µm)	8.53
Total Sand (63-2000µm)	**60.57**
Total Gravels (>2000µm)	**11.19**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.46
1000	8.53
2000	6.30
4000	4.88
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	176.38
Minimum settling velocity of 50% of particles (mm s^1)	25.65
Time for 50% of particles to settle over 1 m (hours)	0.011
D10 (µm)	9.64
Minimum settling velocity of 90% of particles (mm s^1)	0.08
Time for 90% of particles to settle over 1 m (hours)	3.623

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some sand, rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP29
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.03**
Very Fine Silt % (4-8µm)	3.32
Fine Silt % (8-16µm)	4.47
Medium Silt % (16-31µm)	5.74
Course Silt % (31-63µm)	11.66
Total Silt (4-63µm)	**25.18**
Very Fine sand % (63-125µm)	16.57
Fine sand % (125-250µm)	12.50
Medium sand % (250-500µm)	11.60
Coarse sand % (500-1000µm)	11.01
Very Coarse sand % (1000-2000µm)	5.71
Total Sand (63-2000µm)	**57.40**
Total Gravels (>2000µm)	**11.39**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.01
1000	5.71
2000	6.99
4000	4.40
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	139.29
Minimum settling velocity of 50% of particles (mm s^1)	16.00
Time for 50% of particles to settle over 1 m (hours)	0.017
D10 (µm)	9.00
Minimum settling velocity of 90% of particles (mm s^1)	0.07
Time for 90% of particles to settle over 1 m (hours)	4.161

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some sand, rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	OP30
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.03**
Very Fine Silt % (4-8µm)	4.29
Fine Silt % (8-16µm)	6.81
Medium Silt % (16-31µm)	9.15
Course Silt % (31-63µm)	18.97
Total Silt (4-63µm)	**39.22**
Very Fine sand % (63-125µm)	29.65
Fine sand % (125-250µm)	17.39
Medium sand % (250-500µm)	5.86
Coarse sand % (500-1000µm)	0.33
Very Coarse sand % (1000-2000µm)	0.24
Total Sand (63-2000µm)	**53.47**
Total Gravels (>2000µm)	**0.28**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	0.33
1000	0.24
2000	0.28
4000	0.00
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	69.16
Minimum settling velocity of 50% of particles (mm s^1)	3.94
Time for 50% of particles to settle over 1 m (hours)	0.070
D10 (µm)	6.65
Minimum settling velocity of 90% of particles (mm s^1)	0.04
Time for 90% of particles to settle over 1 m (hours)	7.621

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some sand and shell present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

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Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG1
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.58**
Very Fine Silt % (4-8µm)	2.22
Fine Silt % (8-16µm)	2.62
Medium Silt % (16-31µm)	3.09
Course Silt % (31-63µm)	4.89
Total Silt (4-63µm)	**12.82**
Very Fine sand % (63-125µm)	7.40
Fine sand % (125-250µm)	12.15
Medium sand % (250-500µm)	15.80
Coarse sand % (500-1000µm)	15.58
Very Coarse sand % (1000-2000µm)	13.07
Total Sand (63-2000µm)	**64.00**
Total Gravels (>2000µm)	**18.60**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.58
1000	13.07
2000	12.84
4000	5.25
8000	0.51
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	435.73
Minimum settling velocity of 50% of particles (mm s^1)	156.56
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	18.34
Minimum settling velocity of 90% of particles (mm s^1)	0.28
Time for 90% of particles to settle over 1 m (hours)	1.002

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG2
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.78**
Very Fine Silt % (4-8µm)	2.42
Fine Silt % (8-16µm)	2.94
Medium Silt % (16-31µm)	3.51
Course Silt % (31-63µm)	5.48
Total Silt (4-63µm)	**14.36**
Very Fine sand % (63-125µm)	7.11
Fine sand % (125-250µm)	11.97
Medium sand % (250-500µm)	18.14
Coarse sand % (500-1000µm)	15.73
Very Coarse sand % (1000-2000µm)	9.64
Total Sand (63-2000µm)	**62.58**
Total Gravels (>2000µm)	**18.28**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.73
1000	9.64
2000	9.40
4000	5.68
8000	3.20
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	386.56
Minimum settling velocity of 50% of particles (mm s^1)	123.22
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	15.52
Minimum settling velocity of 90% of particles (mm s^1)	0.20
Time for 90% of particles to settle over 1 m (hours)	1.398

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater
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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

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Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG3
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	29/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.76**
Very Fine Silt % (4-8µm)	2.16
Fine Silt % (8-16µm)	2.91
Medium Silt % (16-31µm)	3.81
Course Silt % (31-63µm)	5.57
Total Silt (4-63µm)	**14.45**
Very Fine sand % (63-125µm)	9.66
Fine sand % (125-250µm)	16.70
Medium sand % (250-500µm)	16.59
Coarse sand % (500-1000µm)	18.91
Very Coarse sand % (1000-2000µm)	10.92
Total Sand (63-2000µm)	**72.79**
Total Gravels (>2000µm)	**9.00**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	18.91
1000	10.92
2000	7.35
4000	1.64
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	307.92
Minimum settling velocity of 50% of particles (mm s^1)	78.18
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	20.02
Minimum settling velocity of 90% of particles (mm s^1)	0.33
Time for 90% of particles to settle over 1 m (hours)	0.841

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG4
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.83**
Very Fine Silt % (4-8µm)	2.70
Fine Silt % (8-16µm)	3.71
Medium Silt % (16-31µm)	4.79
Course Silt % (31-63µm)	6.40
Total Silt (4-63µm)	**17.60**
Very Fine sand % (63-125µm)	11.00
Fine sand % (125-250µm)	13.92
Medium sand % (250-500µm)	8.27
Coarse sand % (500-1000µm)	9.26
Very Coarse sand % (1000-2000µm)	9.31
Total Sand (63-2000µm)	**51.75**
Total Gravels (>2000µm)	**25.81**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.26
1000	9.31
2000	9.44
4000	8.49
8000	7.88
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	297.96
Minimum settling velocity of 50% of particles (mm s^1)	73.21
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	13.06
Minimum settling velocity of 90% of particles (mm s^1)	0.14
Time for 90% of particles to settle over 1 m (hours)	1.975

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG5
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.13**
Very Fine Silt % (4-8µm)	2.31
Fine Silt % (8-16µm)	3.23
Medium Silt % (16-31µm)	4.28
Course Silt % (31-63µm)	5.73
Total Silt (4-63µm)	**15.54**
Very Fine sand % (63-125µm)	11.53
Fine sand % (125-250µm)	15.30
Medium sand % (250-500µm)	9.19
Coarse sand % (500-1000µm)	11.21
Very Coarse sand % (1000-2000µm)	10.14
Total Sand (63-2000µm)	**57.38**
Total Gravels (>2000µm)	**22.96**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.21
1000	10.14
2000	11.06
4000	5.20
8000	4.00
16000	2.70

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	309.59
Minimum settling velocity of 50% of particles (mm s^1)	79.03
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	16.97
Minimum settling velocity of 90% of particles (mm s^1)	0.24
Time for 90% of particles to settle over 1 m (hours)	1.170

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG6
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.28**
Very Fine Silt % (4-8µm)	2.37
Fine Silt % (8-16µm)	3.37
Medium Silt % (16-31µm)	4.57
Course Silt % (31-63µm)	6.49
Total Silt (4-63µm)	**16.80**
Very Fine sand % (63-125µm)	15.79
Fine sand % (125-250µm)	20.31
Medium sand % (250-500µm)	9.08
Coarse sand % (500-1000µm)	8.88
Very Coarse sand % (1000-2000µm)	9.07
Total Sand (63-2000µm)	**63.14**
Total Gravels (>2000µm)	**15.78**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.88
1000	9.07
2000	11.14
4000	4.64
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	189.35
Minimum settling velocity of 50% of particles (mm s^1)	29.56
Time for 50% of particles to settle over 1 m (hours)	0.009
D10 (µm)	15.94
Minimum settling velocity of 90% of particles (mm s^1)	0.21
Time for 90% of particles to settle over 1 m (hours)	1.326

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Accreditation Number: 10603
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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG7
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.11**
Very Fine Silt % (4-8µm)	2.47
Fine Silt % (8-16µm)	3.63
Medium Silt % (16-31µm)	4.97
Course Silt % (31-63µm)	6.38
Total Silt (4-63µm)	**17.46**
Very Fine sand % (63-125µm)	17.01
Fine sand % (125-250µm)	24.39
Medium sand % (250-500µm)	10.39
Coarse sand % (500-1000µm)	7.54
Very Coarse sand % (1000-2000µm)	7.44
Total Sand (63-2000µm)	**66.78**
Total Gravels (>2000µm)	**11.65**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.54
1000	7.44
2000	7.07
4000	4.58
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	168.90
Minimum settling velocity of 50% of particles (mm s^1)	23.52
Time for 50% of particles to settle over 1 m (hours)	0.012
D10 (µm)	15.49
Minimum settling velocity of 90% of particles (mm s^1)	0.20
Time for 90% of particles to settle over 1 m (hours)	1.404

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment
Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG8
Sampling Date:	18/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.20**
Very Fine Silt % (4-8µm)	2.29
Fine Silt % (8-16µm)	3.03
Medium Silt % (16-31µm)	3.85
Course Silt % (31-63µm)	6.06
Total Silt (4-63µm)	**15.22**
Very Fine sand % (63-125µm)	10.38
Fine sand % (125-250µm)	13.19
Medium sand % (250-500µm)	13.40
Coarse sand % (500-1000µm)	15.59
Very Coarse sand % (1000-2000µm)	10.39
Total Sand (63-2000µm)	**62.94**
Total Gravels (>2000µm)	**17.64**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.59
1000	10.39
2000	6.96
4000	4.17
8000	6.51
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	352.55
Minimum settling velocity of 50% of particles (mm s^1)	102.49
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	17.53
Minimum settling velocity of 90% of particles (mm s^1)	0.25
Time for 90% of particles to settle over 1 m (hours)	1.097

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG9
Sampling Date:	18/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.74**
Very Fine Silt % (4-8µm)	2.11
Fine Silt % (8-16µm)	2.77
Medium Silt % (16-31µm)	3.61
Course Silt % (31-63µm)	5.53
Total Silt (4-63µm)	**14.01**
Very Fine sand % (63-125µm)	10.11
Fine sand % (125-250µm)	13.53
Medium sand % (250-500µm)	9.92
Coarse sand % (500-1000µm)	11.33
Very Coarse sand % (1000-2000µm)	8.84
Total Sand (63-2000µm)	**53.73**
Total Gravels (>2000µm)	**28.52**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.33
1000	8.84
2000	9.40
4000	4.29
8000	14.84
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	441.67
Minimum settling velocity of 50% of particles (mm s^1)	160.86
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	21.06
Minimum settling velocity of 90% of particles (mm s^1)	0.37
Time for 90% of particles to settle over 1 m (hours)	0.759

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG10
Sampling Date:	18/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.64**
Very Fine Silt % (4-8µm)	2.85
Fine Silt % (8-16µm)	4.25
Medium Silt % (16-31µm)	5.70
Course Silt % (31-63µm)	6.46
Total Silt (4-63µm)	**19.26**
Very Fine sand % (63-125µm)	12.70
Fine sand % (125-250µm)	22.02
Medium sand % (250-500µm)	12.57
Coarse sand % (500-1000µm)	9.17
Very Coarse sand % (1000-2000µm)	6.78
Total Sand (63-2000µm)	**63.24**
Total Gravels (>2000µm)	**12.87**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.17
1000	6.78
2000	5.76
4000	7.11
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	189.46
Minimum settling velocity of 50% of particles (mm s^1)	29.60
Time for 50% of particles to settle over 1 m (hours)	0.009
D10 (µm)	12.51
Minimum settling velocity of 90% of particles (mm s^1)	0.13
Time for 90% of particles to settle over 1 m (hours)	2.154

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG11
Sampling Date:	18/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**5.07**
Very Fine Silt % (4-8µm)	3.23
Fine Silt % (8-16µm)	5.12
Medium Silt % (16-31µm)	7.05
Course Silt % (31-63µm)	7.47
Total Silt (4-63µm)	**22.86**
Very Fine sand % (63-125µm)	13.00
Fine sand % (125-250µm)	22.13
Medium sand % (250-500µm)	10.08
Coarse sand % (500-1000µm)	6.00
Very Coarse sand % (1000-2000µm)	4.88
Total Sand (63-2000µm)	**56.10**
Total Gravels (>2000µm)	**15.97**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.00
1000	4.88
2000	4.15
4000	3.09
8000	8.73
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	165.40
Minimum settling velocity of 50% of particles (mm s^1)	22.56
Time for 50% of particles to settle over 1 m (hours)	0.012
D10 (µm)	10.51
Minimum settling velocity of 90% of particles (mm s^1)	0.09
Time for 90% of particles to settle over 1 m (hours)	3.050

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG12
Sampling Date:	18/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	30/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.62**
Very Fine Silt % (4-8µm)	2.36
Fine Silt % (8-16µm)	3.10
Medium Silt % (16-31µm)	3.77
Course Silt % (31-63µm)	5.36
Total Silt (4-63µm)	**14.59**
Very Fine sand % (63-125µm)	8.04
Fine sand % (125-250µm)	11.92
Medium sand % (250-500µm)	13.47
Coarse sand % (500-1000µm)	15.70
Very Coarse sand % (1000-2000µm)	10.15
Total Sand (63-2000µm)	**59.26**
Total Gravels (>2000µm)	**21.53**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.70
1000	10.15
2000	9.88
4000	8.04
8000	3.60
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	427.08
Minimum settling velocity of 50% of particles (mm s^1)	150.40
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	15.77
Minimum settling velocity of 90% of particles (mm s^1)	0.21
Time for 90% of particles to settle over 1 m (hours)	1.354

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4

Sample Name:	SG13
Sampling Date:	18/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-4
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.89**
Very Fine Silt % (4-8µm)	2.60
Fine Silt % (8-16µm)	3.25
Medium Silt % (16-31µm)	4.05
Course Silt % (31-63µm)	5.95
Total Silt (4-63µm)	**15.85**
Very Fine sand % (63-125µm)	10.96
Fine sand % (125-250µm)	13.85
Medium sand % (250-500µm)	9.90
Coarse sand % (500-1000µm)	15.52
Very Coarse sand % (1000-2000µm)	11.46
Total Sand (63-2000µm)	**61.69**
Total Gravels (>2000µm)	**17.57**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.52
1000	11.46
2000	9.75
4000	3.50
8000	4.31
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	328.28
Minimum settling velocity of 50% of particles (mm s^1)	88.87
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	13.91
Minimum settling velocity of 90% of particles (mm s^1)	0.16
Time for 90% of particles to settle over 1 m (hours)	1.742

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 6/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS01
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.12**
Very Fine Silt % (4-8µm)	2.05
Fine Silt % (8-16µm)	3.02
Medium Silt % (16-31µm)	3.62
Course Silt % (31-63µm)	5.81
Total Silt (4-63µm)	**14.50**
Very Fine sand % (63-125µm)	10.47
Fine sand % (125-250µm)	9.53
Medium sand % (250-500µm)	6.98
Coarse sand % (500-1000µm)	15.04
Very Coarse sand % (1000-2000µm)	13.46
Total Sand (63-2000µm)	**55.48**
Total Gravels (>2000µm)	**26.90**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.04
1000	13.46
2000	14.88
4000	10.50
8000	1.52
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	679.39
Minimum settling velocity of 50% of particles (mm s^1)	380.61
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	22.46
Minimum settling velocity of 90% of particles (mm s^1)	0.42
Time for 90% of particles to settle over 1 m (hours)	0.668

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock and shell present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS02
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.60**
Very Fine Silt % (4-8µm)	2.97
Fine Silt % (8-16µm)	4.12
Medium Silt % (16-31µm)	4.57
Course Silt % (31-63µm)	6.59
Total Silt (4-63µm)	**18.25**
Very Fine sand % (63-125µm)	9.90
Fine sand % (125-250µm)	7.61
Medium sand % (250-500µm)	6.35
Coarse sand % (500-1000µm)	8.77
Very Coarse sand % (1000-2000µm)	11.00
Total Sand (63-2000µm)	**43.63**
Total Gravels (>2000µm)	**33.52**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.77
1000	11.00
2000	17.81
4000	15.71
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	687.53
Minimum settling velocity of 50% of particles (mm s^1)	389.79
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	12.34
Minimum settling velocity of 90% of particles (mm s^1)	0.13
Time for 90% of particles to settle over 1 m (hours)	2.211

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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WORLD RECOGNISED ACCREDITATION

Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS03
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.68**
Very Fine Silt % (4-8µm)	2.39
Fine Silt % (8-16µm)	3.19
Medium Silt % (16-31µm)	3.45
Course Silt % (31-63µm)	3.87
Total Silt (4-63µm)	**12.90**
Very Fine sand % (63-125µm)	3.41
Fine sand % (125-250µm)	2.04
Medium sand % (250-500µm)	3.47
Coarse sand % (500-1000µm)	7.78
Very Coarse sand % (1000-2000µm)	6.93
Total Sand (63-2000µm)	**23.63**
Total Gravels (>2000µm)	**59.79**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.78
1000	6.93
2000	13.02
4000	16.91
8000	10.07
16000	19.79

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	3503.91
Minimum settling velocity of 50% of particles (mm s^1)	10124.00
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	18.49
Minimum settling velocity of 90% of particles (mm s^1)	0.28
Time for 90% of particles to settle over 1 m (hours)	0.986

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS04
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**5.68**
Very Fine Silt % (4-8µm)	3.65
Fine Silt % (8-16µm)	5.04
Medium Silt % (16-31µm)	5.69
Course Silt % (31-63µm)	6.81
Total Silt (4-63µm)	**21.19**
Very Fine sand % (63-125µm)	6.13
Fine sand % (125-250µm)	7.56
Medium sand % (250-500µm)	11.00
Coarse sand % (500-1000µm)	9.20
Very Coarse sand % (1000-2000µm)	7.83
Total Sand (63-2000µm)	**41.73**
Total Gravels (>2000µm)	**31.40**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.20
1000	7.83
2000	12.52
4000	15.73
8000	3.15
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	442.93
Minimum settling velocity of 50% of particles (mm s^1)	161.78
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	8.89
Minimum settling velocity of 90% of particles (mm s^1)	0.07
Time for 90% of particles to settle over 1 m (hours)	4.265

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science

Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS05
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.92**
Very Fine Silt % (4-8µm)	4.29
Fine Silt % (8-16µm)	5.83
Medium Silt % (16-31µm)	6.64
Course Silt % (31-63µm)	7.79
Total Silt (4-63µm)	**24.55**
Very Fine sand % (63-125µm)	7.46
Fine sand % (125-250µm)	8.02
Medium sand % (250-500µm)	8.34
Coarse sand % (500-1000µm)	8.90
Very Coarse sand % (1000-2000µm)	8.83
Total Sand (63-2000µm)	**41.55**
Total Gravels (>2000µm)	**26.98**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.90
1000	8.83
2000	11.57
4000	13.55
8000	1.86
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	313.98
Minimum settling velocity of 50% of particles (mm s^1)	81.29
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	6.71
Minimum settling velocity of 90% of particles (mm s^1)	0.04
Time for 90% of particles to settle over 1 m (hours)	7.473

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some sand, rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS06
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.06**
Very Fine Silt % (4-8µm)	1.90
Fine Silt % (8-16µm)	2.53
Medium Silt % (16-31µm)	2.86
Course Silt % (31-63µm)	3.76
Total Silt (4-63µm)	**11.05**
Very Fine sand % (63-125µm)	3.64
Fine sand % (125-250µm)	5.31
Medium sand % (250-500µm)	11.15
Coarse sand % (500-1000µm)	19.81
Very Coarse sand % (1000-2000µm)	12.75
Total Sand (63-2000µm)	**52.66**
Total Gravels (>2000µm)	**33.23**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	19.81
1000	12.75
2000	15.37
4000	13.68
8000	4.18
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	898.48
Minimum settling velocity of 50% of particles (mm s^1)	665.67
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	28.72
Minimum settling velocity of 90% of particles (mm s^1)	0.68
Time for 90% of particles to settle over 1 m (hours)	0.409

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS07
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.38**
Very Fine Silt % (4-8µm)	2.09
Fine Silt % (8-16µm)	2.76
Medium Silt % (16-31µm)	3.15
Course Silt % (31-63µm)	4.58
Total Silt (4-63µm)	**12.57**
Very Fine sand % (63-125µm)	5.17
Fine sand % (125-250µm)	8.71
Medium sand % (250-500µm)	12.94
Coarse sand % (500-1000µm)	14.59
Very Coarse sand % (1000-2000µm)	16.45
Total Sand (63-2000µm)	**57.86**
Total Gravels (>2000µm)	**26.19**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	14.59
1000	16.45
2000	10.59
4000	7.11
8000	8.50
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	747.83
Minimum settling velocity of 50% of particles (mm s^1)	461.16
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	23.57
Minimum settling velocity of 90% of particles (mm s^1)	0.46
Time for 90% of particles to settle over 1 m (hours)	0.607

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater
Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS08
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.21**
Very Fine Silt % (4-8µm)	1.99
Fine Silt % (8-16µm)	2.68
Medium Silt % (16-31µm)	3.09
Course Silt % (31-63µm)	4.02
Total Silt (4-63µm)	**11.78**
Very Fine sand % (63-125µm)	4.18
Fine sand % (125-250µm)	5.80
Medium sand % (250-500µm)	8.24
Coarse sand % (500-1000µm)	11.04
Very Coarse sand % (1000-2000µm)	11.20
Total Sand (63-2000µm)	**40.47**
Total Gravels (>2000µm)	**44.54**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.04
1000	11.20
2000	13.96
4000	18.73
8000	11.85
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1512.45
Minimum settling velocity of 50% of particles (mm s^1)	1886.28
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	25.40
Minimum settling velocity of 90% of particles (mm s^1)	0.53
Time for 90% of particles to settle over 1 m (hours)	0.522

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS09
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	1/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.31**
Very Fine Silt % (4-8µm)	2.08
Fine Silt % (8-16µm)	2.70
Medium Silt % (16-31µm)	3.03
Course Silt % (31-63µm)	4.03
Total Silt (4-63µm)	**11.84**
Very Fine sand % (63-125µm)	4.11
Fine sand % (125-250µm)	3.94
Medium sand % (250-500µm)	6.68
Coarse sand % (500-1000µm)	14.61
Very Coarse sand % (1000-2000µm)	10.45
Total Sand (63-2000µm)	**39.79**
Total Gravels (>2000µm)	**45.07**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	14.61
1000	10.45
2000	12.11
4000	12.46
8000	20.49
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1527.74
Minimum settling velocity of 50% of particles (mm s^1)	1924.61
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	24.53
Minimum settling velocity of 90% of particles (mm s^1)	0.50
Time for 90% of particles to settle over 1 m (hours)	0.560

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand,shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS10
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.92**
Very Fine Silt % (4-8µm)	2.42
Fine Silt % (8-16µm)	3.19
Medium Silt % (16-31µm)	3.56
Course Silt % (31-63µm)	5.02
Total Silt (4-63µm)	**14.20**
Very Fine sand % (63-125µm)	5.75
Fine sand % (125-250µm)	5.99
Medium sand % (250-500µm)	8.44
Coarse sand % (500-1000µm)	19.00
Very Coarse sand % (1000-2000µm)	19.25
Total Sand (63-2000µm)	**58.42**
Total Gravels (>2000µm)	**23.47**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	19.00
1000	19.25
2000	15.65
4000	7.54
8000	0.28
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	808.26
Minimum settling velocity of 50% of particles (mm s^1)	538.70
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	17.56
Minimum settling velocity of 90% of particles (mm s^1)	0.25
Time for 90% of particles to settle over 1 m (hours)	1.093

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS11
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.42**
Very Fine Silt % (4-8µm)	1.55
Fine Silt % (8-16µm)	2.01
Medium Silt % (16-31µm)	2.26
Course Silt % (31-63µm)	3.18
Total Silt (4-63µm)	**8.99**
Very Fine sand % (63-125µm)	3.64
Fine sand % (125-250µm)	3.48
Medium sand % (250-500µm)	5.48
Coarse sand % (500-1000µm)	13.99
Very Coarse sand % (1000-2000µm)	12.13
Total Sand (63-2000µm)	**38.72**
Total Gravels (>2000µm)	**49.87**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.99
1000	12.13
2000	16.42
4000	12.45
8000	2.43
16000	18.57

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1988.95
Minimum settling velocity of 50% of particles (mm s^1)	3262.08
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	47.62
Minimum settling velocity of 90% of particles (mm s^1)	1.87
Time for 90% of particles to settle over 1 m (hours)	0.149

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS12
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.57**
Very Fine Silt % (4-8µm)	2.22
Fine Silt % (8-16µm)	3.03
Medium Silt % (16-31µm)	3.53
Course Silt % (31-63µm)	4.79
Total Silt (4-63µm)	**13.57**
Very Fine sand % (63-125µm)	5.37
Fine sand % (125-250µm)	6.38
Medium sand % (250-500µm)	9.02
Coarse sand % (500-1000µm)	12.77
Very Coarse sand % (1000-2000µm)	9.41
Total Sand (63-2000µm)	**42.95**
Total Gravels (>2000µm)	**39.91**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.77
1000	9.41
2000	17.03
4000	15.15
8000	7.73
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	973.49
Minimum settling velocity of 50% of particles (mm s^1)	781.47
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	20.15
Minimum settling velocity of 90% of particles (mm s^1)	0.33
Time for 90% of particles to settle over 1 m (hours)	0.830

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS13
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.36**
Very Fine Silt % (4-8µm)	2.07
Fine Silt % (8-16µm)	2.82
Medium Silt % (16-31µm)	3.28
Course Silt % (31-63µm)	4.66
Total Silt (4-63µm)	**12.82**
Very Fine sand % (63-125µm)	5.30
Fine sand % (125-250µm)	5.82
Medium sand % (250-500µm)	8.17
Coarse sand % (500-1000µm)	12.69
Very Coarse sand % (1000-2000µm)	14.52
Total Sand (63-2000µm)	**46.50**
Total Gravels (>2000µm)	**37.31**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.69
1000	14.52
2000	19.34
4000	17.97
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1126.58
Minimum settling velocity of 50% of particles (mm s^1)	1046.57
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	23.09
Minimum settling velocity of 90% of particles (mm s^1)	0.44
Time for 90% of particles to settle over 1 m (hours)	0.632

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment
Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS14
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.25**
Very Fine Silt % (4-8µm)	2.48
Fine Silt % (8-16µm)	3.27
Medium Silt % (16-31µm)	3.75
Course Silt % (31-63µm)	4.97
Total Silt (4-63µm)	**14.48**
Very Fine sand % (63-125µm)	5.53
Fine sand % (125-250µm)	5.99
Medium sand % (250-500µm)	6.96
Coarse sand % (500-1000µm)	11.35
Very Coarse sand % (1000-2000µm)	12.02
Total Sand (63-2000µm)	**41.85**
Total Gravels (>2000µm)	**39.42**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.35
1000	12.02
2000	15.85
4000	14.75
8000	8.82
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1119.97
Minimum settling velocity of 50% of particles (mm s^1)	1034.32
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	15.99
Minimum settling velocity of 90% of particles (mm s^1)	0.21
Time for 90% of particles to settle over 1 m (hours)	1.317

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS15
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.18**
Very Fine Silt % (4-8µm)	1.93
Fine Silt % (8-16µm)	2.52
Medium Silt % (16-31µm)	2.89
Course Silt % (31-63µm)	4.04
Total Silt (4-63µm)	**11.37**
Very Fine sand % (63-125µm)	4.65
Fine sand % (125-250µm)	5.01
Medium sand % (250-500µm)	5.34
Coarse sand % (500-1000µm)	3.29
Very Coarse sand % (1000-2000µm)	3.91
Total Sand (63-2000µm)	**22.22**
Total Gravels (>2000µm)	**63.24**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	3.29
1000	3.91
2000	10.12
4000	19.74
8000	33.38
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	4631.10
Minimum settling velocity of 50% of particles (mm s^1)	17685.37
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	27.82
Minimum settling velocity of 90% of particles (mm s^1)	0.64
Time for 90% of particles to settle over 1 m (hours)	0.435

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand and shell present.

Signatory: Jamie Woodward
Date: 10/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS16
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.94**
Very Fine Silt % (4-8µm)	1.77
Fine Silt % (8-16µm)	2.30
Medium Silt % (16-31µm)	2.62
Course Silt % (31-63µm)	3.48
Total Silt (4-63µm)	**10.18**
Very Fine sand % (63-125µm)	3.94
Fine sand % (125-250µm)	4.43
Medium sand % (250-500µm)	4.77
Coarse sand % (500-1000µm)	7.88
Very Coarse sand % (1000-2000µm)	8.78
Total Sand (63-2000µm)	**29.79**
Total Gravels (>2000µm)	**57.09**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	7.88
1000	8.78
2000	20.98
4000	25.00
8000	11.12
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2676.18
Minimum settling velocity of 50% of particles (mm s^1)	5905.75
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	33.80
Minimum settling velocity of 90% of particles (mm s^1)	0.94
Time for 90% of particles to settle over 1 m (hours)	0.295

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS17
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.84**
Very Fine Silt % (4-8µm)	1.60
Fine Silt % (8-16µm)	2.00
Medium Silt % (16-31µm)	2.25
Course Silt % (31-63µm)	3.34
Total Silt (4-63µm)	**9.19**
Very Fine sand % (63-125µm)	4.30
Fine sand % (125-250µm)	8.30
Medium sand % (250-500µm)	14.87
Coarse sand % (500-1000µm)	15.32
Very Coarse sand % (1000-2000µm)	10.59
Total Sand (63-2000µm)	**53.38**
Total Gravels (>2000µm)	**34.59**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.32
1000	10.59
2000	14.08
4000	13.71
8000	6.80
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	842.85
Minimum settling velocity of 50% of particles (mm s^1)	585.80
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	42.67
Minimum settling velocity of 90% of particles (mm s^1)	1.50
Time for 90% of particles to settle over 1 m (hours)	0.185

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS18
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	2/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.49**
Very Fine Silt % (4-8µm)	1.45
Fine Silt % (8-16µm)	1.85
Medium Silt % (16-31µm)	2.10
Course Silt % (31-63µm)	3.36
Total Silt (4-63µm)	**8.76**
Very Fine sand % (63-125µm)	4.26
Fine sand % (125-250µm)	8.25
Medium sand % (250-500µm)	14.81
Coarse sand % (500-1000µm)	11.66
Very Coarse sand % (1000-2000µm)	14.70
Total Sand (63-2000µm)	**53.69**
Total Gravels (>2000µm)	**35.06**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.66
1000	14.70
2000	18.37
4000	12.37
8000	4.32
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	989.87
Minimum settling velocity of 50% of particles (mm s^1)	807.98
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	50.37
Minimum settling velocity of 90% of particles (mm s^1)	2.09
Time for 90% of particles to settle over 1 m (hours)	0.133

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS19
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.76**
Very Fine Silt % (4-8µm)	2.33
Fine Silt % (8-16µm)	3.20
Medium Silt % (16-31µm)	3.66
Course Silt % (31-63µm)	4.65
Total Silt (4-63µm)	**13.83**
Very Fine sand % (63-125µm)	4.68
Fine sand % (125-250µm)	5.42
Medium sand % (250-500µm)	8.27
Coarse sand % (500-1000µm)	9.26
Very Coarse sand % (1000-2000µm)	7.95
Total Sand (63-2000µm)	**35.57**
Total Gravels (>2000µm)	**46.83**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.26
1000	7.95
2000	10.64
4000	12.45
8000	23.74
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1601.05
Minimum settling velocity of 50% of particles (mm s^1)	2113.77
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	18.31
Minimum settling velocity of 90% of particles (mm s^1)	0.28
Time for 90% of particles to settle over 1 m (hours)	1.005

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 10/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS20
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.44**
Very Fine Silt % (4-8µm)	2.76
Fine Silt % (8-16µm)	3.78
Medium Silt % (16-31µm)	4.34
Course Silt % (31-63µm)	5.79
Total Silt (4-63µm)	**16.67**
Very Fine sand % (63-125µm)	5.95
Fine sand % (125-250µm)	5.64
Medium sand % (250-500µm)	9.90
Coarse sand % (500-1000µm)	13.24
Very Coarse sand % (1000-2000µm)	13.78
Total Sand (63-2000µm)	**48.51**
Total Gravels (>2000µm)	**30.38**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.24
1000	13.78
2000	16.98
4000	10.65
8000	2.74
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	779.42
Minimum settling velocity of 50% of particles (mm s^1)	500.94
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	13.62
Minimum settling velocity of 90% of particles (mm s^1)	0.15
Time for 90% of particles to settle over 1 m (hours)	1.815

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 10/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA WORLD RECOGNISED ACCREDITATION
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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS21
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.33**
Very Fine Silt % (4-8µm)	2.13
Fine Silt % (8-16µm)	2.95
Medium Silt % (16-31µm)	3.46
Course Silt % (31-63µm)	4.63
Total Silt (4-63µm)	**13.16**
Very Fine sand % (63-125µm)	4.92
Fine sand % (125-250µm)	4.22
Medium sand % (250-500µm)	7.09
Coarse sand % (500-1000µm)	14.93
Very Coarse sand % (1000-2000µm)	10.41
Total Sand (63-2000µm)	**41.58**
Total Gravels (>2000µm)	**41.93**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	14.93
1000	10.41
2000	8.91
4000	15.79
8000	17.23
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1224.91
Minimum settling velocity of 50% of particles (mm s^1)	1237.24
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	21.92
Minimum settling velocity of 90% of particles (mm s^1)	0.40
Time for 90% of particles to settle over 1 m (hours)	0.701

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS22
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.04**
Very Fine Silt % (4-8µm)	0.73
Fine Silt % (8-16µm)	1.15
Medium Silt % (16-31µm)	1.61
Course Silt % (31-63µm)	2.64
Total Silt (4-63µm)	**6.14**
Very Fine sand % (63-125µm)	3.64
Fine sand % (125-250µm)	3.08
Medium sand % (250-500µm)	5.35
Coarse sand % (500-1000µm)	25.71
Very Coarse sand % (1000-2000µm)	18.89
Total Sand (63-2000µm)	**56.66**
Total Gravels (>2000µm)	**36.16**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	25.71
1000	18.89
2000	21.69
4000	14.47
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1267.38
Minimum settling velocity of 50% of particles (mm s^1)	1324.51
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	107.11
Minimum settling velocity of 90% of particles (mm s^1)	9.46
Time for 90% of particles to settle over 1 m (hours)	0.029

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS23
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.26**
Very Fine Silt % (4-8µm)	2.07
Fine Silt % (8-16µm)	2.93
Medium Silt % (16-31µm)	3.43
Course Silt % (31-63µm)	4.56
Total Silt (4-63µm)	**12.99**
Very Fine sand % (63-125µm)	4.79
Fine sand % (125-250µm)	3.95
Medium sand % (250-500µm)	5.75
Coarse sand % (500-1000µm)	13.61
Very Coarse sand % (1000-2000µm)	10.04
Total Sand (63-2000µm)	**38.14**
Total Gravels (>2000µm)	**45.60**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.61
1000	10.04
2000	7.12
4000	15.94
8000	22.55
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1562.24
Minimum settling velocity of 50% of particles (mm s^1)	2012.54
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	22.59
Minimum settling velocity of 90% of particles (mm s^1)	0.42
Time for 90% of particles to settle over 1 m (hours)	0.660

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS25
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.52**
Very Fine Silt % (4-8µm)	1.00
Fine Silt % (8-16µm)	1.41
Medium Silt % (16-31µm)	1.83
Course Silt % (31-63µm)	2.77
Total Silt (4-63µm)	**7.01**
Very Fine sand % (63-125µm)	3.30
Fine sand % (125-250µm)	2.60
Medium sand % (250-500µm)	2.70
Coarse sand % (500-1000µm)	14.23
Very Coarse sand % (1000-2000µm)	18.02
Total Sand (63-2000µm)	**40.85**
Total Gravels (>2000µm)	**50.62**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	14.23
1000	18.02
2000	10.43
4000	10.77
8000	29.42
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2118.57
Minimum settling velocity of 50% of particles (mm s^1)	3701.11
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	85.31
Minimum settling velocity of 90% of particles (mm s^1)	6.00
Time for 90% of particles to settle over 1 m (hours)	0.046

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rock with some sand, mud, shell and coral present. Lots of large rocks up to 9cm in size present, could not be included in the sub sample.

Signatory: Jamie Woodward
Date: 14/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS26
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.31**
Very Fine Silt % (4-8µm)	1.44
Fine Silt % (8-16µm)	1.96
Medium Silt % (16-31µm)	2.31
Course Silt % (31-63µm)	3.22
Total Silt (4-63µm)	**8.94**
Very Fine sand % (63-125µm)	3.45
Fine sand % (125-250µm)	2.58
Medium sand % (250-500µm)	3.33
Coarse sand % (500-1000µm)	12.97
Very Coarse sand % (1000-2000µm)	11.48
Total Sand (63-2000µm)	**33.80**
Total Gravels (>2000µm)	**54.95**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.97
1000	11.48
2000	9.79
4000	9.47
8000	18.45
16000	17.25

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	3011.27
Minimum settling velocity of 50% of particles (mm s^1)	7477.32
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	49.28
Minimum settling velocity of 90% of particles (mm s^1)	2.00
Time for 90% of particles to settle over 1 m (hours)	0.139

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rock with some sand, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS27
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.79**
Very Fine Silt % (4-8µm)	1.15
Fine Silt % (8-16µm)	1.57
Medium Silt % (16-31µm)	1.83
Course Silt % (31-63µm)	2.47
Total Silt (4-63µm)	**7.02**
Very Fine sand % (63-125µm)	2.64
Fine sand % (125-250µm)	1.62
Medium sand % (250-500µm)	2.87
Coarse sand % (500-1000µm)	13.34
Very Coarse sand % (1000-2000µm)	14.24
Total Sand (63-2000µm)	**34.72**
Total Gravels (>2000µm)	**56.46**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.34
1000	14.24
2000	10.94
4000	19.81
8000	11.65
16000	14.07

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	3181.82
Minimum settling velocity of 50% of particles (mm s^1)	8348.30
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	83.97
Minimum settling velocity of 90% of particles (mm s^1)	5.81
Time for 90% of particles to settle over 1 m (hours)	0.048

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rock with some sand, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS31
Sampling Date:	21/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	3/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.99**
Very Fine Silt % (4-8µm)	1.21
Fine Silt % (8-16µm)	1.58
Medium Silt % (16-31µm)	1.84
Course Silt % (31-63µm)	2.84
Total Silt (4-63µm)	**7.47**
Very Fine sand % (63-125µm)	3.48
Fine sand % (125-250µm)	2.58
Medium sand % (250-500µm)	4.02
Coarse sand % (500-1000µm)	8.55
Very Coarse sand % (1000-2000µm)	15.86
Total Sand (63-2000µm)	**34.49**
Total Gravels (>2000µm)	**56.05**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.55
1000	15.86
2000	25.05
4000	23.59
8000	7.41
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2483.21
Minimum settling velocity of 50% of particles (mm s^1)	5084.78
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	70.02
Minimum settling velocity of 90% of particles (mm s^1)	4.04
Time for 90% of particles to settle over 1 m (hours)	0.069

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rock with some sand, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS32
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.46**
Very Fine Silt % (4-8µm)	0.44
Fine Silt % (8-16µm)	0.60
Medium Silt % (16-31µm)	0.69
Course Silt % (31-63µm)	2.21
Total Silt (4-63µm)	**3.95**
Very Fine sand % (63-125µm)	2.75
Fine sand % (125-250µm)	11.87
Medium sand % (250-500µm)	27.14
Coarse sand % (500-1000µm)	12.82
Very Coarse sand % (1000-2000µm)	14.10
Total Sand (63-2000µm)	**68.69**
Total Gravels (>2000µm)	**26.91**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.82
1000	14.10
2000	17.70
4000	8.83
8000	0.38
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	649.64
Minimum settling velocity of 50% of particles (mm s^1)	348.01
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	170.44
Minimum settling velocity of 90% of particles (mm s^1)	23.95
Time for 90% of particles to settle over 1 m (hours)	0.012

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS33
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.29**
Very Fine Silt % (4-8µm)	0.30
Fine Silt % (8-16µm)	0.41
Medium Silt % (16-31µm)	0.48
Course Silt % (31-63µm)	1.40
Total Silt (4-63µm)	**2.59**
Very Fine sand % (63-125µm)	1.75
Fine sand % (125-250µm)	6.19
Medium sand % (250-500µm)	19.97
Coarse sand % (500-1000µm)	25.79
Very Coarse sand % (1000-2000µm)	23.06
Total Sand (63-2000µm)	**76.76**
Total Gravels (>2000µm)	**20.35**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	25.79
1000	23.06
2000	16.77
4000	3.58
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	872.30
Minimum settling velocity of 50% of particles (mm s^1)	627.45
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	239.03
Minimum settling velocity of 90% of particles (mm s^1)	47.11
Time for 90% of particles to settle over 1 m (hours)	0.006

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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WORLD RECOGNISED ACCREDITATION

Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS34
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.00**
Very Fine Silt % (4-8µm)	0.00
Fine Silt % (8-16µm)	0.09
Medium Silt % (16-31µm)	0.07
Course Silt % (31-63µm)	1.20
Total Silt (4-63µm)	**1.36**
Very Fine sand % (63-125µm)	0.61
Fine sand % (125-250µm)	12.33
Medium sand % (250-500µm)	51.32
Coarse sand % (500-1000µm)	15.54
Very Coarse sand % (1000-2000µm)	6.89
Total Sand (63-2000µm)	**86.70**
Total Gravels (>2000µm)	**11.94**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.54
1000	6.89
2000	5.50
4000	6.44
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	410.54
Minimum settling velocity of 50% of particles (mm s^1)	138.98
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	226.39
Minimum settling velocity of 90% of particles (mm s^1)	42.26
Time for 90% of particles to settle over 1 m (hours)	0.007

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory
Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS35
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.51**
Very Fine Silt % (4-8µm)	0.92
Fine Silt % (8-16µm)	1.24
Medium Silt % (16-31µm)	1.51
Course Silt % (31-63µm)	3.09
Total Silt (4-63µm)	**6.76**
Very Fine sand % (63-125µm)	3.16
Fine sand % (125-250µm)	12.52
Medium sand % (250-500µm)	32.61
Coarse sand % (500-1000µm)	12.87
Very Coarse sand % (1000-2000µm)	8.68
Total Sand (63-2000µm)	**69.83**
Total Gravels (>2000µm)	**21.90**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.87
1000	8.68
2000	12.54
4000	9.15
8000	0.21
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	434.07
Minimum settling velocity of 50% of particles (mm s^1)	155.37
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	89.50
Minimum settling velocity of 90% of particles (mm s^1)	6.60
Time for 90% of particles to settle over 1 m (hours)	0.042

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS36
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.05**
Very Fine Silt % (4-8µm)	0.17
Fine Silt % (8-16µm)	0.35
Medium Silt % (16-31µm)	0.33
Course Silt % (31-63µm)	1.27
Total Silt (4-63µm)	**2.12**
Very Fine sand % (63-125µm)	2.00
Fine sand % (125-250µm)	5.48
Medium sand % (250-500µm)	31.22
Coarse sand % (500-1000µm)	33.34
Very Coarse sand % (1000-2000µm)	16.28
Total Sand (63-2000µm)	**88.33**
Total Gravels (>2000µm)	**9.50**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	33.34
1000	16.28
2000	7.92
4000	1.58
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	636.80
Minimum settling velocity of 50% of particles (mm s^1)	334.39
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	253.26
Minimum settling velocity of 90% of particles (mm s^1)	52.89
Time for 90% of particles to settle over 1 m (hours)	0.005

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS37
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.00**
Very Fine Silt % (4-8µm)	0.00
Fine Silt % (8-16µm)	0.00
Medium Silt % (16-31µm)	0.04
Course Silt % (31-63µm)	0.56
Total Silt (4-63µm)	**0.60**
Very Fine sand % (63-125µm)	0.32
Fine sand % (125-250µm)	2.55
Medium sand % (250-500µm)	30.07
Coarse sand % (500-1000µm)	35.10
Very Coarse sand % (1000-2000µm)	20.16
Total Sand (63-2000µm)	**88.20**
Total Gravels (>2000µm)	**11.20**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	35.10
1000	20.16
2000	8.91
4000	2.30
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	734.44
Minimum settling velocity of 50% of particles (mm s^1)	444.80
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	319.07
Minimum settling velocity of 90% of particles (mm s^1)	83.95
Time for 90% of particles to settle over 1 m (hours)	0.003

Settings	
SOP Name	SOP-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS38
Sampling Date:	19/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.17**
Very Fine Silt % (4-8µm)	1.23
Fine Silt % (8-16µm)	1.61
Medium Silt % (16-31µm)	2.01
Course Silt % (31-63µm)	3.50
Total Silt (4-63µm)	**8.36**
Very Fine sand % (63-125µm)	3.92
Fine sand % (125-250µm)	15.33
Medium sand % (250-500µm)	26.73
Coarse sand % (500-1000µm)	11.19
Very Coarse sand % (1000-2000µm)	12.70
Total Sand (63-2000µm)	**69.87**
Total Gravels (>2000µm)	**19.60**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.19
1000	12.70
2000	9.74
4000	4.63
8000	5.23
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	412.25
Minimum settling velocity of 50% of particles (mm s^1)	140.14
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	57.23
Minimum settling velocity of 90% of particles (mm s^1)	2.70
Time for 90% of particles to settle over 1 m (hours)	0.103

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS39
Sampling Date:	19/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.00**
Very Fine Silt % (4-8µm)	0.06
Fine Silt % (8-16µm)	0.15
Medium Silt % (16-31µm)	0.17
Course Silt % (31-63µm)	0.40
Total Silt (4-63µm)	**0.79**
Very Fine sand % (63-125µm)	0.26
Fine sand % (125-250µm)	1.53
Medium sand % (250-500µm)	17.45
Coarse sand % (500-1000µm)	33.59
Very Coarse sand % (1000-2000µm)	27.61
Total Sand (63-2000µm)	**80.44**
Total Gravels (>2000µm)	**18.77**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	33.59
1000	27.61
2000	14.64
4000	4.13
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	946.15
Minimum settling velocity of 50% of particles (mm s^1)	738.19
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	367.89
Minimum settling velocity of 90% of particles (mm s^1)	111.60
Time for 90% of particles to settle over 1 m (hours)	0.002

Settings	
SOP Name	SOP-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS40
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.40**
Very Fine Silt % (4-8µm)	0.82
Fine Silt % (8-16µm)	1.11
Medium Silt % (16-31µm)	1.31
Course Silt % (31-63µm)	3.26
Total Silt (4-63µm)	**6.50**
Very Fine sand % (63-125µm)	4.45
Fine sand % (125-250µm)	12.29
Medium sand % (250-500µm)	27.48
Coarse sand % (500-1000µm)	15.21
Very Coarse sand % (1000-2000µm)	11.01
Total Sand (63-2000µm)	**70.44**
Total Gravels (>2000µm)	**21.65**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.21
1000	11.01
2000	13.90
4000	6.30
8000	1.46
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	471.87
Minimum settling velocity of 50% of particles (mm s^1)	183.61
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	86.68
Minimum settling velocity of 90% of particles (mm s^1)	6.20
Time for 90% of particles to settle over 1 m (hours)	0.045

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS41
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.02**
Very Fine Silt % (4-8µm)	1.15
Fine Silt % (8-16µm)	1.60
Medium Silt % (16-31µm)	1.92
Course Silt % (31-63µm)	5.31
Total Silt (4-63µm)	**9.99**
Very Fine sand % (63-125µm)	8.66
Fine sand % (125-250µm)	14.54
Medium sand % (250-500µm)	27.32
Coarse sand % (500-1000µm)	16.08
Very Coarse sand % (1000-2000µm)	8.90
Total Sand (63-2000µm)	**75.50**
Total Gravels (>2000µm)	**12.49**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	16.08
1000	8.90
2000	8.26
4000	4.23
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	363.21
Minimum settling velocity of 50% of particles (mm s^1)	108.78
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	52.08
Minimum settling velocity of 90% of particles (mm s^1)	2.24
Time for 90% of particles to settle over 1 m (hours)	0.124

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, mud, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS42
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.05**
Very Fine Silt % (4-8µm)	2.29
Fine Silt % (8-16µm)	3.22
Medium Silt % (16-31µm)	4.14
Course Silt % (31-63µm)	7.68
Total Silt (4-63µm)	**17.33**
Very Fine sand % (63-125µm)	9.51
Fine sand % (125-250µm)	14.83
Medium sand % (250-500µm)	27.21
Coarse sand % (500-1000µm)	11.23
Very Coarse sand % (1000-2000µm)	5.09
Total Sand (63-2000µm)	**67.88**
Total Gravels (>2000µm)	**10.74**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.23
1000	5.09
2000	6.78
4000	3.96
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	281.62
Minimum settling velocity of 50% of particles (mm s^1)	65.40
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	17.35
Minimum settling velocity of 90% of particles (mm s^1)	0.25
Time for 90% of particles to settle over 1 m (hours)	1.119

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS44 a
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.13**
Very Fine Silt % (4-8µm)	0.20
Fine Silt % (8-16µm)	0.25
Medium Silt % (16-31µm)	0.24
Course Silt % (31-63µm)	0.51
Total Silt (4-63µm)	**1.20**
Very Fine sand % (63-125µm)	0.42
Fine sand % (125-250µm)	2.07
Medium sand % (250-500µm)	13.92
Coarse sand % (500-1000µm)	31.21
Very Coarse sand % (1000-2000µm)	29.14
Total Sand (63-2000µm)	**76.77**
Total Gravels (>2000µm)	**21.90**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	31.21
1000	29.14
2000	16.69
4000	5.20
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1035.68
Minimum settling velocity of 50% of particles (mm s^1)	884.50
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	363.74
Minimum settling velocity of 90% of particles (mm s^1)	109.10
Time for 90% of particles to settle over 1 m (hours)	0.003

Settings	
SOP Name	SOP-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS44 b
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.14**
Very Fine Silt % (4-8µm)	0.31
Fine Silt % (8-16µm)	0.36
Medium Silt % (16-31µm)	0.32
Course Silt % (31-63µm)	0.79
Total Silt (4-63µm)	**1.78**
Very Fine sand % (63-125µm)	0.53
Fine sand % (125-250µm)	4.75
Medium sand % (250-500µm)	27.00
Coarse sand % (500-1000µm)	24.07
Very Coarse sand % (1000-2000µm)	20.14
Total Sand (63-2000µm)	**76.49**
Total Gravels (>2000µm)	**21.60**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	24.07
1000	20.14
2000	18.98
4000	2.62
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	828.32
Minimum settling velocity of 50% of particles (mm s^1)	565.77
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	278.40
Minimum settling velocity of 90% of particles (mm s^1)	63.91
Time for 90% of particles to settle over 1 m (hours)	0.004

Settings	
SOP Name	SOP-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS45
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.68**
Very Fine Silt % (4-8µm)	0.42
Fine Silt % (8-16µm)	0.59
Medium Silt % (16-31µm)	0.75
Course Silt % (31-63µm)	1.39
Total Silt (4-63µm)	**3.16**
Very Fine sand % (63-125µm)	1.80
Fine sand % (125-250µm)	3.11
Medium sand % (250-500µm)	7.88
Coarse sand % (500-1000µm)	28.23
Very Coarse sand % (1000-2000µm)	29.02
Total Sand (63-2000µm)	**70.04**
Total Gravels (>2000µm)	**26.12**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	28.23
1000	29.02
2000	19.81
4000	6.31
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1177.05
Minimum settling velocity of 50% of particles (mm s^1)	1142.45
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	286.44
Minimum settling velocity of 90% of particles (mm s^1)	67.66
Time for 90% of particles to settle over 1 m (hours)	0.004

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS46
Sampling Date:	19/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	8/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.08**
Very Fine Silt % (4-8µm)	0.08
Fine Silt % (8-16µm)	0.12
Medium Silt % (16-31µm)	0.17
Course Silt % (31-63µm)	0.36
Total Silt (4-63µm)	**0.74**
Very Fine sand % (63-125µm)	0.58
Fine sand % (125-250µm)	0.12
Medium sand % (250-500µm)	3.03
Coarse sand % (500-1000µm)	49.70
Very Coarse sand % (1000-2000µm)	39.42
Total Sand (63-2000µm)	**92.85**
Total Gravels (>2000µm)	**6.33**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	49.70
1000	39.42
2000	5.69
4000	0.64
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	957.20
Minimum settling velocity of 50% of particles (mm s^1)	755.53
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	554.76
Minimum settling velocity of 90% of particles (mm s^1)	253.78
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS47
Sampling Date:	19/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.66**
Very Fine Silt % (4-8µm)	1.49
Fine Silt % (8-16µm)	2.14
Medium Silt % (16-31µm)	2.90
Course Silt % (31-63µm)	7.71
Total Silt (4-63µm)	**14.24**
Very Fine sand % (63-125µm)	14.52
Fine sand % (125-250µm)	14.23
Medium sand % (250-500µm)	11.09
Coarse sand % (500-1000µm)	23.55
Very Coarse sand % (1000-2000µm)	14.24
Total Sand (63-2000µm)	**77.63**
Total Gravels (>2000µm)	**5.47**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	23.55
1000	14.24
2000	5.13
4000	0.33
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	316.70
Minimum settling velocity of 50% of particles (mm s^1)	82.71
Time for 50% of particles to settle over 1 m (hours)	0.003
D10 (µm)	35.09
Minimum settling velocity of 90% of particles (mm s^1)	1.02
Time for 90% of particles to settle over 1 m (hours)	0.274

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS48
Sampling Date:	19/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.31**
Very Fine Silt % (4-8µm)	2.15
Fine Silt % (8-16µm)	2.90
Medium Silt % (16-31µm)	4.55
Course Silt % (31-63µm)	11.00
Total Silt (4-63µm)	**20.61**
Very Fine sand % (63-125µm)	19.55
Fine sand % (125-250µm)	25.51
Medium sand % (250-500µm)	17.44
Coarse sand % (500-1000µm)	3.90
Very Coarse sand % (1000-2000µm)	4.05
Total Sand (63-2000µm)	**70.46**
Total Gravels (>2000µm)	**4.62**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	3.90
1000	4.05
2000	3.09
4000	0.42
8000	1.11
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	146.35
Minimum settling velocity of 50% of particles (mm s^1)	17.66
Time for 50% of particles to settle over 1 m (hours)	0.016
D10 (µm)	18.03
Minimum settling velocity of 90% of particles (mm s^1)	0.27
Time for 90% of particles to settle over 1 m (hours)	1.036

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Marine and Freshwater Research Laboratory Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS49
Sampling Date:	19/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	7/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.95**
Very Fine Silt % (4-8µm)	5.21
Fine Silt % (8-16µm)	7.16
Medium Silt % (16-31µm)	11.06
Course Silt % (31-63µm)	22.24
Total Silt (4-63µm)	**45.67**
Very Fine sand % (63-125µm)	25.48
Fine sand % (125-250µm)	13.02
Medium sand % (250-500µm)	5.28
Coarse sand % (500-1000µm)	0.18
Very Coarse sand % (1000-2000µm)	0.21
Total Sand (63-2000µm)	**44.16**
Total Gravels (>2000µm)	**0.22**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	0.18
1000	0.21
2000	0.22
4000	0.00
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	54.37
Minimum settling velocity of 50% of particles (mm s^1)	2.44
Time for 50% of particles to settle over 1 m (hours)	0.114
D10 (µm)	4.03
Minimum settling velocity of 90% of particles (mm s^1)	0.01
Time for 90% of particles to settle over 1 m (hours)	20.737

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some sand, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS70
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.54**
Very Fine Silt % (4-8µm)	2.07
Fine Silt % (8-16µm)	2.81
Medium Silt % (16-31µm)	3.31
Course Silt % (31-63µm)	4.92
Total Silt (4-63µm)	**13.12**
Very Fine sand % (63-125µm)	5.19
Fine sand % (125-250µm)	3.19
Medium sand % (250-500µm)	6.14
Coarse sand % (500-1000µm)	14.51
Very Coarse sand % (1000-2000µm)	25.34
Total Sand (63-2000µm)	**54.36**
Total Gravels (>2000µm)	**28.98**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	14.51
1000	25.34
2000	15.56
4000	6.52
8000	6.90
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1170.63
Minimum settling velocity of 50% of particles (mm s^1)	1130.01
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	22.23
Minimum settling velocity of 90% of particles (mm s^1)	0.41
Time for 90% of particles to settle over 1 m (hours)	0.682

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS74
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.79**
Very Fine Silt % (4-8µm)	1.63
Fine Silt % (8-16µm)	2.26
Medium Silt % (16-31µm)	2.82
Course Silt % (31-63µm)	5.05
Total Silt (4-63µm)	**11.76**
Very Fine sand % (63-125µm)	6.58
Fine sand % (125-250µm)	4.59
Medium sand % (250-500µm)	5.92
Coarse sand % (500-1000µm)	19.18
Very Coarse sand % (1000-2000µm)	16.83
Total Sand (63-2000µm)	**53.10**
Total Gravels (>2000µm)	**32.35**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	19.18
1000	16.83
2000	14.04
4000	14.63
8000	3.68
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	978.65
Minimum settling velocity of 50% of particles $(mm\ s^{1})$	789.77
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	34.13
Minimum settling velocity of 90% of particles $(mm\ s^{1})$	0.96
Time for 90% of particles to settle over 1 m (hours)	0.289

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS75
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.35**
Very Fine Silt % (4-8µm)	1.36
Fine Silt % (8-16µm)	1.84
Medium Silt % (16-31µm)	2.33
Course Silt % (31-63µm)	5.11
Total Silt (4-63µm)	**10.65**
Very Fine sand % (63-125µm)	8.00
Fine sand % (125-250µm)	6.46
Medium sand % (250-500µm)	6.98
Coarse sand % (500-1000µm)	15.51
Very Coarse sand % (1000-2000µm)	12.47
Total Sand (63-2000µm)	**49.41**
Total Gravels (>2000µm)	**37.59**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	15.51
1000	12.47
2000	17.36
4000	15.86
8000	4.37
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1004.55
Minimum settling velocity of 50% of particles (mm s^1)	832.12
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	45.09
Minimum settling velocity of 90% of particles (mm s^1)	1.68
Time for 90% of particles to settle over 1 m (hours)	0.166

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment
Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 14/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	HS77
Sampling Date:	20/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	6/12/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.02**
Very Fine Silt % (4-8µm)	1.72
Fine Silt % (8-16µm)	2.38
Medium Silt % (16-31µm)	3.19
Course Silt % (31-63µm)	6.71
Total Silt (4-63µm)	**14.00**
Very Fine sand % (63-125µm)	10.84
Fine sand % (125-250µm)	19.27
Medium sand % (250-500µm)	19.38
Coarse sand % (500-1000µm)	6.83
Very Coarse sand % (1000-2000µm)	8.85
Total Sand (63-2000µm)	**65.16**
Total Gravels (>2000µm)	**17.82**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.83
1000	8.85
2000	9.98
4000	7.85
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	272.69
Minimum settling velocity of 50% of particles (mm s^1)	61.32
Time for 50% of particles to settle over 1 m (hours)	0.005
D10 (µm)	29.48
Minimum settling velocity of 90% of particles (mm s^1)	0.72
Time for 90% of particles to settle over 1 m (hours)	0.388

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock, shell and coral present.

Signatory: Jamie Woodward
Date: 14/12/2021

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	PTS-57.5-GS
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	15/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.43**
Very Fine Silt % (4-8µm)	1.73
Fine Silt % (8-16µm)	1.84
Medium Silt % (16-31µm)	2.70
Course Silt % (31-63µm)	4.84
Total Silt (4-63µm)	**11.11**
Very Fine sand % (63-125µm)	14.23
Fine sand % (125-250µm)	29.60
Medium sand % (250-500µm)	19.62
Coarse sand % (500-1000µm)	6.29
Very Coarse sand % (1000-2000µm)	6.35
Total Sand (63-2000µm)	**76.09**
Total Gravels (>2000µm)	**9.36**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.29
1000	6.35
2000	5.26
4000	4.10
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	206.90
Minimum settling velocity of 50% of particles (mm s^1)	35.30
Time for 50% of particles to settle over 1 m (hours)	0.008
D10 (µm)	32.77
Minimum settling velocity of 90% of particles (mm s^1)	0.89
Time for 90% of particles to settle over 1 m (hours)	0.314

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock and shell present.

Signatory: Jamie Woodward
Date: 19/11/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	PTS-62.5-GS
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	15/11/2021
Method Number:	9400
Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.62**
Very Fine Silt % (4-8µm)	1.79
Fine Silt % (8-16µm)	1.92
Medium Silt % (16-31µm)	2.71
Course Silt % (31-63µm)	4.81
Total Silt (4-63µm)	**11.23**
Very Fine sand % (63-125µm)	13.06
Fine sand % (125-250µm)	24.50
Medium sand % (250-500µm)	16.19
Coarse sand % (500-1000µm)	10.28
Very Coarse sand % (1000-2000µm)	10.67
Total Sand (63-2000µm)	**74.71**
Total Gravels (>2000µm)	**10.45**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.28
1000	10.67
2000	7.90
4000	2.54
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	233.71
Minimum settling velocity of 50% of particles (mm s^1)	45.04
Time for 50% of particles to settle over 1 m (hours)	0.006
D10 (µm)	30.80
Minimum settling velocity of 90% of particles (mm s^1)	0.78
Time for 90% of particles to settle over 1 m (hours)	0.355
Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock and shell present.

Signatory: Jamie Woodward
Date: 19/11/2021

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-5

Sample Name:	PTS-64.0-GS
Sampling Date:	17/10/2021
Sample Type:	Sediment
MAFRL Job Code:	RPS21-5
Client Reference:	AU213002038.001
Analysis Date:	15/11/2021
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.29**
Very Fine Silt % (4-8µm)	1.61
Fine Silt % (8-16µm)	1.75
Medium Silt % (16-31µm)	2.42
Course Silt % (31-63µm)	4.45
Total Silt (4-63µm)	**10.23**
Very Fine sand % (63-125µm)	11.14
Fine sand % (125-250µm)	20.65
Medium sand % (250-500µm)	15.27
Coarse sand % (500-1000µm)	10.25
Very Coarse sand % (1000-2000µm)	9.10
Total Sand (63-2000µm)	**66.40**
Total Gravels (>2000µm)	**20.09**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.25
1000	9.10
2000	11.26
4000	7.52
8000	1.31
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	295.77
Minimum settling velocity of 50% of particles (mm s^1)	72.13
Time for 50% of particles to settle over 1 m (hours)	0.004
D10 (µm)	37.59
Minimum settling velocity of 90% of particles (mm s^1)	1.17
Time for 90% of particles to settle over 1 m (hours)	0.238

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some rock and shell present.

Signatory: Jamie Woodward
Date: 19/11/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-75_L
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.31**
Very Fine Silt % (4-8µm)	0.16
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.39
Course Silt % (31-63µm)	1.16
Total Silt (4-63µm)	**1.95**
Very Fine sand % (63-125µm)	2.48
Fine sand % (125-250µm)	4.47
Medium sand % (250-500µm)	7.31
Coarse sand % (500-1000µm)	49.11
Very Coarse sand % (1000-2000µm)	25.96
Total Sand (63-2000µm)	**89.34**
Total Gravels (>2000µm)	**8.41**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	49.11
1000	25.96
2000	5.66
4000	2.75
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	840.86
Minimum settling velocity of 50% of particles (mm s^1)	583.04
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	271.85
Minimum settling velocity of 90% of particles (mm s^1)	60.94
Time for 90% of particles to settle over 1 m (hours)	0.005

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment
Sand with some shell, coral, rock and silt present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-75_U
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.42**
Very Fine Silt % (4-8µm)	0.21
Fine Silt % (8-16µm)	0.32
Medium Silt % (16-31µm)	0.52
Course Silt % (31-63µm)	1.60
Total Silt (4-63µm)	**2.65**
Very Fine sand % (63-125µm)	3.11
Fine sand % (125-250µm)	3.52
Medium sand % (250-500µm)	4.46
Coarse sand % (500-1000µm)	38.76
Very Coarse sand % (1000-2000µm)	36.51
Total Sand (63-2000µm)	**86.35**
Total Gravels (>2000µm)	**10.58**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	38.76
1000	36.51
2000	10.34
4000	0.24
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	962.55
Minimum settling velocity of 50% of particles (mm s^1)	764.00
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	263.81
Minimum settling velocity of 90% of particles (mm s^1)	57.39
Time for 90% of particles to settle over 1 m (hours)	0.005

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and mud present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-85_L
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.19**
Very Fine Silt % (4-8µm)	0.11
Fine Silt % (8-16µm)	0.19
Medium Silt % (16-31µm)	0.35
Course Silt % (31-63µm)	0.89
Total Silt (4-63µm)	**1.54**
Very Fine sand % (63-125µm)	1.84
Fine sand % (125-250µm)	2.53
Medium sand % (250-500µm)	2.77
Coarse sand % (500-1000µm)	38.60
Very Coarse sand % (1000-2000µm)	39.27
Total Sand (63-2000µm)	**85.01**
Total Gravels (>2000µm)	**13.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	38.60
1000	39.27
2000	12.06
4000	1.21
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1064.52
Minimum settling velocity of 50% of particles (mm s^1)	934.45
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	514.74
Minimum settling velocity of 90% of particles (mm s^1)	218.48
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and silt present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-85_U
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.22**
Very Fine Silt % (4-8µm)	0.14
Fine Silt % (8-16µm)	0.20
Medium Silt % (16-31µm)	0.29
Course Silt % (31-63µm)	0.58
Total Silt (4-63µm)	**1.21**
Very Fine sand % (63-125µm)	0.88
Fine sand % (125-250µm)	1.39
Medium sand % (250-500µm)	5.17
Coarse sand % (500-1000µm)	42.11
Very Coarse sand % (1000-2000µm)	40.58
Total Sand (63-2000µm)	**90.13**
Total Gravels (>2000µm)	**8.44**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	42.11
1000	40.58
2000	8.44
4000	0.00
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	988.29
Minimum settling velocity of 50% of particles (mm s^1)	805.41
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	513.36
Minimum settling velocity of 90% of particles (mm s^1)	217.32
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-85_U_1
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.23**
Very Fine Silt % (4-8µm)	0.14
Fine Silt % (8-16µm)	0.23
Medium Silt % (16-31µm)	0.41
Course Silt % (31-63µm)	1.02
Total Silt (4-63µm)	**1.80**
Very Fine sand % (63-125µm)	1.79
Fine sand % (125-250µm)	2.53
Medium sand % (250-500µm)	3.63
Coarse sand % (500-1000µm)	42.64
Very Coarse sand % (1000-2000µm)	39.36
Total Sand (63-2000µm)	**89.95**
Total Gravels (>2000µm)	**8.02**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	42.64
1000	39.36
2000	6.05
4000	1.97
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	969.23
Minimum settling velocity of 50% of particles (mm s^1)	774.65
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	500.15
Minimum settling velocity of 90% of particles (mm s^1)	206.28
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and silt present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-95_U
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.96**
Very Fine Silt % (4-8µm)	1.37
Fine Silt % (8-16µm)	1.87
Medium Silt % (16-31µm)	2.75
Course Silt % (31-63µm)	6.32
Total Silt (4-63µm)	**12.31**
Very Fine sand % (63-125µm)	8.74
Fine sand % (125-250µm)	9.71
Medium sand % (250-500µm)	16.65
Coarse sand % (500-1000µm)	23.37
Very Coarse sand % (1000-2000µm)	14.72
Total Sand (63-2000µm)	**73.20**
Total Gravels (>2000µm)	**11.53**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	23.37
1000	14.72
2000	8.72
4000	2.81
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	492.38
Minimum settling velocity of 50% of particles (mm s^1)	199.92
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	36.58
Minimum settling velocity of 90% of particles (mm s^1)	1.10
Time for 90% of particles to settle over 1 m (hours)	0.252

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-95_U_1
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.17**
Very Fine Silt % (4-8µm)	1.92
Fine Silt % (8-16µm)	2.52
Medium Silt % (16-31µm)	3.56
Course Silt % (31-63µm)	7.42
Total Silt (4-63µm)	**15.42**
Very Fine sand % (63-125µm)	9.18
Fine sand % (125-250µm)	9.25
Medium sand % (250-500µm)	16.05
Coarse sand % (500-1000µm)	19.28
Very Coarse sand % (1000-2000µm)	12.50
Total Sand (63-2000µm)	**66.25**
Total Gravels (>2000µm)	**14.16**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	19.28
1000	12.50
2000	9.85
4000	4.31
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	420.82
Minimum settling velocity of 50% of particles (mm s^1)	146.03
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	21.56
Minimum settling velocity of 90% of particles (mm s^1)	0.38
Time for 90% of particles to settle over 1 m (hours)	0.725

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-7_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.16**
Very Fine Silt % (4-8µm)	0.29
Fine Silt % (8-16µm)	0.44
Medium Silt % (16-31µm)	0.53
Course Silt % (31-63µm)	2.02
Total Silt (4-63µm)	**3.28**
Very Fine sand % (63-125µm)	3.12
Fine sand % (125-250µm)	7.84
Medium sand % (250-500µm)	29.29
Coarse sand % (500-1000µm)	23.02
Very Coarse sand % (1000-2000µm)	12.37
Total Sand (63-2000µm)	**75.63**
Total Gravels (>2000µm)	**20.93**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	23.02
1000	12.37
2000	13.79
4000	7.14
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	637.19
Minimum settling velocity of 50% of particles (mm s^1)	334.80
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	201.32
Minimum settling velocity of 90% of particles (mm s^1)	33.42
Time for 90% of particles to settle over 1 m (hours)	0.008

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and mud present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

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Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-8_L
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.07**
Very Fine Silt % (4-8µm)	0.17
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.30
Course Silt % (31-63µm)	0.76
Total Silt (4-63µm)	**1.47**
Very Fine sand % (63-125µm)	1.23
Fine sand % (125-250µm)	3.57
Medium sand % (250-500µm)	17.72
Coarse sand % (500-1000µm)	34.10
Very Coarse sand % (1000-2000µm)	26.60
Total Sand (63-2000µm)	**83.21**
Total Gravels (>2000µm)	**15.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	34.10
1000	26.60
2000	12.00
4000	3.26
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	880.56
Minimum settling velocity of 50% of particles (mm s^1)	639.38
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	306.66
Minimum settling velocity of 90% of particles (mm s^1)	77.54
Time for 90% of particles to settle over 1 m (hours)	0.004

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-8_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.06**
Very Fine Silt % (4-8µm)	0.17
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.28
Course Silt % (31-63µm)	0.72
Total Silt (4-63µm)	**1.41**
Very Fine sand % (63-125µm)	1.09
Fine sand % (125-250µm)	3.49
Medium sand % (250-500µm)	16.95
Coarse sand % (500-1000µm)	32.38
Very Coarse sand % (1000-2000µm)	27.79
Total Sand (63-2000µm)	**81.70**
Total Gravels (>2000µm)	**16.83**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	32.38
1000	27.79
2000	14.32
4000	2.51
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	916.94
Minimum settling velocity of 50% of particles (mm s^1)	693.31
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	313.12
Minimum settling velocity of 90% of particles (mm s^1)	80.85
Time for 90% of particles to settle over 1 m (hours)	0.003

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-23
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.02**
Very Fine Silt % (4-8µm)	0.15
Fine Silt % (8-16µm)	0.20
Medium Silt % (16-31µm)	0.21
Course Silt % (31-63µm)	0.49
Total Silt (4-63µm)	**1.05**
Very Fine sand % (63-125µm)	0.50
Fine sand % (125-250µm)	1.53
Medium sand % (250-500µm)	16.33
Coarse sand % (500-1000µm)	38.58
Very Coarse sand % (1000-2000µm)	26.49
Total Sand (63-2000µm)	**83.43**
Total Gravels (>2000µm)	**15.50**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	38.58
1000	26.49
2000	11.29
4000	4.21
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	896.26
Minimum settling velocity of 50% of particles (mm s^1)	662.39
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	365.82
Minimum settling velocity of 90% of particles (mm s^1)	110.35
Time for 90% of particles to settle over 1 m (hours)	0.003

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-23_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.01**
Very Fine Silt % (4-8µm)	0.14
Fine Silt % (8-16µm)	0.20
Medium Silt % (16-31µm)	0.22
Course Silt % (31-63µm)	0.48
Total Silt (4-63µm)	**1.03**
Very Fine sand % (63-125µm)	0.47
Fine sand % (125-250µm)	1.47
Medium sand % (250-500µm)	15.45
Coarse sand % (500-1000µm)	39.29
Very Coarse sand % (1000-2000µm)	31.12
Total Sand (63-2000µm)	**87.80**
Total Gravels (>2000µm)	**11.16**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	39.29
1000	31.12
2000	10.64
4000	0.51
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	901.75
Minimum settling velocity of 50% of particles (mm s^1)	670.53
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	373.33
Minimum settling velocity of 90% of particles (mm s^1)	114.93
Time for 90% of particles to settle over 1 m (hours)	0.002

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP102-7_L
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**8.80**
Very Fine Silt % (4-8µm)	3.83
Fine Silt % (8-16µm)	4.29
Medium Silt % (16-31µm)	4.61
Course Silt % (31-63µm)	5.09
Total Silt (4-63µm)	**17.83**
Very Fine sand % (63-125µm)	4.02
Fine sand % (125-250µm)	4.46
Medium sand % (250-500µm)	7.79
Coarse sand % (500-1000µm)	6.85
Very Coarse sand % (1000-2000µm)	9.59
Total Sand (63-2000µm)	**32.71**
Total Gravels (>2000µm)	**40.66**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.85
1000	9.59
2000	19.73
4000	14.50
8000	6.43
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1026.04
Minimum settling velocity of 50% of particles (mm s^1)	868.11
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	4.99
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	13.547

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP102-7_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.06**
Very Fine Silt % (4-8µm)	3.24
Fine Silt % (8-16µm)	3.94
Medium Silt % (16-31µm)	5.42
Course Silt % (31-63µm)	8.38
Total Silt (4-63µm)	**20.98**
Very Fine sand % (63-125µm)	7.72
Fine sand % (125-250µm)	5.55
Medium sand % (250-500µm)	6.66
Coarse sand % (500-1000µm)	6.70
Very Coarse sand % (1000-2000µm)	10.08
Total Sand (63-2000µm)	**36.71**
Total Gravels (>2000µm)	**35.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.70
1000	10.08
2000	12.40
4000	9.55
8000	13.32
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	652.36
Minimum settling velocity of 50% of particles (mm s^1)	350.93
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	7.55
Minimum settling velocity of 90% of particles (mm s^1)	0.05
Time for 90% of particles to settle over 1 m (hours)	5.907

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP103-1_L
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.37**
Very Fine Silt % (4-8µm)	4.18
Fine Silt % (8-16µm)	4.82
Medium Silt % (16-31µm)	4.53
Course Silt % (31-63µm)	4.11
Total Silt (4-63µm)	**17.63**
Very Fine sand % (63-125µm)	2.72
Fine sand % (125-250µm)	7.38
Medium sand % (250-500µm)	17.58
Coarse sand % (500-1000µm)	9.51
Very Coarse sand % (1000-2000µm)	6.32
Total Sand (63-2000µm)	**43.51**
Total Gravels (>2000µm)	**29.50**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.51
1000	6.32
2000	9.90
4000	11.58
8000	8.01
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	408.70
Minimum settling velocity of 50% of particles (mm s^1)	137.74
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	4.46
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	16.911

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP103-1_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**8.47**
Very Fine Silt % (4-8µm)	3.79
Fine Silt % (8-16µm)	4.44
Medium Silt % (16-31µm)	4.31
Course Silt % (31-63µm)	4.66
Total Silt (4-63µm)	**17.20**
Very Fine sand % (63-125µm)	4.21
Fine sand % (125-250µm)	4.93
Medium sand % (250-500µm)	10.83
Coarse sand % (500-1000µm)	13.79
Very Coarse sand % (1000-2000µm)	9.31
Total Sand (63-2000µm)	**43.07**
Total Gravels (>2000µm)	**31.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.79
1000	9.31
2000	11.30
4000	10.86
8000	9.10
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	658.13
Minimum settling velocity of 50% of particles (mm s^1)	357.17
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	5.35
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	11.755

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP103-5_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.95**
Very Fine Silt % (4-8µm)	1.70
Fine Silt % (8-16µm)	2.20
Medium Silt % (16-31µm)	2.60
Course Silt % (31-63µm)	3.81
Total Silt (4-63µm)	**10.32**
Very Fine sand % (63-125µm)	4.09
Fine sand % (125-250µm)	3.19
Medium sand % (250-500µm)	5.25
Coarse sand % (500-1000µm)	12.26
Very Coarse sand % (1000-2000µm)	11.95
Total Sand (63-2000µm)	**36.75**
Total Gravels (>2000µm)	**49.98**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.26
1000	11.95
2000	13.97
4000	25.12
8000	10.89
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1998.46
Minimum settling velocity of 50% of particles (mm s^1)	3293.35
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	34.97
Minimum settling velocity of 90% of particles (mm s^1)	1.01
Time for 90% of particles to settle over 1 m (hours)	0.275

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some shell, coral and sand present. Rocks upto approximately 3.5cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP104-9_U
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.55**
Very Fine Silt % (4-8µm)	4.13
Fine Silt % (8-16µm)	4.33
Medium Silt % (16-31µm)	4.67
Course Silt % (31-63µm)	5.99
Total Silt (4-63µm)	**19.13**
Very Fine sand % (63-125µm)	5.90
Fine sand % (125-250µm)	4.65
Medium sand % (250-500µm)	7.13
Coarse sand % (500-1000µm)	11.01
Very Coarse sand % (1000-2000µm)	6.97
Total Sand (63-2000µm)	**35.65**
Total Gravels (>2000µm)	**35.68**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.01
1000	6.97
2000	9.03
4000	22.45
8000	4.19
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	665.89
Minimum settling velocity of 50% of particles (mm s^1)	365.63
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	4.31
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	18.136

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP106_U_a
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.10**
Very Fine Silt % (4-8µm)	3.02
Fine Silt % (8-16µm)	4.41
Medium Silt % (16-31µm)	6.73
Course Silt % (31-63µm)	9.23
Total Silt (4-63µm)	**23.39**
Very Fine sand % (63-125µm)	7.81
Fine sand % (125-250µm)	4.20
Medium sand % (250-500µm)	4.75
Coarse sand % (500-1000µm)	9.97
Very Coarse sand % (1000-2000µm)	12.79
Total Sand (63-2000µm)	**39.51**
Total Gravels (>2000µm)	**31.01**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.97
1000	12.79
2000	18.57
4000	12.44
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	688.86
Minimum settling velocity of 50% of particles (mm s^1)	391.30
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	9.48
Minimum settling velocity of 90% of particles (mm s^1)	0.07
Time for 90% of particles to settle over 1 m (hours)	3.746

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell, sand and coral present. Rocks upto approximately 5cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP106-0_L
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.68**
Very Fine Silt % (4-8µm)	1.85
Fine Silt % (8-16µm)	2.43
Medium Silt % (16-31µm)	3.33
Course Silt % (31-63µm)	6.78
Total Silt (4-63µm)	**14.39**
Very Fine sand % (63-125µm)	8.74
Fine sand % (125-250µm)	5.00
Medium sand % (250-500µm)	5.19
Coarse sand % (500-1000µm)	13.57
Very Coarse sand % (1000-2000µm)	10.70
Total Sand (63-2000µm)	**43.20**
Total Gravels (>2000µm)	**38.73**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.57
1000	10.70
2000	11.21
4000	11.14
8000	16.38
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	978.75
Minimum settling velocity of 50% of particles (mm s^1)	789.92
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	24.81
Minimum settling velocity of 90% of particles (mm s^1)	0.51
Time for 90% of particles to settle over 1 m (hours)	0.547

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell, rock and coral present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP106-0_U
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.45**
Very Fine Silt % (4-8µm)	2.18
Fine Silt % (8-16µm)	3.13
Medium Silt % (16-31µm)	5.09
Course Silt % (31-63µm)	7.91
Total Silt (4-63µm)	**18.31**
Very Fine sand % (63-125µm)	7.07
Fine sand % (125-250µm)	3.72
Medium sand % (250-500µm)	4.14
Coarse sand % (500-1000µm)	8.68
Very Coarse sand % (1000-2000µm)	9.95
Total Sand (63-2000µm)	**33.56**
Total Gravels (>2000µm)	**43.68**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.68
1000	9.95
2000	12.76
4000	26.73
8000	4.19
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1364.98
Minimum settling velocity of 50% of particles (mm s^1)	1536.38
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	16.66
Minimum settling velocity of 90% of particles (mm s^1)	0.23
Time for 90% of particles to settle over 1 m (hours)	1.214

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell, coral and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch University

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP110-4_U2
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	2/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.77**
Very Fine Silt % (4-8µm)	1.39
Fine Silt % (8-16µm)	1.74
Medium Silt % (16-31µm)	2.19
Course Silt % (31-63µm)	3.92
Total Silt (4-63µm)	**9.24**
Very Fine sand % (63-125µm)	4.64
Fine sand % (125-250µm)	2.93
Medium sand % (250-500µm)	3.85
Coarse sand % (500-1000µm)	9.42
Very Coarse sand % (1000-2000µm)	12.87
Total Sand (63-2000µm)	**33.72**
Total Gravels (>2000µm)	**54.28**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.42
1000	12.87
2000	18.95
4000	26.16
8000	9.17
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2451.24
Minimum settling velocity of 50% of particles (mm s^1)	4954.71
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	46.07
Minimum settling velocity of 90% of particles (mm s^1)	1.75
Time for 90% of particles to settle over 1 m (hours)	0.159

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some shell, coral and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP112-4_U
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.16**
Very Fine Silt % (4-8µm)	0.90
Fine Silt % (8-16µm)	1.08
Medium Silt % (16-31µm)	1.44
Course Silt % (31-63µm)	2.33
Total Silt (4-63µm)	**5.75**
Very Fine sand % (63-125µm)	3.72
Fine sand % (125-250µm)	4.46
Medium sand % (250-500µm)	4.80
Coarse sand % (500-1000µm)	8.11
Very Coarse sand % (1000-2000µm)	13.67
Total Sand (63-2000µm)	**34.76**
Total Gravels (>2000µm)	**58.33**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.11
1000	13.67
2000	21.80
4000	27.02
8000	9.51
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2764.31
Minimum settling velocity of 50% of particles (mm s^1)	6301.16
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	113.05
Minimum settling velocity of 90% of particles (mm s^1)	10.54
Time for 90% of particles to settle over 1 m (hours)	0.026

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rock with some sand and mud present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP119-7_L
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400
Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.38**
Very Fine Silt % (4-8µm)	4.66
Fine Silt % (8-16µm)	5.68
Medium Silt % (16-31µm)	6.59
Course Silt % (31-63µm)	7.59
Total Silt (4-63µm)	**24.53**
Very Fine sand % (63-125µm)	5.72
Fine sand % (125-250µm)	5.02
Medium sand % (250-500µm)	5.11
Coarse sand % (500-1000µm)	5.13
Very Coarse sand % (1000-2000µm)	5.90
Total Sand (63-2000µm)	**26.88**
Total Gravels (>2000µm)	**39.22**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.13
1000	5.90
2000	11.16
4000	9.47
8000	18.59
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	524.15
Minimum settling velocity of 50% of particles (mm s^1)	226.55
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	4.42
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	17.258
Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, sand and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP119-7_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.24**
Very Fine Silt % (4-8µm)	3.87
Fine Silt % (8-16µm)	4.90
Medium Silt % (16-31µm)	5.81
Course Silt % (31-63µm)	7.52
Total Silt (4-63µm)	**22.09**
Very Fine sand % (63-125µm)	6.72
Fine sand % (125-250µm)	4.75
Medium sand % (250-500µm)	6.59
Coarse sand % (500-1000µm)	10.25
Very Coarse sand % (1000-2000µm)	7.44
Total Sand (63-2000µm)	**35.75**
Total Gravels (>2000µm)	**34.91**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.25
1000	7.44
2000	7.34
4000	12.06
8000	15.51
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	626.96
Minimum settling velocity of 50% of particles (mm s^1)	324.14
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	6.66
Minimum settling velocity of 90% of particles (mm s^1)	0.04
Time for 90% of particles to settle over 1 m (hours)	7.586

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, sand and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP119-8_U
Sampling Date:	11/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.46**
Very Fine Silt % (4-8µm)	1.89
Fine Silt % (8-16µm)	2.47
Medium Silt % (16-31µm)	2.88
Course Silt % (31-63µm)	3.47
Total Silt (4-63µm)	**10.71**
Very Fine sand % (63-125µm)	3.00
Fine sand % (125-250µm)	1.92
Medium sand % (250-500µm)	2.81
Coarse sand % (500-1000µm)	5.84
Very Coarse sand % (1000-2000µm)	6.06
Total Sand (63-2000µm)	**19.64**
Total Gravels (>2000µm)	**66.18**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.84
1000	6.06
2000	6.85
4000	13.79
8000	19.58
16000	25.97

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	6708.68
Minimum settling velocity of 50% of particles (mm s^1)	37112.44
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	26.59
Minimum settling velocity of 90% of particles (mm s^1)	0.58
Time for 90% of particles to settle over 1 m (hours)	0.477

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocks with some shell, sand and mud present. Large rocks upto approximately 6cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP120-5_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	2/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.19**
Very Fine Silt % (4-8µm)	1.26
Fine Silt % (8-16µm)	1.68
Medium Silt % (16-31µm)	1.93
Course Silt % (31-63µm)	2.67
Total Silt (4-63µm)	**7.53**
Very Fine sand % (63-125µm)	2.93
Fine sand % (125-250µm)	2.36
Medium sand % (250-500µm)	3.29
Coarse sand % (500-1000µm)	5.47
Very Coarse sand % (1000-2000µm)	6.49
Total Sand (63-2000µm)	**20.54**
Total Gravels (>2000µm)	**69.74**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.47
1000	6.49
2000	11.96
4000	13.89
8000	43.89
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	6239.74
Minimum settling velocity of 50% of particles (mm s^1)	32105.42
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	67.13
Minimum settling velocity of 90% of particles (mm s^1)	3.72
Time for 90% of particles to settle over 1 m (hours)	0.075

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some shell and sand present. Rocks upto approximately 4.5cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP120-6
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	2/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.85**
Very Fine Silt % (4-8µm)	4.07
Fine Silt % (8-16µm)	4.62
Medium Silt % (16-31µm)	4.30
Course Silt % (31-63µm)	4.65
Total Silt (4-63µm)	**17.63**
Very Fine sand % (63-125µm)	5.15
Fine sand % (125-250µm)	7.70
Medium sand % (250-500µm)	5.94
Coarse sand % (500-1000µm)	5.71
Very Coarse sand % (1000-2000µm)	5.10
Total Sand (63-2000µm)	**29.60**
Total Gravels (>2000µm)	**45.92**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.71
1000	5.10
2000	3.74
4000	9.89
8000	32.28
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1198.84
Minimum settling velocity of 50% of particles (mm s^1)	1185.14
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	6.93
Minimum settling velocity of 90% of particles (mm s^1)	0.04
Time for 90% of particles to settle over 1 m (hours)	7.006

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP120-6_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.50**
Very Fine Silt % (4-8µm)	4.64
Fine Silt % (8-16µm)	5.14
Medium Silt % (16-31µm)	4.45
Course Silt % (31-63µm)	4.50
Total Silt (4-63µm)	**18.74**
Very Fine sand % (63-125µm)	4.45
Fine sand % (125-250µm)	5.83
Medium sand % (250-500µm)	4.51
Coarse sand % (500-1000µm)	4.04
Very Coarse sand % (1000-2000µm)	3.60
Total Sand (63-2000µm)	**22.43**
Total Gravels (>2000µm)	**51.33**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	4.04
1000	3.60
2000	2.70
4000	7.41
8000	41.22
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2987.64
Minimum settling velocity of 50% of particles (mm s^1)	7360.43
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	5.92
Minimum settling velocity of 90% of particles (mm s^1)	0.03
Time for 90% of particles to settle over 1 m (hours)	9.597

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell and sand present. Large rocks upto approximately 6cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA WORLD RECOGNISED ACCREDITATION

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-75_L
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.31**
Very Fine Silt % (4-8µm)	0.16
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.39
Course Silt % (31-63µm)	1.16
Total Silt (4-63µm)	**1.95**
Very Fine sand % (63-125µm)	2.48
Fine sand % (125-250µm)	4.47
Medium sand % (250-500µm)	7.31
Coarse sand % (500-1000µm)	49.11
Very Coarse sand % (1000-2000µm)	25.96
Total Sand (63-2000µm)	**89.34**
Total Gravels (>2000µm)	**8.41**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	49.11
1000	25.96
2000	5.66
4000	2.75
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	840.86
Minimum settling velocity of 50% of particles (mm s^1)	583.04
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	271.85
Minimum settling velocity of 90% of particles (mm s^1)	60.94
Time for 90% of particles to settle over 1 m (hours)	0.005

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and silt present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-75_U
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.42**
Very Fine Silt % (4-8µm)	0.21
Fine Silt % (8-16µm)	0.32
Medium Silt % (16-31µm)	0.52
Course Silt % (31-63µm)	1.60
Total Silt (4-63µm)	**2.65**
Very Fine sand % (63-125µm)	3.11
Fine sand % (125-250µm)	3.52
Medium sand % (250-500µm)	4.46
Coarse sand % (500-1000µm)	38.76
Very Coarse sand % (1000-2000µm)	36.51
Total Sand (63-2000µm)	**86.35**
Total Gravels (>2000µm)	**10.58**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	38.76
1000	36.51
2000	10.34
4000	0.24
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	962.55
Minimum settling velocity of 50% of particles (mm s^1)	764.00
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	263.81
Minimum settling velocity of 90% of particles (mm s^1)	57.39
Time for 90% of particles to settle over 1 m (hours)	0.005

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and mud present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-85_L
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.19**
Very Fine Silt % (4-8µm)	0.11
Fine Silt % (8-16µm)	0.19
Medium Silt % (16-31µm)	0.35
Course Silt % (31-63µm)	0.89
Total Silt (4-63µm)	**1.54**
Very Fine sand % (63-125µm)	1.84
Fine sand % (125-250µm)	2.53
Medium sand % (250-500µm)	2.77
Coarse sand % (500-1000µm)	38.60
Very Coarse sand % (1000-2000µm)	39.27
Total Sand (63-2000µm)	**85.01**
Total Gravels (>2000µm)	**13.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	38.60
1000	39.27
2000	12.06
4000	1.21
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1064.52
Minimum settling velocity of 50% of particles (mm s^1)	934.45
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	514.74
Minimum settling velocity of 90% of particles (mm s^1)	218.48
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and silt present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-85_U
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.22**
Very Fine Silt % (4-8µm)	0.14
Fine Silt % (8-16µm)	0.20
Medium Silt % (16-31µm)	0.29
Course Silt % (31-63µm)	0.58
Total Silt (4-63µm)	**1.21**
Very Fine sand % (63-125µm)	0.88
Fine sand % (125-250µm)	1.39
Medium sand % (250-500µm)	5.17
Coarse sand % (500-1000µm)	42.11
Very Coarse sand % (1000-2000µm)	40.58
Total Sand (63-2000µm)	**90.13**
Total Gravels (>2000µm)	**8.44**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	42.11
1000	40.58
2000	8.44
4000	0.00
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	988.29
Minimum settling velocity of 50% of particles (mm s^1)	805.41
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	513.36
Minimum settling velocity of 90% of particles (mm s^1)	217.32
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-85_U_1
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.23**
Very Fine Silt % (4-8µm)	0.14
Fine Silt % (8-16µm)	0.23
Medium Silt % (16-31µm)	0.41
Course Silt % (31-63µm)	1.02
Total Silt (4-63µm)	**1.80**
Very Fine sand % (63-125µm)	1.79
Fine sand % (125-250µm)	2.53
Medium sand % (250-500µm)	3.63
Coarse sand % (500-1000µm)	42.64
Very Coarse sand % (1000-2000µm)	39.36
Total Sand (63-2000µm)	**89.95**
Total Gravels (>2000µm)	**8.02**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	42.64
1000	39.36
2000	6.05
4000	1.97
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	969.23
Minimum settling velocity of 50% of particles (mm s^1)	774.65
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	500.15
Minimum settling velocity of 90% of particles (mm s^1)	206.28
Time for 90% of particles to settle over 1 m (hours)	0.001

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and silt present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-95_U
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.96**
Very Fine Silt % (4-8µm)	1.37
Fine Silt % (8-16µm)	1.87
Medium Silt % (16-31µm)	2.75
Course Silt % (31-63µm)	6.32
Total Silt (4-63µm)	**12.31**
Very Fine sand % (63-125µm)	8.74
Fine sand % (125-250µm)	9.71
Medium sand % (250-500µm)	16.65
Coarse sand % (500-1000µm)	23.37
Very Coarse sand % (1000-2000µm)	14.72
Total Sand (63-2000µm)	**73.20**
Total Gravels (>2000µm)	**11.53**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	23.37
1000	14.72
2000	8.72
4000	2.81
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	492.38
Minimum settling velocity of 50% of particles (mm s^1)	199.92
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	36.58
Minimum settling velocity of 90% of particles (mm s^1)	1.10
Time for 90% of particles to settle over 1 m (hours)	0.252

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP92-95_U_1
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.17**
Very Fine Silt % (4-8µm)	1.92
Fine Silt % (8-16µm)	2.52
Medium Silt % (16-31µm)	3.56
Course Silt % (31-63µm)	7.42
Total Silt (4-63µm)	**15.42**
Very Fine sand % (63-125µm)	9.18
Fine sand % (125-250µm)	9.25
Medium sand % (250-500µm)	16.05
Coarse sand % (500-1000µm)	19.28
Very Coarse sand % (1000-2000µm)	12.50
Total Sand (63-2000µm)	**66.25**
Total Gravels (>2000µm)	**14.16**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	19.28
1000	12.50
2000	9.85
4000	4.31
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	420.82
Minimum settling velocity of 50% of particles (mm s^1)	146.03
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	21.56
Minimum settling velocity of 90% of particles (mm s^1)	0.38
Time for 90% of particles to settle over 1 m (hours)	0.725

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-7_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.16**
Very Fine Silt % (4-8µm)	0.29
Fine Silt % (8-16µm)	0.44
Medium Silt % (16-31µm)	0.53
Course Silt % (31-63µm)	2.02
Total Silt (4-63µm)	**3.28**
Very Fine sand % (63-125µm)	3.12
Fine sand % (125-250µm)	7.84
Medium sand % (250-500µm)	29.29
Coarse sand % (500-1000µm)	23.02
Very Coarse sand % (1000-2000µm)	12.37
Total Sand (63-2000µm)	**75.63**
Total Gravels (>2000µm)	**20.93**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	23.02
1000	12.37
2000	13.79
4000	7.14
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	637.19
Minimum settling velocity of 50% of particles (mm s^1)	334.80
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	201.32
Minimum settling velocity of 90% of particles (mm s^1)	33.42
Time for 90% of particles to settle over 1 m (hours)	0.008

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral, rock and mud present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-8_L
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.07**
Very Fine Silt % (4-8µm)	0.17
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.30
Course Silt % (31-63µm)	0.76
Total Silt (4-63µm)	**1.47**
Very Fine sand % (63-125µm)	1.23
Fine sand % (125-250µm)	3.57
Medium sand % (250-500µm)	17.72
Coarse sand % (500-1000µm)	34.10
Very Coarse sand % (1000-2000µm)	26.60
Total Sand (63-2000µm)	**83.21**
Total Gravels (>2000µm)	**15.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	34.10
1000	26.60
2000	12.00
4000	3.26
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	880.56
Minimum settling velocity of 50% of particles (mm s^1)	639.38
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	306.66
Minimum settling velocity of 90% of particles (mm s^1)	77.54
Time for 90% of particles to settle over 1 m (hours)	0.004

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-8_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.06**
Very Fine Silt % (4-8µm)	0.17
Fine Silt % (8-16µm)	0.24
Medium Silt % (16-31µm)	0.28
Course Silt % (31-63µm)	0.72
Total Silt (4-63µm)	**1.41**
Very Fine sand % (63-125µm)	1.09
Fine sand % (125-250µm)	3.49
Medium sand % (250-500µm)	16.95
Coarse sand % (500-1000µm)	32.38
Very Coarse sand % (1000-2000µm)	27.79
Total Sand (63-2000µm)	**81.70**
Total Gravels (>2000µm)	**16.83**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	32.38
1000	27.79
2000	14.32
4000	2.51
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	916.94
Minimum settling velocity of 50% of particles (mm s^1)	693.31
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	313.12
Minimum settling velocity of 90% of particles (mm s^1)	80.85
Time for 90% of particles to settle over 1 m (hours)	0.003

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA WORLD RECOGNISED ACCREDITATION

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-23
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.02**
Very Fine Silt % (4-8µm)	0.15
Fine Silt % (8-16µm)	0.20
Medium Silt % (16-31µm)	0.21
Course Silt % (31-63µm)	0.49
Total Silt (4-63µm)	**1.05**
Very Fine sand % (63-125µm)	0.50
Fine sand % (125-250µm)	1.53
Medium sand % (250-500µm)	16.33
Coarse sand % (500-1000µm)	38.58
Very Coarse sand % (1000-2000µm)	26.49
Total Sand (63-2000µm)	**83.43**
Total Gravels (>2000µm)	**15.50**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	38.58
1000	26.49
2000	11.29
4000	4.21
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	896.26
Minimum settling velocity of 50% of particles (mm s^1)	662.39
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	365.82
Minimum settling velocity of 90% of particles (mm s^1)	110.35
Time for 90% of particles to settle over 1 m (hours)	0.003

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP93-23_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	7/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**0.01**
Very Fine Silt % (4-8µm)	0.14
Fine Silt % (8-16µm)	0.20
Medium Silt % (16-31µm)	0.22
Course Silt % (31-63µm)	0.48
Total Silt (4-63µm)	**1.03**
Very Fine sand % (63-125µm)	0.47
Fine sand % (125-250µm)	1.47
Medium sand % (250-500µm)	15.45
Coarse sand % (500-1000µm)	39.29
Very Coarse sand % (1000-2000µm)	31.12
Total Sand (63-2000µm)	**87.80**
Total Gravels (>2000µm)	**11.16**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	39.29
1000	31.12
2000	10.64
4000	0.51
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	901.75
Minimum settling velocity of 50% of particles (mm s^1)	670.53
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	373.33
Minimum settling velocity of 90% of particles (mm s^1)	114.93
Time for 90% of particles to settle over 1 m (hours)	0.002

Settings	
SOP Name	SOP-3REPS-default-0% obscuration.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Sand with some shell, coral and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP102-7_L
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**8.80**
Very Fine Silt % (4-8µm)	3.83
Fine Silt % (8-16µm)	4.29
Medium Silt % (16-31µm)	4.61
Course Silt % (31-63µm)	5.09
Total Silt (4-63µm)	**17.83**
Very Fine sand % (63-125µm)	4.02
Fine sand % (125-250µm)	4.46
Medium sand % (250-500µm)	7.79
Coarse sand % (500-1000µm)	6.85
Very Coarse sand % (1000-2000µm)	9.59
Total Sand (63-2000µm)	**32.71**
Total Gravels (>2000µm)	**40.66**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.85
1000	9.59
2000	19.73
4000	14.50
8000	6.43
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1026.04
Minimum settling velocity of 50% of particles (mm s^1)	868.11
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	4.99
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	13.547

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP102-7_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.06**
Very Fine Silt % (4-8µm)	3.24
Fine Silt % (8-16µm)	3.94
Medium Silt % (16-31µm)	5.42
Course Silt % (31-63µm)	8.38
Total Silt (4-63µm)	**20.98**
Very Fine sand % (63-125µm)	7.72
Fine sand % (125-250µm)	5.55
Medium sand % (250-500µm)	6.66
Coarse sand % (500-1000µm)	6.70
Very Coarse sand % (1000-2000µm)	10.08
Total Sand (63-2000µm)	**36.71**
Total Gravels (>2000µm)	**35.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	6.70
1000	10.08
2000	12.40
4000	9.55
8000	13.32
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	652.36
Minimum settling velocity of 50% of particles (mm s^1)	350.93
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	7.55
Minimum settling velocity of 90% of particles (mm s^1)	0.05
Time for 90% of particles to settle over 1 m (hours)	5.907

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP103-1_L
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.37**
Very Fine Silt % (4-8µm)	4.18
Fine Silt % (8-16µm)	4.82
Medium Silt % (16-31µm)	4.53
Course Silt % (31-63µm)	4.11
Total Silt (4-63µm)	**17.63**
Very Fine sand % (63-125µm)	2.72
Fine sand % (125-250µm)	7.38
Medium sand % (250-500µm)	17.58
Coarse sand % (500-1000µm)	9.51
Very Coarse sand % (1000-2000µm)	6.32
Total Sand (63-2000µm)	**43.51**
Total Gravels (>2000µm)	**29.50**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.51
1000	6.32
2000	9.90
4000	11.58
8000	8.01
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	408.70
Minimum settling velocity of 50% of particles (mm s^1)	137.74
Time for 50% of particles to settle over 1 m (hours)	0.002
D10 (µm)	4.46
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	16.911

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP103-1_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**8.47**
Very Fine Silt % (4-8µm)	3.79
Fine Silt % (8-16µm)	4.44
Medium Silt % (16-31µm)	4.31
Course Silt % (31-63µm)	4.66
Total Silt (4-63µm)	**17.20**
Very Fine sand % (63-125µm)	4.21
Fine sand % (125-250µm)	4.93
Medium sand % (250-500µm)	10.83
Coarse sand % (500-1000µm)	13.79
Very Coarse sand % (1000-2000µm)	9.31
Total Sand (63-2000µm)	**43.07**
Total Gravels (>2000µm)	**31.26**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.79
1000	9.31
2000	11.30
4000	10.86
8000	9.10
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	

Calculations	
D50 (µm)	658.13
Minimum settling velocity of 50% of particles (mm s^1)	357.17
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	5.35
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	11.755

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP103-5_U
Sampling Date:	7/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.95**
Very Fine Silt % (4-8µm)	1.70
Fine Silt % (8-16µm)	2.20
Medium Silt % (16-31µm)	2.60
Course Silt % (31-63µm)	3.81
Total Silt (4-63µm)	**10.32**
Very Fine sand % (63-125µm)	4.09
Fine sand % (125-250µm)	3.19
Medium sand % (250-500µm)	5.25
Coarse sand % (500-1000µm)	12.26
Very Coarse sand % (1000-2000µm)	11.95
Total Sand (63-2000µm)	**36.75**
Total Gravels (>2000µm)	**49.98**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	12.26
1000	11.95
2000	13.97
4000	25.12
8000	10.89
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1998.46
Minimum settling velocity of 50% of particles (mm s^1)	3293.35
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	34.97
Minimum settling velocity of 90% of particles (mm s^1)	1.01
Time for 90% of particles to settle over 1 m (hours)	0.275

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some shell, coral and sand present. Rocks upto approximately 3.5cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

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Environmental Science
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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP104-9_U
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.55**
Very Fine Silt % (4-8µm)	4.13
Fine Silt % (8-16µm)	4.33
Medium Silt % (16-31µm)	4.67
Course Silt % (31-63µm)	5.99
Total Silt (4-63µm)	**19.13**
Very Fine sand % (63-125µm)	5.90
Fine sand % (125-250µm)	4.65
Medium sand % (250-500µm)	7.13
Coarse sand % (500-1000µm)	11.01
Very Coarse sand % (1000-2000µm)	6.97
Total Sand (63-2000µm)	**35.65**
Total Gravels (>2000µm)	**35.68**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	11.01
1000	6.97
2000	9.03
4000	22.45
8000	4.19
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	665.89
Minimum settling velocity of 50% of particles (mm s^1)	365.63
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	4.31
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	18.136

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, rock and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP106_U_a
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.10**
Very Fine Silt % (4-8µm)	3.02
Fine Silt % (8-16µm)	4.41
Medium Silt % (16-31µm)	6.73
Course Silt % (31-63µm)	9.23
Total Silt (4-63µm)	**23.39**
Very Fine sand % (63-125µm)	7.81
Fine sand % (125-250µm)	4.20
Medium sand % (250-500µm)	4.75
Coarse sand % (500-1000µm)	9.97
Very Coarse sand % (1000-2000µm)	12.79
Total Sand (63-2000µm)	**39.51**
Total Gravels (>2000µm)	**31.01**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.97
1000	12.79
2000	18.57
4000	12.44
8000	0.00
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	688.86
Minimum settling velocity of 50% of particles (mm s^1)	391.30
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	9.48
Minimum settling velocity of 90% of particles (mm s^1)	0.07
Time for 90% of particles to settle over 1 m (hours)	3.746

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell, sand and coral present. Rocks upto approximately 5cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA WORLD RECOGNISED ACCREDITATION

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Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP106-0_L
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.68**
Very Fine Silt % (4-8µm)	1.85
Fine Silt % (8-16µm)	2.43
Medium Silt % (16-31µm)	3.33
Course Silt % (31-63µm)	6.78
Total Silt (4-63µm)	**14.39**
Very Fine sand % (63-125µm)	8.74
Fine sand % (125-250µm)	5.00
Medium sand % (250-500µm)	5.19
Coarse sand % (500-1000µm)	13.57
Very Coarse sand % (1000-2000µm)	10.70
Total Sand (63-2000µm)	**43.20**
Total Gravels (>2000µm)	**38.73**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	13.57
1000	10.70
2000	11.21
4000	11.14
8000	16.38
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	978.75
Minimum settling velocity of 50% of particles (mm s^1)	789.92
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	24.81
Minimum settling velocity of 90% of particles (mm s^1)	0.51
Time for 90% of particles to settle over 1 m (hours)	0.547

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy sand with some shell, rock and coral present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP106-0_U
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	4/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**4.45**
Very Fine Silt % (4-8µm)	2.18
Fine Silt % (8-16µm)	3.13
Medium Silt % (16-31µm)	5.09
Course Silt % (31-63µm)	7.91
Total Silt (4-63µm)	**18.31**
Very Fine sand % (63-125µm)	7.07
Fine sand % (125-250µm)	3.72
Medium sand % (250-500µm)	4.14
Coarse sand % (500-1000µm)	8.68
Very Coarse sand % (1000-2000µm)	9.95
Total Sand (63-2000µm)	**33.56**
Total Gravels (>2000µm)	**43.68**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.68
1000	9.95
2000	12.76
4000	26.73
8000	4.19
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1364.98
Minimum settling velocity of 50% of particles (mm s^1)	1536.38
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	16.66
Minimum settling velocity of 90% of particles (mm s^1)	0.23
Time for 90% of particles to settle over 1 m (hours)	1.214

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell, coral and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP110-4_U2
Sampling Date:	10/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	2/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.77**
Very Fine Silt % (4-8µm)	1.39
Fine Silt % (8-16µm)	1.74
Medium Silt % (16-31µm)	2.19
Course Silt % (31-63µm)	3.92
Total Silt (4-63µm)	**9.24**
Very Fine sand % (63-125µm)	4.64
Fine sand % (125-250µm)	2.93
Medium sand % (250-500µm)	3.85
Coarse sand % (500-1000µm)	9.42
Very Coarse sand % (1000-2000µm)	12.87
Total Sand (63-2000µm)	**33.72**
Total Gravels (>2000µm)	**54.28**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	9.42
1000	12.87
2000	18.95
4000	26.16
8000	9.17
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2451.24
Minimum settling velocity of 50% of particles (mm s^1)	4954.71
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	46.07
Minimum settling velocity of 90% of particles (mm s^1)	1.75
Time for 90% of particles to settle over 1 m (hours)	0.159

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment
Muddy rock with some shell, coral and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP112-4_U
Sampling Date:	6/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	31/01/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**1.16**
Very Fine Silt % (4-8µm)	0.90
Fine Silt % (8-16µm)	1.08
Medium Silt % (16-31µm)	1.44
Course Silt % (31-63µm)	2.33
Total Silt (4-63µm)	**5.75**
Very Fine sand % (63-125µm)	3.72
Fine sand % (125-250µm)	4.46
Medium sand % (250-500µm)	4.80
Coarse sand % (500-1000µm)	8.11
Very Coarse sand % (1000-2000µm)	13.67
Total Sand (63-2000µm)	**34.76**
Total Gravels (>2000µm)	**58.33**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	8.11
1000	13.67
2000	21.80
4000	27.02
8000	9.51
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2764.31
Minimum settling velocity of 50% of particles (mm s^1)	6301.16
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	113.05
Minimum settling velocity of 90% of particles (mm s^1)	10.54
Time for 90% of particles to settle over 1 m (hours)	0.026

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rock with some sand and mud present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP119-7_L
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**9.38**
Very Fine Silt % (4-8µm)	4.66
Fine Silt % (8-16µm)	5.68
Medium Silt % (16-31µm)	6.59
Course Silt % (31-63µm)	7.59
Total Silt (4-63µm)	**24.53**
Very Fine sand % (63-125µm)	5.72
Fine sand % (125-250µm)	5.02
Medium sand % (250-500µm)	5.11
Coarse sand % (500-1000µm)	5.13
Very Coarse sand % (1000-2000µm)	5.90
Total Sand (63-2000µm)	**26.88**
Total Gravels (>2000µm)	**39.22**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.13
1000	5.90
2000	11.16
4000	9.47
8000	18.59
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	524.15
Minimum settling velocity of 50% of particles (mm s^1)	226.55
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	4.42
Minimum settling velocity of 90% of particles (mm s^1)	0.02
Time for 90% of particles to settle over 1 m (hours)	17.258

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, sand and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP119-7_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.24**
Very Fine Silt % (4-8µm)	3.87
Fine Silt % (8-16µm)	4.90
Medium Silt % (16-31µm)	5.81
Course Silt % (31-63µm)	7.52
Total Silt (4-63µm)	**22.09**
Very Fine sand % (63-125µm)	6.72
Fine sand % (125-250µm)	4.75
Medium sand % (250-500µm)	6.59
Coarse sand % (500-1000µm)	10.25
Very Coarse sand % (1000-2000µm)	7.44
Total Sand (63-2000µm)	**35.75**
Total Gravels (>2000µm)	**34.91**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	10.25
1000	7.44
2000	7.34
4000	12.06
8000	15.51
16000	0.00

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	626.96
Minimum settling velocity of 50% of particles (mm s^1)	324.14
Time for 50% of particles to settle over 1 m (hours)	0.001
D10 (µm)	6.66
Minimum settling velocity of 90% of particles (mm s^1)	0.04
Time for 90% of particles to settle over 1 m (hours)	7.586

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Mud with some shell, sand and rock present.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP119-8_U
Sampling Date:	11/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	1/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**3.46**
Very Fine Silt % (4-8µm)	1.89
Fine Silt % (8-16µm)	2.47
Medium Silt % (16-31µm)	2.88
Course Silt % (31-63µm)	3.47
Total Silt (4-63µm)	**10.71**
Very Fine sand % (63-125µm)	3.00
Fine sand % (125-250µm)	1.92
Medium sand % (250-500µm)	2.81
Coarse sand % (500-1000µm)	5.84
Very Coarse sand % (1000-2000µm)	6.06
Total Sand (63-2000µm)	**19.64**
Total Gravels (>2000µm)	**66.18**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.84
1000	6.06
2000	6.85
4000	13.79
8000	19.58
16000	25.97

Settling Velocity calculations using Stokes Law	
Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	6708.68
Minimum settling velocity of 50% of particles (mm s^1)	37112.44
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	26.59
Minimum settling velocity of 90% of particles (mm s^1)	0.58
Time for 90% of particles to settle over 1 m (hours)	0.477

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocks with some shell, sand and mud present. Large rocks upto approximately 6cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP120-5_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	2/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**2.19**
Very Fine Silt % (4-8µm)	1.26
Fine Silt % (8-16µm)	1.68
Medium Silt % (16-31µm)	1.93
Course Silt % (31-63µm)	2.67
Total Silt (4-63µm)	**7.53**
Very Fine sand % (63-125µm)	2.93
Fine sand % (125-250µm)	2.36
Medium sand % (250-500µm)	3.29
Coarse sand % (500-1000µm)	5.47
Very Coarse sand % (1000-2000µm)	6.49
Total Sand (63-2000µm)	**20.54**
Total Gravels (>2000µm)	**69.74**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.47
1000	6.49
2000	11.96
4000	13.89
8000	43.89
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	6239.74
Minimum settling velocity of 50% of particles (mm s^1)	32105.42
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	67.13
Minimum settling velocity of 90% of particles (mm s^1)	3.72
Time for 90% of particles to settle over 1 m (hours)	0.075

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Muddy rock with some shell and sand present. Rocks upto approximately 4.5cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

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Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

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PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP120-6
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	2/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**6.85**
Very Fine Silt % (4-8µm)	4.07
Fine Silt % (8-16µm)	4.62
Medium Silt % (16-31µm)	4.30
Course Silt % (31-63µm)	4.65
Total Silt (4-63µm)	**17.63**
Very Fine sand % (63-125µm)	5.15
Fine sand % (125-250µm)	7.70
Medium sand % (250-500µm)	5.94
Coarse sand % (500-1000µm)	5.71
Very Coarse sand % (1000-2000µm)	5.10
Total Sand (63-2000µm)	**29.60**
Total Gravels (>2000µm)	**45.92**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	5.71
1000	5.10
2000	3.74
4000	9.89
8000	32.28
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	1198.84
Minimum settling velocity of 50% of particles (mm s^1)	1185.14
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	6.93
Minimum settling velocity of 90% of particles (mm s^1)	0.04
Time for 90% of particles to settle over 1 m (hours)	7.006

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

Sample visual assessment

Rocky mud with some shell and sand present.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

PARTICLE SIZE ANALYSIS REPORT

Contact: Katharine Thorne
Customer: RPS
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 17/02/2022
Date Received: 13/01/2022
Our Reference: RPS22-1

Sample Name:	KP120-6_U
Sampling Date:	8/01/2022
Sample Type:	Sediment
MAFRL Job Code:	RPS22-1
Client Reference:	NA
Analysis Date:	3/02/2022
Method Number:	9400

Wentworth Size Classifications	
Total Clay % (0-4µm)	**7.50**
Very Fine Silt % (4-8µm)	4.64
Fine Silt % (8-16µm)	5.14
Medium Silt % (16-31µm)	4.45
Course Silt % (31-63µm)	4.50
Total Silt (4-63µm)	**18.74**
Very Fine sand % (63-125µm)	4.45
Fine sand % (125-250µm)	5.83
Medium sand % (250-500µm)	4.51
Coarse sand % (500-1000µm)	4.04
Very Coarse sand % (1000-2000µm)	3.60
Total Sand (63-2000µm)	**22.43**
Total Gravels (>2000µm)	**51.33**

Extended range by sieving

Extended size, µm	Extended percent retained at size
500	4.04
1000	3.60
2000	2.70
4000	7.41
8000	41.22
16000	0.00

Settling Velocity calculations using Stokes Law

Parameters	
Particle density (ρp)(g/cm^3)	2.65
Liquid density (ρf) (g/cm^3)	1.025
Acceleration due to Gravity (g) (ms^{-2})	9.81
Liquid viscosity (η) (cp)	1.074
*Liquid parameters based on seawater of 35ppt @ 20°C	
Calculations	
D50 (µm)	2987.64
Minimum settling velocity of 50% of particles (mm s^1)	7360.43
Time for 50% of particles to settle over 1 m (hours)	0.000
D10 (µm)	5.92
Minimum settling velocity of 90% of particles (mm s^1)	0.03
Time for 90% of particles to settle over 1 m (hours)	9.597

Settings	
SOP Name	SOP-LV-3REPS-default.msop
Analysis Model	General Purpose
Result Units	Volume
Instrument	Mastersizer3000
RI/ABS:	2.74 / 1
Dispersant	Water
Additives	10mL Sodium Hexametaphosphate
Sonication (s)	300

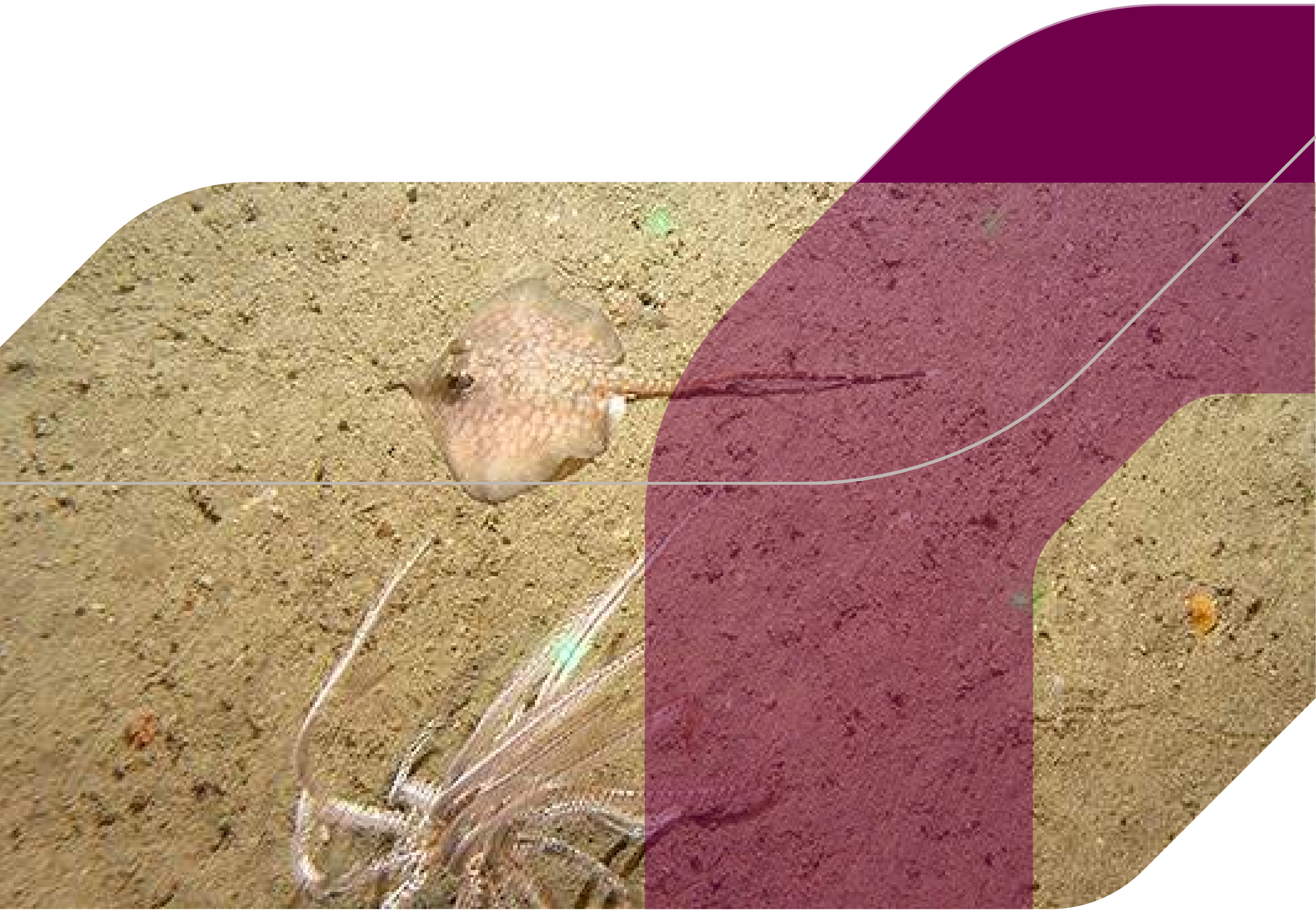
Sample visual assessment

Rocky mud with some shell and sand present. Large rocks upto approximately 6cm in size not included in the sub sample.

Signatory: Jamie Woodward
Date: 17/02/2022

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Appendix E
Laboratory sediment infauna data



Voucher#	Phylum	Class/Order	Family	Morpho-sp	OP01	OP02	OP03	OP04	OP05	OP06	OP07	OP09	OP10	OP11	OP12	OP13	OP14	OP15	OP16	OP17	OP18	OP19	OP20	OP21	OP22	OP23	OP24	OP25	OP26	OP27	OP28	OP29	OP30	SG01	SG02	SG03	SG04	SG05	SG06	SG07	SG08	SG09	SG10	SG11	SG12	SG13
112	Annelida	Polychaeta	Ampharetidae	*Isolda pulchella*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	Annelida	Polychaeta	Amphinomidae	Amphinomidae 1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	Annelida	Polychaeta	Amphinomidae	Amphinomidae 2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	Annelida	Polychaeta	Arenicolidae	*Arenicola sp.1*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96	Annelida	Polychaeta	Capitellidae	*Capitella sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	4	2	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Annelida	Polychaeta	Capitellidae	*Notomastus sp.1*	0	0	0	2	0	0	1	2	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0
65	Annelida	Polychaeta	Chaetopteridae	*Mesochaetopterus sp.1*	0	7	2	1	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101	Annelida	Polychaeta	Chrysopetalidae	Chrysopetalidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Annelida	Polychaeta	Cirratulidae	*Caulleriella sp.1*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2	Annelida	Polychaeta	Eunicidae	*Eunice sp.1*	0	0	0	0	0	1	0	0	0	1	2	0	3	1	1	0	0	2	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
14	Annelida	Polychaeta	Eunicidae	*Eunice sp.2*	1	3	0	0	0	1	0	2	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	0	0	1	0	1	0	1
53	Annelida	Polychaeta	Eunicidae	*Eunice sp.3*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
107	Annelida	Polychaeta	Eunicidae	*Eunice sp.4*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	Annelida	Polychaeta	Eunicidae	*Nematonereis unicornis*	7	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
42	Annelida	Polychaeta	Flabelligeridae	*Pherusa sp.1*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
44	Annelida	Polychaeta	Glyceridae	*Glycera sp.1*	0	0	0	0	0	0	0	1	0	2	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
11	Annelida	Polychaeta	Goniadidae	*Goniada sp.1*	0	0	0	1	0	0	1	2	1	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
9	Annelida	Polychaeta	Lumbrineridae	*Lumbrineris sp.1*	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	0	1	1	0	1	0	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0
10	Annelida	Polychaeta	Lumbrineridae	*Lumbrineris sp.2*	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	0	1	0	0
3	Annelida	Polychaeta	Magelonidae	*Magelona sp.1*	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
17	Annelida	Polychaeta	Maldanidae	*Axiothella sp.1*	0	0	0	0	1	0	2	2	1	1	0	0	1	1	1	2	2	2	0	1	1	1	1	0	0	0	2	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0
13	Annelida	Polychaeta	Nephtyidae	*Nephtys sp.1*	0	0	0	1	0	1	1	1	2	1	0	2	1	0	3	0	1	1	0	2	0	4	1	0	0	0	1	1	0	0	0	3	0	0	1	2	0	0	0	2	0	0
41	Annelida	Polychaeta	Nereididae	Nereididae 1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
28	Annelida	Polychaeta	Oenonidae	*Arabella sp.1*	1	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0
55	Annelida	Polychaeta	Oenonidae	*Oenone sp.1*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	Annelida	Polychaeta	Onuphidae	*Diopatra sp.1*	8	1	2	1	1	2	0	2	2	0	0	0	0	3	1	0	1	2	0	0	0	0	0	0	0	0	1	1	3	0	0	0	0	2	0	0	0	0	0	0	0	0
73	Annelida	Polychaeta	Opheliidae	*Armandia sp.1*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Annelida	Polychaeta	Opheliidae	*Ophelia sp.1*	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
63	Annelida	Polychaeta	Orbiniidae	Orbiniidae 1	0	3	0	0	0	0	0	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
113	Annelida	Polychaeta	Orbiniidae	*Scoloplos sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	Annelida	Polychaeta	Paralacydoniidae	*Paralacydonia sp.1*	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	Annelida	Polychaeta	Phyllodocidae	Phyllodocidae 1	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	Annelida	Polychaeta	Pilargidae	*Hermundura gladstonensis*	4	6	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	Annelida	Polychaeta	Pilargidae	*Litocorsa sp.1*	0	3	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	Annelida	Polychaeta	Poecilochaetidae	*Poecilochaetus sp.1*	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	Annelida	Polychaeta	Sabellariidae	*Sabellaria sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	Annelida	Polychaeta	Sigalionidae	Sigalionidae 1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
82	Annelida	Polychaeta	Sigalionidae	Sigalionidae 2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	Annelida	Polychaeta	Sigalionidae	Sigalionidae 3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Annelida	Polychaeta	Spionidae	Spionidae sp.1	0	2	0	2	0	0	1	0	0	0	0	1	0	1	1	3	0	1	0	1	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
58	Annelida	Polychaeta	Spionidae	Spionidae sp.2	1	4	3	0	0	0	2	0	1	0	0	0	0	4	1	0	2	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
111	Annelida	Polychaeta	Spionidae	Spionidae sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Annelida	Polychaeta	Sternapsidae	Sternapsis scutata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
32	Annelida	Polychaeta	Syllidae	Syllidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
46	Annelida	Polychaeta	Syllidae	Syllidae 2	0	0	0	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
29	Annelida	Polychaeta	Trichobranchidae	Trichobranchidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
104	Brachiopoda	Lingulida	Lingulidae	*Lingula sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99	Chordata	Actinopterygii	Gobiidae	Gobiidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	Chordata	Cephalochordata	Branchiostomidae	*Branchiostoma sp.1*	0	0	0	0	1	0	1	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	Cnidaria	Anthozoa	Pennatulacea	Pennatulacea 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
98	Cnidaria	Zoanthazoa	Zoanthazoa	Zoanthazoa 1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Crustacea	Amphipoda	Ampeliscidae	Ampeliscidae 1	2	2	1	2	4	0	11	4	0	1	2	5	2	1	0	4	0	1	0	0	1	0	3	0	1	0	0	0	0	0	0	0	0	0	1	2	1	0	5	1	0	1
47	Crustacea	Amphipoda	Aoridae	Aoridae 1	1	0	0	0	0	2	2	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
68	Crustacea	Amphipoda	Caprellidae	Caprellidae 1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	Crustacea	Amphipoda	Corophiidae	Corophiidae 1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	Crustacea	Amphipoda	Cyproideidae	Cyproideidae 1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Crustacea	Amphipoda	Ischyroceridae	Ischyroceridae 1	1	0	0	2	1	3	2	3	1	0	0	3	0	4	3	3	2	0	0	1	2	0	3	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0	0	0	0	2
75	Crustacea	Amphipoda	Leucothoidae	Leucothoidae 1	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	Crustacea	Amphipoda	Liljeborgiidae	Liljeborgiidae 1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
109	Crustacea	Amphipoda	Lysianassidae	Lysianassidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	Crustacea	Amphipoda	Metilidae	Metilidae 1	3	0	0	2	0	1	2	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	7	0	1	0	0
102	Crustacea	Amphipoda	Oxycephalidae	Oxycephalidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	Crustacea	Amphipoda	Phoxocephalidae	Phoxocephalidae 1	1	1	0	2	1	1	2	1	1	0	1	0	1	0	2	4	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
97	Crustacea	Amphipoda	Podoceridae	Podoceridae 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Crustacea	Anomura	Diogenidae	Diogenidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
86	Crustacea	Brachyura	Dromidae	Dromidae 1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	Crustacea	Brachyura	Goneplacidae	Goneplacidae 1	0	0	1	0	0	1	0	0	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
94	Crustacea	Brachyura	Goneplacidae	Goneplacidae 2	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	Crustacea	Brachyura	Leucosiidae	*Myra sp.1*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
108	Crustacea	Brachyura	Porcallinidae	Porcallinidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	Crustacea	Caridea	Alpheidae	*Alpheus sp.1*	0	0	0	1	0	0	0	2	0	1	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
67	Crustacea	Caridea	Ogyrididae	*Ogyrides deli*	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	Crustacea	Caridea	Pasiphaeidae	Pasiphaeidae 1	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
76	Crustacea	Cumacea	Bodotriidae	Bodotriidae 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	Crustacea	Cumacea	Ceratocumatidae	Ceratocumatidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4	Crustacea	Isopoda	Anthuridea	Anthuridea 1	1	1	0	0	2	1	0	2	0	3	2	0	0	2	1	2	0	0	0	0	3	0	4	1	1	0	2	2	0	3	0	0	2	2	2	2	0	5	0	1	0	0
37	Crustacea	Isopoda	Anthuridea	Anthuridea 2	0	1	1	0	1	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4
39	Crustacea	Isopoda	Corallanidae	Corallanidae 1	0	1	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
90	Crustacea	Isopoda	Gnathidae	Gnathidae 1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	Crustacea	Isopoda	Serolidae	*Serolina sp.1*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Crustacea	Isopoda	Sphearomatidae	Sphaeromatidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
48	Crustacea	Isopoda	Sphearomatidae	Chitonopsis sp.1	4	0	0	1	3	0	0	0	0	1	0	1	3	13	1	5	1	3	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
72	Crustacea	Isopoda	Sphearomatidae	Sphearomatidae 2	0	0	0	0	1	1	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	Crustacea	Isopoda	Sphearomatidae	Sphearomatidae 3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	Crustacea	Isopoda	Velifera	Velifera 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Crustacea	Ostracoda	Ostracoda	Ostracoda 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
20	Crustacea	Ostracoda	Ostracoda	Ostracoda 2	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
85	Crustacea	Ostracoda	Ostracoda	Ostracoda 3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	Crustacea	Ostracoda	Ostracoda	Ostracoda 4	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Crustacea	Pycnogonida	Pycnogonida	Pycnogonida 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
56	Crustacea	Pycnogonida	Pycnogonida	Pycnogonida 2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

38	Crustacea	Stomatopoda	Squillidae	*Squillidae sp.1*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
43	Crustacea	Tanaidacea	Apseudidae	Apseudidae 1	0	0	0	0	1	1	1	1	2	0	1	0	2	2	0	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
5	Crustacea	Tanaidacea	Pseudozeuxoidae	Pseudozeuxoidae 1	0	0	3	2	2	5	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	2	0	0	3	3	2	1	5	2	4	1	11
19	Crustacea	Tanaidacea	Tanaidae	Tanaidae 1	1	1	0	1	0	1	0	0	0	0	0	0	2	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
40	Crustacea	Thalassinidae	Callianassidae	Callianassidae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
60	Echinodermata	Echinoidae	Echinometridae	Echinometridae 1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Echinodermata	Echinoidae	Fibulariidae	*Fibularia sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
16	Echinodermata	Holothuroidea	Holothuroidea	Holothuroidea 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
93	Echinodermata	Holothuroidea	Holothuroidea	Holothuroidea 2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	Echinodermata	Ophiuroidea	Ophiuridae	Ophiuridae 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Echinodermata	Ophiuroidea	Ophiuroidea	Ophiuroidea 1	0	0	0	0	0	0	2	1	0	0	1	3	1	0	1	1	0	0	0	1	0	1	3	0	0	2	0	0	0	0	0	0	0	1	3	1	0	1	0	2	0	5
106	Echiura	Echiura	Echiura	Echiura 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	Mollusca	Bivalvia	Cardiidae	*Vasticardium sp.1*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
105	Mollusca	Bivalvia	Corbulidae	*Corbula sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	Mollusca	Bivalvia	Mytillidae	*Musculus sp.1*	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
103	Mollusca	Bivalvia	Psammobiidae	*Gari sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	Mollusca	Bivalvia	Veneridae	*Cire sp.1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	Mollusca	Gastropoda	Ranellidae	*Biplex sp.1*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Nematode	Nematode	Nematode	Nematode 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
87	Porifera	Porifera	Porifera	Porifera 1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Sipuncula	Sipuncula	Sipuncula	Sipuncula 1	0	0	0	0	1	1	2	6	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0
34	Sipuncula	Sipuncula	Sipuncula	Sipuncula 2	0	4	2	0	0	0	0	0	0	0	0	0	2	3	1	1	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0

Appendix F
Laboratory sediment and water naturally occurring radioactive materials data

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Natalie Robson
Client	RPS AUSTRALIA WEST PTY LTD
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Project	**NORM analysis of waters & Sediment sampl**
Order Number	(Not specified)
Samples	59

LABORATORY DETAILS

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SGS Reference	**ME323489 R0**
Date Received	3/11/2021
Date Reported	14/2/2022

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(22793).

SIGNATORIES

Adam ATKINSON
Australian Chemistry Manager

Radionuclides by Gamma Ray Spectrometry in liquids [AS301/AS406] Tested: 1/12/2021

PARAMETER	UOM	LOR	OP1B WATER - 16/10/2021 ME323489.001	OP2B WATER - 16/10/2021 ME323489.002	OP3B WATER - 16/10/2021 ME323489.003	OP4B WATER - 16/10/2021 ME323489.004	OP5B WATER - 16/10/2021 ME323489.005
Radium-226	Bq/L	-	<0.045	<0.051	<0.063	0.023 ±0.011	<0.027
Radium-228	Bq/L	-	<0.130	<0.150	<0.130	<0.087	<0.100
Thorium-228	Bq/L	-	<0.021	<0.021	<0.048	<0.026	<0.024

PARAMETER	UOM	LOR	OP6B WATER - 16/10/2021 ME323489.006	OP7B WATER - 17/10/2021 ME323489.007	OP8B WATER - 17/10/2021 ME323489.008	OP9B WATER - 17/10/2021 ME323489.009	OP10B WATER - 17/10/2021 ME323489.010
Radium-226	Bq/L	-	0.018 ±0.011	<0.064	<0.045	<0.053	<0.057
Radium-228	Bq/L	-	<0.110	<0.084	<0.140	<0.150	<0.160
Thorium-228	Bq/L	-	<0.021	<0.031	<0.025	<0.024	<0.035

PARAMETER	UOM	LOR	SG7B WATER - 17/10/2021 ME323489.011	SG11B WATER - 17/10/2021 ME323489.012	SG1B WATER - 18/10/2021 ME323489.013	SG12B WATER - 18/10/2021 ME323489.014	SG13B WATER - 18/10/2021 ME323489.015
Radium-226	Bq/L	-	<0.044	<0.050	<0.039	<0.037	<0.046
Radium-228	Bq/L	-	<0.130	<0.150	<0.110	<0.086	<0.094
Thorium-228	Bq/L	-	<0.029	<0.025	<0.033	<0.027	<0.034

PARAMETER	UOM	LOR	SG8B WATER - 18/10/2021 ME323489.016	SG4B WATER - 18/10/2021 ME323489.017
Radium-226	Bq/L	-	<0.043	<0.044
Radium-228	Bq/L	-	<0.086	<0.140
Thorium-228	Bq/L	-	<0.032	<0.023

Radionuclides by Gamma Ray Spectrometry in solids [AS303/AS406] Tested: 4/1/2022

PARAMETER	UOM	LOR	OP1 SOIL - 15/10/2021 ME323489.018	OP2 SOIL - 15/10/2021 ME323489.019	OP3 SOIL - 15/10/2021 ME323489.020	OP4 SOIL - 15/10/2021 ME323489.021	OP5 SOIL - 15/10/2021 ME323489.022
Radium-226	Bq/kg	-	8.1 ±1.0	3.6 ±0.4	8.3 ±0.9	9.8 ±1.0	9.5 ±1.0
Radium-228	Bq/kg	-	8.1 ±1.5	4.2 ±0.6	10 ±1	8.2 ±1.3	9.2 ±1.2
Thorium-228	Bq/kg	-	8.8 ±1.2	4.3 ±0.5	12 ±1	11 ±1	12 ±1

PARAMETER	UOM	LOR	OP6 SOIL - 15/10/2021 ME323489.023	OP7 SOIL - 15/10/2021 ME323489.024	OP9 SOIL - 15/10/2021 ME323489.025	OP10 SOIL - 15/10/2021 ME323489.026	OP11 SOIL - 15/10/2021 ME323489.027
Radium-226	Bq/kg	-	9.7 ±1.0	11 ±1	9.7 ±1.0	10 ±1	11 ±1
Radium-228	Bq/kg	-	11 ±1	13 ±1	10 ±1	10 ±1	11 ±1
Thorium-228	Bq/kg	-	14 ±1	13 ±1	13 ±1	12 ±1	13 ±1

PARAMETER	UOM	LOR	OP12 SOIL - 15/10/2021 ME323489.028	OP13 SOIL - 15/10/2021 ME323489.029	OP14 SOIL - 15/10/2021 ME323489.030	OP15 SOIL - 15/10/2021 ME323489.031	OP16 SOIL - 16/10/2021 ME323489.032
Radium-226	Bq/kg	-	11 ±1	11 ±1	11 ±1	9.6 ±1.0	10 ±1
Radium-228	Bq/kg	-	12 ±1	11 ±1	13 ±1	10 ±1	11 ±1
Thorium-228	Bq/kg	-	17 ±2	13 ±1	15 ±1	11 ±1	13 ±1

PARAMETER	UOM	LOR	OP17 SOIL - 16/10/2021 ME323489.033	OP18 SOIL - 16/10/2021 ME323489.034	OP19 SOIL - 16/10/2021 ME323489.035	OP20 SOIL - 16/10/2021 ME323489.036	OP21 SOIL - 16/10/2021 ME323489.037
Radium-226	Bq/kg	-	9.6 ±1.0	9.2 ±1.1	9.3 ±1.3	10 ±1	8.8 ±1.2
Radium-228	Bq/kg	-	11 ±1	12 ±2	11 ±2	12 ±2	12 ±2
Thorium-228	Bq/kg	-	13 ±1	14 ±1	15 ±2	15 ±2	16 ±2

PARAMETER	UOM	LOR	OP22 SOIL - 16/10/2021 ME323489.038	OP23 SOIL - 16/10/2021 ME323489.039	OP24 SOIL - 17/10/2021 ME323489.040	OP25 SOIL - 17/10/2021 ME323489.041	OP26 SOIL - 17/10/2021 ME323489.042
Radium-226	Bq/kg	-	9.4 ±1.0	10 ±1	8.1 ±0.9	11 ±1	12 ±1
Radium-228	Bq/kg	-	12 ±2	13 ±2	13 ±2	18 ±2	13 ±3
Thorium-228	Bq/kg	-	14 ±1	17 ±2	15 ±2	20 ±2	18 ±2

PARAMETER	UOM	LOR	OP27 SOIL - 17/10/2021 ME323489.043	OP28 SOIL - 17/10/2021 ME323489.044	OP29 SOIL - 17/10/2021 ME323489.045	OP30 SOIL - 17/10/2021 ME323489.046	SG1 SOIL - 18/10/2021 ME323489.047
Radium-226	Bq/kg	-	14 ±2	15 ±1	14 ±2	17 ±2	0.83 ±0.09
Radium-228	Bq/kg	-	15 ±2	19 ±2	17 ±2	26 ±3	1.1 ±0.2
Thorium-228	Bq/kg	-	20 ±2	21 ±2	23 ±2	24 ±3	1.4 ±0.2

PARAMETER	UOM	LOR	SG2 SOIL - 17/10/2021 ME323489.048	SG3 SOIL - 17/10/2021 ME323489.049	SG4 SOIL - 17/10/2021 ME323489.050	SG5 SOIL - 17/10/2021 ME323489.051	SG6 SOIL - 17/10/2021 ME323489.052
Radium-226	Bq/kg	-	9.7 ±1.0	10 ±1	13 ±1	12 ±1	12 ±1
Radium-228	Bq/kg	-	12 ±2	12 ±2	16 ±2	14 ±2	18 ±3
Thorium-228	Bq/kg	-	16 ±2	16 ±2	21 ±2	20 ±2	18 ±2

Radionuclides by Gamma Ray Spectrometry in solids [AS303/AS406] Tested: 4/1/2022 (continued)

PARAMETER	UOM	LOR	SG7 SOIL - 17/10/2021 ME323489.053	SG8 SOIL - 18/10/2021 ME323489.054	SG9 SOIL - 18/10/2021 ME323489.055	SG10 SOIL - 18/10/2021 ME323489.056	SG11 SOIL - 18/10/2021 ME323489.057
Radium-226	Bq/kg	-	14 ±2	9.5 ±1.2	10 ±1	13 ±1	15 ±1
Radium-228	Bq/kg	-	19 ±3	10 ±2	13 ±2	17 ±2	18 ±2
Thorium-228	Bq/kg	-	20 ±3	15 ±2	16 ±2	18 ±2	19 ±2

PARAMETER	UOM	LOR	SG12 SOIL - 18/10/2021 ME323489.058	SG13 SOIL - 18/10/2021 ME323489.059
Radium-226	Bq/kg	-	10 ±1	9.0 ±1.2
Radium-228	Bq/kg	-	12 ±2	11 ±2
Thorium-228	Bq/kg	-	15 ±2	13 ±2

METHOD	METHODOLOGY SUMMARY
ARS-SOP-AS301/AS406	Analysis of radionuclides in liquids by high resolution gamma ray spectrometry after radiochemical preparation . Radiochemical preparation involves total sample evaporation, sample co-precipitation using stable elemental carriers, or a combination thereof. In some cases, preparation may involve merely transferring liquid to a standard geometry container such as a Marinelli beaker.
AS303/406	Analysis of radionuclides in solid samples by high resolution gamma ray spectrometry after preparation to meet standard calibrated geometries. Preparation involves drying, crushing and sieving, and setting in an epoxy resin where necessary.

FOOTNOTES

*	NATA accreditation does not cover the performance of this service.	-	Not analysed.	UOM	Unit of Measure.
**	Indicative data, theoretical holding time exceeded.	NVL	Not validated.	LOR	Limit of Reporting.
***	Indicates that both * and ** apply.	IS	Insufficient sample for analysis.	↑↓	Raised/lowered Limit of Reporting.
		LNR	Sample listed, but not received.		

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calculated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

SGS

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Natalie Robson
Client	RPS AUSTRALIA WEST PTY LTD
Address	Level 2, 27-31 Troode Street West Perth, WA 6005 PO Box 170, West Perth WA 6872 6005
Telephone	61 8 92111111
Facsimile	(Not specified)
Email	natalie.robson@rpsgroup.com.au
Project	**NORM analysis of waters & Sediment sampl**
Order Number	(Not specified)
Samples	59

LABORATORY DETAILS

Manager	Adam Atkinson
Laboratory	SGS Melbourne EH&S
Address	10/585 Blackburn Road Notting Hill Victoria 3168
Telephone	+61395743200
Facsimile	+61395743399
Email	Au.SampleReceipt.Melbourne@sgs.com
SGS Reference	**ME323489 R0**
Date Received	3/11/2021
Date Reported	14/2/2022

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(22793).

SIGNATORIES

Adam ATKINSON
Australian Chemistry Manager

ANALYTICAL RESULTS

Radionuclides by Gamma Ray Spectrometry in liquids [AS301/AS406]   Tested: 1/12/2021

PARAMETER	UOM	LOR	OP1B WATER - 16/10/2021 ME323489.001	OP2B WATER - 16/10/2021 ME323489.002	OP3B WATER - 16/10/2021 ME323489.003	OP4B WATER - 16/10/2021 ME323489.004	OP5B WATER - 16/10/2021 ME323489.005
Radium-226	Bq/L	-	<0.045	<0.051	<0.063	0.023 ±0.011	<0.027
Radium-228	Bq/L	-	<0.130	<0.150	<0.130	<0.087	<0.100
Thorium-228	Bq/L	-	<0.021	<0.021	<0.048	<0.026	<0.024

PARAMETER	UOM	LOR	OP6B WATER - 16/10/2021 ME323489.006	OP7B WATER - 17/10/2021 ME323489.007	OP8B WATER - 17/10/2021 ME323489.008	OP9B WATER - 17/10/2021 ME323489.009	OP10B WATER - 17/10/2021 ME323489.010
Radium-226	Bq/L	-	0.018 ±0.011	<0.064	<0.045	<0.053	<0.057
Radium-228	Bq/L	-	<0.110	<0.084	<0.140	<0.150	<0.160
Thorium-228	Bq/L	-	<0.021	<0.031	<0.025	<0.024	<0.035

PARAMETER	UOM	LOR	SG7B WATER - 17/10/2021 ME323489.011	SG11B WATER - 17/10/2021 ME323489.012	SG1B WATER - 18/10/2021 ME323489.013	SG12B WATER - 18/10/2021 ME323489.014	SG13B WATER - 18/10/2021 ME323489.015
Radium-226	Bq/L	-	<0.044	<0.050	<0.039	<0.037	<0.046
Radium-228	Bq/L	-	<0.130	<0.150	<0.110	<0.086	<0.094
Thorium-228	Bq/L	-	<0.029	<0.025	<0.033	<0.027	<0.034

PARAMETER	UOM	LOR	SG8B WATER - 18/10/2021 ME323489.016	SG4B WATER - 18/10/2021 ME323489.017
Radium-226	Bq/L	-	<0.043	<0.044
Radium-228	Bq/L	-	<0.086	<0.140
Thorium-228	Bq/L	-	<0.032	<0.023

Radionuclides by Gamma Ray Spectrometry in solids [AS303/AS406] Tested: 4/1/2022

PARAMETER	UOM	LOR	OP1 SOIL - 15/10/2021 ME323489.018	OP2 SOIL - 15/10/2021 ME323489.019	OP3 SOIL - 15/10/2021 ME323489.020	OP4 SOIL - 15/10/2021 ME323489.021	OP5 SOIL - 15/10/2021 ME323489.022
Radium-226	Bq/kg	-	8.1 ±1.0	3.6 ±0.4	8.3 ±0.9	9.8 ±1.0	9.5 ±1.0
Radium-228	Bq/kg	-	8.1 ±1.5	4.2 ±0.6	10 ±1	8.2 ±1.3	9.2 ±1.2
Thorium-228	Bq/kg	-	8.8 ±1.2	4.3 ±0.5	12 ±1	11 ±1	12 ±1

PARAMETER	UOM	LOR	OP6 SOIL - 15/10/2021 ME323489.023	OP7 SOIL - 15/10/2021 ME323489.024	OP9 SOIL - 15/10/2021 ME323489.025	OP10 SOIL - 15/10/2021 ME323489.026	OP11 SOIL - 15/10/2021 ME323489.027
Radium-226	Bq/kg	-	9.7 ±1.0	11 ±1	9.7 ±1.0	10 ±1	11 ±1
Radium-228	Bq/kg	-	11 ±1	13 ±1	10 ±1	10 ±1	11 ±1
Thorium-228	Bq/kg	-	14 ±1	13 ±1	13 ±1	12 ±1	13 ±1

PARAMETER	UOM	LOR	OP12 SOIL - 15/10/2021 ME323489.028	OP13 SOIL - 15/10/2021 ME323489.029	OP14 SOIL - 15/10/2021 ME323489.030	OP15 SOIL - 15/10/2021 ME323489.031	OP16 SOIL - 16/10/2021 ME323489.032
Radium-226	Bq/kg	-	11 ±1	11 ±1	11 ±1	9.6 ±1.0	10 ±1
Radium-228	Bq/kg	-	12 ±1	11 ±1	13 ±1	10 ±1	11 ±1
Thorium-228	Bq/kg	-	17 ±2	13 ±1	15 ±1	11 ±1	13 ±1

PARAMETER	UOM	LOR	OP17 SOIL - 16/10/2021 ME323489.033	OP18 SOIL - 16/10/2021 ME323489.034	OP19 SOIL - 16/10/2021 ME323489.035	OP20 SOIL - 16/10/2021 ME323489.036	OP21 SOIL - 16/10/2021 ME323489.037
Radium-226	Bq/kg	-	9.6 ±1.0	9.2 ±1.1	9.3 ±1.3	10 ±1	8.8 ±1.2
Radium-228	Bq/kg	-	11 ±1	12 ±2	11 ±2	12 ±2	12 ±2
Thorium-228	Bq/kg	-	13 ±1	14 ±1	15 ±2	15 ±2	16 ±2

PARAMETER	UOM	LOR	OP22 SOIL - 16/10/2021 ME323489.038	OP23 SOIL - 16/10/2021 ME323489.039	OP24 SOIL - 17/10/2021 ME323489.040	OP25 SOIL - 17/10/2021 ME323489.041	OP26 SOIL - 17/10/2021 ME323489.042
Radium-226	Bq/kg	-	9.4 ±1.0	10 ±1	8.1 ±0.9	11 ±1	12 ±1
Radium-228	Bq/kg	-	12 ±2	13 ±2	13 ±2	18 ±2	13 ±3
Thorium-228	Bq/kg	-	14 ±1	17 ±2	15 ±2	20 ±2	18 ±2

PARAMETER	UOM	LOR	OP27 SOIL - 17/10/2021 ME323489.043	OP28 SOIL - 17/10/2021 ME323489.044	OP29 SOIL - 17/10/2021 ME323489.045	OP30 SOIL - 17/10/2021 ME323489.046	SG1 SOIL - 18/10/2021 ME323489.047
Radium-226	Bq/kg	-	14 ±2	15 ±1	14 ±2	17 ±2	0.83 ±0.09
Radium-228	Bq/kg	-	15 ±2	19 ±2	17 ±2	26 ±3	1.1 ±0.2
Thorium-228	Bq/kg	-	20 ±2	21 ±2	23 ±2	24 ±3	1.4 ±0.2

PARAMETER	UOM	LOR	SG2 SOIL - 17/10/2021 ME323489.048	SG3 SOIL - 17/10/2021 ME323489.049	SG4 SOIL - 17/10/2021 ME323489.050	SG5 SOIL - 17/10/2021 ME323489.051	SG6 SOIL - 17/10/2021 ME323489.052
Radium-226	Bq/kg	-	9.7 ±1.0	10 ±1	13 ±1	12 ±1	12 ±1
Radium-228	Bq/kg	-	12 ±2	12 ±2	16 ±2	14 ±2	18 ±3
Thorium-228	Bq/kg	-	16 ±2	16 ±2	21 ±2	20 ±2	18 ±2

Radionuclides by Gamma Ray Spectrometry in solids [AS303/AS406] Tested: 4/1/2022 (continued)

PARAMETER	UOM	LOR	SG7 SOIL - 17/10/2021 ME323489.053	SG8 SOIL - 18/10/2021 ME323489.054	SG9 SOIL - 18/10/2021 ME323489.055	SG10 SOIL - 18/10/2021 ME323489.056	SG11 SOIL - 18/10/2021 ME323489.057
Radium-226	Bq/kg	-	14 ±2	9.5 ±1.2	10 ±1	13 ±1	15 ±1
Radium-228	Bq/kg	-	19 ±3	10 ±2	13 ±2	17 ±2	18 ±2
Thorium-228	Bq/kg	-	20 ±3	15 ±2	16 ±2	18 ±2	19 ±2

PARAMETER	UOM	LOR	SG12 SOIL - 18/10/2021 ME323489.058	SG13 SOIL - 18/10/2021 ME323489.059
Radium-226	Bq/kg	-	10 ±1	9.0 ±1.2
Radium-228	Bq/kg	-	12 ±2	11 ±2
Thorium-228	Bq/kg	-	15 ±2	13 ±2

METHOD	METHODOLOGY SUMMARY
ARS-SOP-AS301/AS406	Analysis of radionuclides in liquids by high resolution gamma ray spectrometry after radiochemical preparation. Radiochemical preparation involves total sample evaporation, sample co-precipitation using stable elemental carriers, or a combination thereof. In some cases, preparation may involve merely transferring liquid to a standard geometry container such as a Marinelli beaker.
AS303/406	Analysis of radionuclides in solid samples by high resolution gamma ray spectrometry after preparation to meet standard calibrated geometries. Preparation involves drying, crushing and sieving, and setting in an epoxy resin where necessary.

FOOTNOTES

*	NATA accreditation does not cover the performance of this service.	-	Not analysed.	UOM	Unit of Measure.
**	Indicative data, theoretical holding time exceeded.	NVL	Not validated.	LOR	Limit of Reporting.
***	Indicates that both * and ** apply.	IS	Insufficient sample for analysis.	↑↓	Raised/lowered Limit of Reporting.
		LNR	Sample listed, but not received.		

Unless it is reported that sampling has been performed by SGS, the samples have been analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calculated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC and MU criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here: www.sgs.com.au/en-gb/environment-health-and-safety.

Appendix G

Laboratory sediment and water metals, nutrients, chlorophyll-a and total suspended solids data

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

SEDIMENT DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	2600 TKN mg.N/g	4500 TOTAL P mg.P/g	6200 TOC % C	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg
Reporting Limit		<0.1	<0.05	<0.1	<20	<2	<0.2	<0.1	<0.2	<0.2	<0.2	<5	<0.7	<0.5	<0.01
Analysis Date		23/11/2021	23/11/2021	12/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	24/11/2021	19/11/2021
File		21112301,02	21112301,02	21111201	21112401A	21112401A	21112401A	21112401A	21112401A	21112401A	21112401A	21112401A	21112401A	21112401A	21111901-02
OP1	15/10/2021	0.3	0.36	0.2	3500	13	5.5	0.2	2.6	11	1.2	8300	4.0	4.5	<0.01
OP2	15/10/2021	0.3	0.42	0.2	4900	16	6.7	0.3	3.3	13	1.6	9700	5.1	5.6	<0.01
OP3	15/10/2021	0.6	0.47	0.4	7800	13	8.0	0.3	4.2	18	2.5	11000	6.8	8.6	<0.01
OP4	15/10/2021	0.3	0.49	0.2	4400	22	6.3	0.3	4.1	12	1.3	11000	4.7	5.6	<0.01
OP5	15/10/2021	0.3	0.52	0.2	5000	23	7.2	0.2	3.8	13	1.5	12000	5.2	5.7	<0.01
OP6	15/10/2021	0.5	0.53	0.3	6500	20	6.8	0.2	4.5	15	2.0	13000	6.4	7.5	<0.01
OP7	15/10/2021	0.3	0.53	0.2	4900	31	6.5	0.2	5.6	12	1.5	13000	5.9	5.9	<0.01
OP9	15/10/2021	0.4	0.50	0.2	5800	21	7.6	0.3	4.3	13	1.7	12000	5.9	6.1	<0.01
OP10	15/10/2021	0.3	0.53	0.2	5500	24	7.8	0.3	4.4	12	1.5	13000	5.2	5.4	<0.01
OP11	15/10/2021	0.3	0.53	0.2	6100	27	7.8	0.2	5.6	14	1.7	14000	6.4	6.1	<0.01
OP12	15/10/2021	0.6	0.55	0.3	8300	21	9.2	0.3	4.8	16	2.2	14000	6.9	7.9	<0.01
OP13	15/10/2021	0.3	0.57	0.2	6200	30	8.3	0.3	5.0	14	1.4	15000	5.8	5.9	<0.01
OP14	15/10/2021	0.3	0.56	0.2	5600	35	7.3	0.3	5.4	13	1.5	15000	6.3	5.5	<0.01
OP15	15/10/2021	0.3	0.50	0.2	4700	23	6.9	0.3	4.0	12	1.4	12000	5.1	5.0	<0.01
OP16	16/10/2021	0.4	0.44	0.2	6300	17	8.4	0.2	4.6	14	1.7	11000	6.1	6.2	<0.01
OP17	16/10/2021	0.3	0.42	0.2	4500	16	7.2	0.3	4.1	12	1.3	11000	5.2	5.1	<0.01
OP18	16/10/2021	0.4	0.41	0.3	6600	13	8.3	0.2	4.3	14	1.8	11000	5.7	6.4	<0.01
OP19	16/10/2021	0.3	0.40	0.2	5100	16	81	0.2	3.9	13	1.5	11000	6.3	5.9	<0.01
OP20	16/10/2021	0.5	0.37	0.3	5700	10	7.2	0.2	3.7	13	1.7	9100	5.3	6.4	<0.01
OP21	16/10/2021	0.5	0.37	0.3	5700	7	7.5	0.2	3.8	13	1.8	8800	5.6	6.5	<0.01
OP22	16/10/2021	0.4	0.48	0.2	7100	19	7.7	0.2	5.1	15	1.8	14000	6.8	6.9	<0.01
OP23	16/10/2021	0.5	0.38	0.4	8600	12	9.1	0.2	4.3	18	2.6	13000	7.5	9.1	<0.01
OP24	17/10/2021	0.5	0.49	0.3	8900	17	9.8	0.3	4.2	15	2.2	12000	6.3	7.3	<0.01
OP25	17/10/2021	0.4	0.48	0.3	8600	18	9.2	0.1	4.7	17	2.3	14000	6.7	8.2	<0.01
OP26	17/10/2021	0.5	0.55	0.3	8800	18	9.7	0.2	5.0	16	2.3	15000	5.7	8.6	<0.01
OP27	17/10/2021	0.5	0.45	0.4	9400	13	10	<0.1	5.4	19	2.9	14000	7.2	10	<0.01
OP28	17/10/2021	0.4	0.43	0.4	9000	15	13	0.2	5.1	19	2.7	14000	6.4	10	<0.01
OP29	17/10/2021	0.5	0.38	0.4	9100	13	11	0.1	5.1	22	3.2	15000	6.4	11	<0.01

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

Murdoch UNIVERSITY

SEDIMENT DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	2600 TKN mg.N/g	4500 TOTAL P mg.P/g	6200 TOC % C	ICP002 Total Ext Al mg/kg	ICP002 Total Ext As mg/kg	ICP002 Total Ext Ba mg/kg	ICP002 Total Ext Cd mg/kg	ICP002 Total Ext Co mg/kg	ICP002 Total Ext Cr mg/kg	ICP002 Total Ext Cu mg/kg	ICP002 Total Ext Fe mg/kg	ICP002 Total Ext Ni mg/kg	ICP002 Total Ext Zn mg/kg	ICP007 Total Ext Hg mg/kg
Reporting Limit		**<0.1**	**<0.05**	**<0.1**	**<20**	**<2**	**<0.2**	**<0.1**	**<0.2**	**<0.2**	**<0.2**	**<5**	**<0.7**	**<0.5**	**<0.01**
Analysis Date File		**23/11/2021 21112301,02**	**23/11/2021 21112301,02**	**12/11/2021 21111201**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**24/11/2021 21112401A**	**19/11/2021 21111901-02**
OP30	17/10/2021	0.6	0.45	0.5	12000	11	13	0.2	6.3	26	4.7	15000	8.7	16	<0.01
SG1	17/10/2021	0.4	0.59	0.3	8700	33	13	0.1	5.7	19	2.5	20000	6.4	11	<0.01
SG2	17/10/2021	0.4	0.60	0.3	10000	38	11	0.2	5.8	20	2.5	23000	6.7	10	<0.01
SG3	17/10/2021	0.4	0.50	0.3	7900	27	12	0.2	4.8	15	2.6	15000	5.8	9.4	<0.01
SG4	17/10/2021	0.4	0.48	0.4	9500	22	14	0.2	5.8	20	3.7	19000	7.1	12	<0.01
SG5	17/10/2021	0.4	0.50	0.3	9000	27	12	0.2	5.5	18	3.4	17000	6.7	12	<0.01
SG6	17/10/2021	0.4	0.45	0.3	9300	24	15	0.2	5.3	17	3.6	16000	6.9	11	<0.01
SG7	17/10/2021	0.4	0.45	0.3	7200	19	13	0.2	4.9	16	3.3	14000	6.3	11	<0.01
SG8	18/10/2021	0.4	0.58	0.3	9400	27	13	0.1	5.6	18	2.7	16000	6.0	11	<0.01
SG9	18/10/2021	0.4	0.51	0.4	8300	24	11	0.2	5.2	17	2.9	15000	6.3	10	<0.01
SG10	18/10/2021	0.3	0.38	0.3	7300	18	13	0.1	4.5	16	3.3	14000	6.2	10	<0.01
SG11	18/10/2021	0.3	0.37	0.3	6200	18	13	0.1	4.2	16	4.7	15000	7.3	12	<0.01
SG12	18/10/2021	0.4	0.62	0.3	9000	38	12	0.1	4.9	17	2.2	20000	5.7	9.5	<0.01
SG13	18/10/2021	0.5	0.54	0.4	7700	25	11	0.2	4.8	15	2.2	15000	5.4	9.0	<0.01
Triplicate A	17/10/2021	0.3	0.59	0.2	5500	35	7.8	0.2	5.2	12	1.4	14000	5.8	5.9	<0.01
Triplicate B	17/10/2021	0.4	0.51	0.3	7300	26	12	0.3	4.2	14	2.5	14000	5.3	8.9	<0.01
Triplicate C	17/10/2021	0.4	0.53	0.2	7400	25	12	0.2	4.6	14	2.6	14000	5.4	8.7	<0.01
Triplicate D	17/10/2021	0.4	0.46	0.3	9600	21	13	0.2	5.6	18	3.4	15000	6.9	12	<0.01
Trip Blank		<0.1	<0.05	<0.1	630	<2	4.1	<0.1	<0.2	1.5	<0.2	110	<0.7	<0.5	<0.01

Note: For results for compliance purposes uncertainity of measurement (MU) will sometimes affect the interpretation whether the result passes or fails the compliance limit.
Tables for measurement uncertainity are available online at www.mafrl.murdoch.edu.au

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations and/or measurements included is this document are traceable to Australian/national standards.

WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 6/12/2021
Date Received: 25/10/2021
Our Reference: RPS21-4
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	ICP001 Total Ext Al mg/L	ICP001 Total Ext As mg/L	ICP001 Total Ext Ba mg/L	ICP001 Total Ext Cd mg/L	ICP001 Total Ext Co mg/L	ICP001 Total Ext Cr mg/L	ICP001 Total Ext Cu mg/L	ICP001 Total Ext Fe mg/L	ICP001 Total Ext Ni mg/L	ICP001 Total Ext Zn mg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<5**	**<50**	**<0.01**	**<0.02**	**<0.0004**	**<0.0006**	**<0.002**	**<0.001**	**<0.001**	**<0.01**	**<0.007**	**<0.005**	**<0.0004**
Analysis Date		**10/11/2021**	**10/11/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**1/12/2021**	**26/11/2021**
File		**21111001**	**21111001**	**21120101**	**21120101**	**21120101**	**21120101**	**21120101**	**21120101**	**21120101**	**21120101**	**21120101**	**21120101**	**21112601**
Equipment Blank	18/10/2021	220	680	17	<0.02	0.030	<0.0006	0.007	0.043	0.005	14	0.023	0.24	<0.0004
Field Blank	18/102021	<5	70	<0.01	<0.02	<0.0004	<0.0006	<0.002	<0.001	0.001	<0.01	<0.007	<0.005	<0.0004

Signatory: Jamie Woodward
Date: 6/12/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2200737**	Page	: 1 of 16
Amendment	: **(Preliminary Report)**		
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 12-Jan-2022 08:20
Order number	: ----	Date Analysis Commenced	: 13-Jan-2022
C-O-C number	: ----	Issue Date	: 25-Jan-2022 14:47
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 18		
No. of samples analysed	: 17		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

This report contains preliminary authorised results. The report may contain semi-quantitative results. Any result presented in this preliminary report may be subject to change in the final report.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2200737_002 (KP92-95_U_1) Shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP93-23_U' (EB2200737-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP120-6_U' (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- AES 6318477 T/O 6314877
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP120-6_U (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP92-95_U_1 (EB2200737-002) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EP071 (TRH Semivolatiles): Sample 'KP92-95_U_1' shows poor matrix spike recovery due to sample heterogeneity. Confirmed by re-extraction and re-analysis.
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

(Preliminary Report)

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.8	9.6	9.9	9.7	9.1
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.008	0.080	0.010	0.015	0.526
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	50	<10	<10	328
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	43.4	47.0	36.3	2.13	19.3
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	8680	9390	7250	425	3860
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	13.9	15.0	11.6	0.68	6.19
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	0.08	<0.02	<0.02	0.52
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	50	<10	<10	328
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	4	<1	<1	25
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	17.1	24.3	16.8	16.0	41.3
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	600	2620	760	340	9520
Iron	7439-89-6	50	mg/kg	8560	10700	10000	1680	29100
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	17.8	18.5	18.6	1.21	27.3
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	9.9	13.7	11.4	1.7	33.2
Copper	7440-50-8	1.0	mg/kg	<1.0	1.8	1.3	1.1	5.7
Cobalt	7440-48-4	0.5	mg/kg	1.2	2.5	1.4	<0.5	8.7
Lead	7439-92-1	1.0	mg/kg	2.4	3.8	2.7	24.1	10.6

(Preliminary Report)

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**362**	**371**	**311**	<10	**173**
Nickel	7440-02-0	1.0	mg/kg	**1.7**	**3.7**	**2.3**	<1.0	**9.8**
Selenium	7782-49-2	0.1	mg/kg	**0.1**	**0.2**	**0.1**	<0.1	**0.6**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**1.8**	**5.1**	**2.8**	**1.6**	**17.2**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**60**	**160**	**60**	**50**	**210**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**315**	**283**	**312**	**44**	**210**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.04**	**0.60**	**0.05**	<0.02	**0.53**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	**3**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	**3**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	**3**	**3**	<3	**4**
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<3	**3**	**3**	<3	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	Not Authorised
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	Not Authorised

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	**Not Authorised**
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	**Not Authorised**
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**90.6**	**90.0**	**94.8**	**97.3**	**83.6**
Toluene-D8	2037-26-5	0.2	%	**81.0**	**84.0**	**82.3**	**89.3**	**77.6**
4-Bromofluorobenzene	460-00-4	0.2	%	**91.5**	**95.2**	**94.7**	**102**	**87.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**113**	**132**	**90.4**	**93.8**	**110**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**65.2**	**25.9**	**55.4**	**56.4**	**Not Authorised**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**60.0**	**27.5**	**58.8**	**63.8**	**32.5**

(Preliminary Report)

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	*CAS Number*	*LOR*	*Unit*	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.9**	**9.6**	**9.6**	**9.9**	**9.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.011**	**0.020**	**0.011**	**0.015**	**0.052**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**13**	<10	<10	**33**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**48.5**	**15.4**	**36.4**	**36.3**	**47.8**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**9700**	**3070**	**7280**	**7250**	**9560**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**15.6**	**4.92**	**11.7**	**11.6**	**15.3**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	**0.02**	<0.02	<0.02	**0.05**
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	**13**	<10	<10	**33**
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	**2**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**20.1**	**24.9**	**18.8**	**16.4**	**24.2**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**670**	**2430**	**2780**	**960**	**2670**
Iron	7439-89-6	50	mg/kg	**5540**	**18500**	**9710**	**10500**	**11800**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**12.8**	**14.6**	**12.6**	**19.8**	**18.3**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**6.4**	**15.6**	**13.3**	**15.0**	**16.4**
Copper	7440-50-8	1.0	mg/kg	<1.0	**2.1**	**2.0**	<1.0	**1.6**
Cobalt	7440-48-4	0.5	mg/kg	**0.9**	**3.0**	**2.8**	**1.4**	**2.4**
Lead	7439-92-1	1.0	mg/kg	**1.9**	**7.8**	**4.1**	**2.9**	**3.8**

(Preliminary Report)

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
				EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**250**	**167**	**177**	**512**	**397**
Nickel	7440-02-0	1.0	mg/kg	**1.5**	**3.3**	**3.8**	**2.1**	**3.6**
Selenium	7782-49-2	0.1	mg/kg	<0.1	**0.2**	**0.2**	**0.1**	**0.2**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**1.3**	**6.5**	**7.6**	**1.7**	**5.4**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**90**	**240**	**170**	**50**	**140**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**346**	**340**	**262**	**247**	**335**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.06**	**0.14**	**0.11**	**0.05**	**0.12**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	**3**	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	**10**	**6**	<3	**4**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	**10**	**9**	<3	**4**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	**3**	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	**3**	**4**	**4**	**3**	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	**4**	<3	**4**
C29 - C36 Fraction	----	5	mg/kg	<5	**8**	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	**12**	**8**	**3**	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	Not Authorised	<0.25	Not Authorised	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	Not Authorised	<0.50	Not Authorised	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	80.1	84.2	89.4	97.6	88.5
Toluene-D8	2037-26-5	0.2	%	70.2	76.8	81.4	88.9	82.6
4-Bromofluorobenzene	460-00-4	0.2	%	80.0	88.4	91.2	98.2	91.8
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	106	121	84.3	103	128
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	46.1	Not Authorised	56.7	Not Authorised	55.8
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	47.5	52.5	52.5	68.8	55.0

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.4	9.2	9.4	9.9	9.9
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.042	0.340	0.102	0.010	0.014
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	26	212	64	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	14.2	40.8	23.6	35.0	45.5
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	2830	8160	4720	6990	9090
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	4.54	13.1	7.56	11.2	14.6
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.04	0.34	0.10	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	26	212	64	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	2	16	5	<1	<1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	29.7	35.8	32.4	19.2	7.7
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	5840	6700	5590	720	760
Iron	7439-89-6	50	mg/kg	32300	24700	22200	7960	8110
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	11.0	26.6	20.5	19.6	16.5
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	28.5	27.8	37.0	9.3	11.6
Copper	7440-50-8	1.0	mg/kg	6.1	3.6	3.2	<1.0	<1.0
Cobalt	7440-48-4	0.5	mg/kg	4.2	7.0	5.9	1.1	1.2
Lead	7439-92-1	1.0	mg/kg	13.4	9.5	9.8	2.4	2.4

(Preliminary Report)

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**102**	**156**	**212**	**228**	**316**
Nickel	7440-02-0	1.0	mg/kg	**5.3**	**7.6**	**6.5**	**1.7**	**1.9**
Selenium	7782-49-2	0.1	mg/kg	**0.3**	**0.4**	**0.3**	**0.1**	**0.1**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**10.2**	**12.1**	**11.0**	**1.6**	**1.8**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**110**	**40**	**60**	**60**	**80**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**181**	**27**	**35**	**292**	**355**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.15**	**0.56**	**0.20**	**0.04**	**0.06**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	**4**	**3**	**4**	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	**4**	**3**	**4**	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	**3**	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**3**	<3	**4**	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	<3	**7**	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
Sampling date / time				08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
				EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	62.9	62.8	65.4	70.9	73.7
Toluene-D8	2037-26-5	0.2	%	55.0	53.9	56.7	61.8	63.9
4-Bromofluorobenzene	460-00-4	0.2	%	64.3	70.2	74.9	79.0	84.5
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	78.4	90.8	127	127	81.1
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	60.5	59.5	55.1	37.7	65.4
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	62.5	65.0	62.5	50.0	63.8

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	TB	FB	----	----	----
			Sampling date / time	10-Jan-2022 00:00	10-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200737-010	EB2200737-011	--------	--------	--------
				Result	Result	----	----	----
EP071: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	50	µg/L	----	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	----	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	----	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	----	<50	----	----	----
EP071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	100	µg/L	----	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	----	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	----	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	----	<100	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ Total Xylenes	----	2	µg/L	<2	----	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**115**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**97.4**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**98.7**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP131A: Organochlorine Pesticides

(SOIL) EP131S: OC Pesticide Surrogate

(SOIL) EP131B: Polychlorinated Biphenyls (as Aroclors)

(SOIL) EP131T: PCB Surrogate

CERTIFICATE OF ANALYSIS

Work Order	: **EB2200737**	Page	: 1 of 16
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 12-Jan-2022 08:20
Order number	: ----	Date Analysis Commenced	: 13-Jan-2022
C-O-C number	: ----	Issue Date	: 28-Jan-2022 09:11
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 18		
No. of samples analysed	: 17		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2200737_002 (KP92-95_U_1) Shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP93-23_U' (EB2200737-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP120-6_U' (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- AES 6318477 T/O 6314877
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP120-6_U (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP92-95_U_1 (EB2200737-002) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EP071 (TRH Semivolatiles): Sample 'KP92-95_U_1' shows poor matrix spike recovery due to sample heterogeneity. Confirmed by re-extraction and re-analysis.
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
				EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.8**	**9.6**	**9.9**	**9.7**	**9.1**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.008**	**0.080**	**0.010**	**0.015**	**0.526**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**50**	<10	<10	**328**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**43.4**	**47.0**	**36.3**	**2.13**	**19.3**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**8680**	**9390**	**7250**	**425**	**3860**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**13.9**	**15.0**	**11.6**	**0.68**	**6.19**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	**0.08**	<0.02	<0.02	**0.52**
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	**50**	<10	<10	**328**
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	**4**	<1	<1	**25**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**17.1**	**24.3**	**16.8**	**16.0**	**41.3**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**600**	**2620**	**760**	**340**	**9520**
Iron	7439-89-6	50	mg/kg	**8560**	**10700**	**10000**	**1680**	**29100**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**17.8**	**18.5**	**18.6**	**1.21**	**27.3**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**9.9**	**13.7**	**11.4**	**1.7**	**33.2**
Copper	7440-50-8	1.0	mg/kg	<1.0	**1.8**	**1.3**	**1.1**	**5.7**
Cobalt	7440-48-4	0.5	mg/kg	**1.2**	**2.5**	**1.4**	<0.5	**8.7**
Lead	7439-92-1	1.0	mg/kg	**2.4**	**3.8**	**2.7**	**24.1**	**10.6**

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
Sampling date / time				08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
				EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	362	371	311	<10	173
Nickel	7440-02-0	1.0	mg/kg	1.7	3.7	2.3	<1.0	9.8
Selenium	7782-49-2	0.1	mg/kg	0.1	0.2	0.1	<0.1	0.6
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	1.8	5.1	2.8	1.6	17.2
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	60	160	60	50	210
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	315	283	312	44	210
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.04	0.60	0.05	<0.02	0.53
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	3	3	<3	4
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	3	3	<3	4
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**90.6**	**90.0**	**94.8**	**97.3**	**83.6**
Toluene-D8	2037-26-5	0.2	%	**81.0**	**84.0**	**82.3**	**89.3**	**77.6**
4-Bromofluorobenzene	460-00-4	0.2	%	**91.5**	**95.2**	**94.7**	**102**	**87.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**113**	**132**	**90.4**	**93.8**	**110**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**65.2**	**25.9**	**55.4**	**56.4**	**50.6**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**60.0**	**27.5**	**58.8**	**63.8**	**32.5**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.9**	**9.6**	**9.6**	**9.9**	**9.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.011**	**0.020**	**0.011**	**0.015**	**0.052**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**13**	<10	<10	**33**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**48.5**	**15.4**	**36.4**	**36.3**	**47.8**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**9700**	**3070**	**7280**	**7250**	**9560**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**15.6**	**4.92**	**11.7**	**11.6**	**15.3**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	**0.02**	<0.02	<0.02	**0.05**
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	**13**	<10	<10	**33**
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	**2**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**20.1**	**24.9**	**18.8**	**16.4**	**24.2**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**670**	**2430**	**2780**	**960**	**2670**
Iron	7439-89-6	50	mg/kg	**5540**	**18500**	**9710**	**10500**	**11800**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**12.8**	**14.6**	**12.6**	**19.8**	**18.3**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**6.4**	**15.6**	**13.3**	**15.0**	**16.4**
Copper	7440-50-8	1.0	mg/kg	<1.0	**2.1**	**2.0**	<1.0	**1.6**
Cobalt	7440-48-4	0.5	mg/kg	**0.9**	**3.0**	**2.8**	**1.4**	**2.4**
Lead	7439-92-1	1.0	mg/kg	**1.9**	**7.8**	**4.1**	**2.9**	**3.8**

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
				EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**250**	**167**	**177**	**512**	**397**
Nickel	7440-02-0	1.0	mg/kg	**1.5**	**3.3**	**3.8**	**2.1**	**3.6**
Selenium	7782-49-2	0.1	mg/kg	<0.1	**0.2**	**0.2**	**0.1**	**0.2**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**1.3**	**6.5**	**7.6**	**1.7**	**5.4**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**90**	**240**	**170**	**50**	**140**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**346**	**340**	**262**	**247**	**335**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.06**	**0.14**	**0.11**	**0.05**	**0.12**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	**3**	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	**10**	**6**	<3	**4**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	**10**	**9**	<3	**4**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	**3**	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	**3**	**4**	**4**	**3**	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	**4**	<3	**4**
C29 - C36 Fraction	----	5	mg/kg	<5	**8**	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	**12**	**8**	**3**	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ **Sum of Aldrin + Dieldrin**	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ **Total Polychlorinated biphenyls**	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**80.1**	**84.2**	**89.4**	**97.6**	**88.5**
Toluene-D8	2037-26-5	0.2	%	**70.2**	**76.8**	**81.4**	**88.9**	**82.6**
4-Bromofluorobenzene	460-00-4	0.2	%	**80.0**	**88.4**	**91.2**	**98.2**	**91.8**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**106**	**121**	**84.3**	**103**	**128**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**46.1**	**44.9**	**56.7**	**48.9**	**55.8**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**47.5**	**52.5**	**52.5**	**68.8**	**55.0**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.4**	**9.2**	**9.4**	**9.9**	**9.9**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.042**	**0.340**	**0.102**	**0.010**	**0.014**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**26**	**212**	**64**	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**14.2**	**40.8**	**23.6**	**35.0**	**45.5**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**2830**	**8160**	**4720**	**6990**	**9090**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**4.54**	**13.1**	**7.56**	**11.2**	**14.6**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.04**	**0.34**	**0.10**	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**26**	**212**	**64**	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**2**	**16**	**5**	<1	<1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**29.7**	**35.8**	**32.4**	**19.2**	**7.7**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**5840**	**6700**	**5590**	**720**	**760**
Iron	7439-89-6	50	mg/kg	**32300**	**24700**	**22200**	**7960**	**8110**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**11.0**	**26.6**	**20.5**	**19.6**	**16.5**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**28.5**	**27.8**	**37.0**	**9.3**	**11.6**
Copper	7440-50-8	1.0	mg/kg	**6.1**	**3.6**	**3.2**	<1.0	<1.0
Cobalt	7440-48-4	0.5	mg/kg	**4.2**	**7.0**	**5.9**	**1.1**	**1.2**
Lead	7439-92-1	1.0	mg/kg	**13.4**	**9.5**	**9.8**	**2.4**	**2.4**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**102**	**156**	**212**	**228**	**316**
Nickel	7440-02-0	1.0	mg/kg	**5.3**	**7.6**	**6.5**	**1.7**	**1.9**
Selenium	7782-49-2	0.1	mg/kg	**0.3**	**0.4**	**0.3**	**0.1**	**0.1**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**10.2**	**12.1**	**11.0**	**1.6**	**1.8**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**110**	**40**	**60**	**60**	**80**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**181**	**27**	**35**	**292**	**355**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.15**	**0.56**	**0.20**	**0.04**	**0.06**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	**4**	**3**	**4**	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	**4**	**3**	**4**	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	**3**	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**3**	<3	**4**	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	<3	**7**	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
				EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	μgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	μgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	μgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	62.9	62.8	65.4	70.9	73.7
Toluene-D8	2037-26-5	0.2	%	55.0	53.9	56.7	61.8	63.9
4-Bromofluorobenzene	460-00-4	0.2	%	64.3	70.2	74.9	79.0	84.5
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	78.4	90.8	127	127	81.1
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	60.5	59.5	55.1	37.7	65.4
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	62.5	65.0	62.5	50.0	63.8

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	TB	FB	----	----	----
			Sampling date / time	10-Jan-2022 00:00	10-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200737-010	EB2200737-011	--------	--------	--------
				Result	Result	----	----	----
EP071: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	50	µg/L	----	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	----	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	----	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	----	<50	----	----	----
EP071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	100	µg/L	----	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	----	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	----	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	----	<100	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ Total Xylenes	----	2	µg/L	<2	----	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**115**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**97.4**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**98.7**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: SOIL		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106

Sub-Matrix: WATER		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP131A: Organochlorine Pesticides

(SOIL) EP131S: OC Pesticide Surrogate

(SOIL) EP131B: Polychlorinated Biphenyls (as Aroclors)

(SOIL) EP131T: PCB Surrogate

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2200550**	Page	: 1 of 16
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 11-Jan-2022 06:10
Order number	: ----	Date Analysis Commenced	: 12-Jan-2022
C-O-C number	: ----	Issue Date	: 21-Jan-2022 11:18
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 15		
No. of samples analysed	: 13		

ilac-MRA NATA

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Mark Hallas	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD
Thomas Donovan	Senior Organic Chemist - PFAS	Brisbane Organics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- **OC Pesticides (Ultratrace) & PCB's (Ultratrace) analysis is conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**
- **Ultra trace organics analysis is conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**
- EK067G (Total Phosphorus as P): Sample EB2200550_001 (KP93.7_U) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- EK067G (Total Phosphorus as P) / EK061G (Total Kjeldahl Nitrogen as N): Sample EB2200550_002 (KP93.8_U) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG020-SD (Total Metals Sediments by ICP-MS): Sample 'KP106.0_L' (EB2200550-012) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93.7_U	KP93.8_U	KP93.8_L	KP102.7_U	KP102.7_L
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200550-001	EB2200550-002	EB2200550-003	EB2200550-004	EB2200550-005
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.8	9.8	9.8	9.2	9.2
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.013	0.011	0.006	0.226	0.249
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	141	155
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	47.5	46.6	48.5	22.2	21.8
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	9500	9310	9680	4430	4350
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	15.2	14.9	15.5	7.11	6.98
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	0.22	0.25
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	<10	141	155
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	10	12
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	21.2	24.9	17.2	28.7	29.6
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	820	1170	710	5480	4440
Iron	7439-89-6	50	mg/kg	8380	13700	7870	13500	13200
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	16.0	23.9	19.2	14.7	11.9
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	8.8	12.8	9.4	17.0	20.2
Copper	7440-50-8	1.0	mg/kg	1.1	1.9	2.6	4.8	4.6
Cobalt	7440-48-4	0.5	mg/kg	1.3	2.0	1.3	3.9	4.1
Lead	7439-92-1	1.0	mg/kg	2.0	4.6	2.4	5.0	6.3

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP93.7_U	KP93.8_U	KP93.8_L	KP102.7_U	KP102.7_L
Sampling date / time				07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00
				EB2200550-001	EB2200550-002	EB2200550-003	EB2200550-004	EB2200550-005
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**463**	**628**	**710**	**170**	**113**
Nickel	7440-02-0	1.0	mg/kg	**1.7**	**2.7**	**1.8**	**5.2**	**4.9**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**2.5**	**4.3**	**1.8**	**8.1**	**7.5**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**90**	**90**	**60**	**80**	**210**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**336**	**238**	**242**	**55**	**560**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.07**	**0.05**	**0.05**	**0.27**	**0.24**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	**3**	**3**
>C16 - C34 Fraction	----	3	mg/kg	<3	**3**	**7**	**10**	**8**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	**3**	**7**	**13**	**11**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	**3**	**3**
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	**4**	**8**	**9**
C15 - C28 Fraction	----	3	mg/kg	<3	**3**	**7**	**8**	**6**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	**3**	**11**	**16**	**15**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93.7_U	KP93.8_U	KP93.8_L	KP102.7_U	KP102.7_L
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200550-001	EB2200550-002	EB2200550-003	EB2200550-004	EB2200550-005
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93.7_U	KP93.8_U	KP93.8_L	KP102.7_U	KP102.7_L
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200550-001	EB2200550-002	EB2200550-003	EB2200550-004	EB2200550-005
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ **Sum of Aldrin + Dieldrin**	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ **Total Polychlorinated biphenyls**	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**94.4**	**95.2**	**93.8**	**86.8**	**85.8**
Toluene-D8	2037-26-5	0.2	%	**82.1**	**82.8**	**82.7**	**78.9**	**74.5**
4-Bromofluorobenzene	460-00-4	0.2	%	**96.7**	**97.0**	**97.2**	**93.8**	**87.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**98.4**	**92.9**	**98.4**	**75.3**	**111**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**50.8**	**49.9**	**46.6**	**60.2**	**45.8**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**50.0**	**65.0**	**67.5**	**50.0**	**52.5**

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP103.1_U	KP103.1_L	KP103.5_U	KP104.9_U	KP106.0_U
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	06-Jan-2022 00:00	06-Jan-2022 00:00
				EB2200550-006	EB2200550-007	EB2200550-008	EB2200550-009	EB2200550-011
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.4**	**9.2**	**9.6**	**9.4**	**9.4**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.097**	**0.214**	**0.009**	**0.011**	**0.012**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**60**	**133**	<10	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**21.4**	**7.44**	**34.9**	**36.4**	**43.5**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**4260**	**1480**	**6970**	**7270**	**8690**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**6.84**	**2.38**	**11.2**	**11.7**	**13.9**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.10**	**0.21**	<0.02	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**60**	**133**	<10	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**4**	**10**	<1	<1	<1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**25.8**	**22.7**	**30.4**	**33.8**	**27.6**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**4330**	**3810**	**2660**	**4320**	**4380**
Iron	7439-89-6	50	mg/kg	**18400**	**15200**	**12000**	**26800**	**26600**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**14.3**	**13.3**	**13.1**	**17.6**	**15.4**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**41.7**	**17.6**	**15.4**	**29.3**	**37.8**
Copper	7440-50-8	1.0	mg/kg	**4.4**	**4.4**	**3.1**	**4.0**	**4.2**
Cobalt	7440-48-4	0.5	mg/kg	**4.6**	**4.0**	**2.3**	**3.5**	**5.5**
Lead	7439-92-1	1.0	mg/kg	**7.9**	**6.4**	**4.0**	**5.7**	**11.9**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP103.1_U	KP103.1_L	KP103.5_U	KP104.9_U	KP106.0_U
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	06-Jan-2022 00:00	06-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200550-006	EB2200550-007	EB2200550-008	EB2200550-009	EB2200550-011
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	102	77	158	155	216
Nickel	7440-02-0	1.0	mg/kg	4.7	3.8	3.6	5.0	7.2
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	7.4	5.3	6.8	9.4	10.5
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	0.01	0.01	0.01	0.01	0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	110	90	180	200	120
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	128	97	291	428	647
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.14	0.21	0.13	0.12	0.12
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	4	<3	6
>C16 - C34 Fraction	----	3	mg/kg	9	5	11	6	10
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	9	5	15	6	16
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	4	<3	6
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	9	5	8	7	11
C15 - C28 Fraction	----	3	mg/kg	6	4	8	5	9
C29 - C36 Fraction	----	5	mg/kg	6	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	21	9	16	12	20
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP103.1_U	KP103.1_L	KP103.5_U	KP104.9_U	KP106.0_U
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	06-Jan-2022 00:00	06-Jan-2022 00:00
				EB2200550-006	EB2200550-007	EB2200550-008	EB2200550-009	EB2200550-011
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP103.1_U	KP103.1_L	KP103.5_U	KP104.9_U	KP106.0_U
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	06-Jan-2022 00:00	06-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200550-006	EB2200550-007	EB2200550-008	EB2200550-009	EB2200550-011
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	94.2	94.6	93.6	91.4	93.9
Toluene-D8	2037-26-5	0.2	%	83.0	83.2	83.3	79.7	82.9
4-Bromofluorobenzene	460-00-4	0.2	%	98.2	98.3	98.1	93.4	97.2
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	92.6	103	102	79.2	76.2
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	74.7	44.2	70.0	57.6	57.8
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	57.5	67.5	45.0	53.8	67.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP106.0_L	KP106_U_A	----	----	----
			Sampling date / time	06-Jan-2022 00:00	06-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200550-012	EB2200550-013	--------	--------	--------
				Result	Result	----	----	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.5**	**9.4**	----	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	----	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	----	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.014**	**0.013**	----	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	----	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**48.5**	**43.5**	----	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**9680**	**8700**	----	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**15.5**	**13.9**	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	----	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	----	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	----	----	----
Liming Rate	----	1	kg CaCO3/t	<1	<1	----	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	<0.02	----	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	<10	----	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**36.1**	**29.6**	----	----	----
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**3920**	**4890**	----	----	----
Iron	7439-89-6	50	mg/kg	**15400**	**23000**	----	----	----
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	----	----	----
Arsenic	7440-38-2	1.00	mg/kg	**12.3**	**13.0**	----	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	----	----	----
Chromium	7440-47-3	1.0	mg/kg	**23.9**	**26.8**	----	----	----
Copper	7440-50-8	1.0	mg/kg	**3.9**	**6.2**	----	----	----
Cobalt	7440-48-4	0.5	mg/kg	**3.4**	**4.6**	----	----	----
Lead	7439-92-1	1.0	mg/kg	**6.7**	**9.5**	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP106.0_L	KP106_U_A	----	----	----
			Sampling date / time	06-Jan-2022 00:00	06-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200550-012	EB2200550-013	--------	--------	--------
				Result	Result	----	----	----
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**175**	**211**	----	----	----
Nickel	7440-02-0	1.0	mg/kg	**4.8**	**6.5**	----	----	----
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	----	----	----
Zinc	7440-66-6	1.0	mg/kg	**8.4**	**9.4**	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	**0.02**	**0.01**	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**220**	**170**	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**290**	**282**	----	----	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.18**	**0.14**	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	**5**	**7**	----	----	----
>C16 - C34 Fraction	----	3	mg/kg	**10**	**11**	----	----	----
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	----	----	----
>C10 - C40 Fraction (sum)	----	3	mg/kg	**15**	**18**	----	----	----
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	**5**	**7**	----	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	----	----	----
C10 - C14 Fraction	----	3	mg/kg	**8**	**13**	----	----	----
C15 - C28 Fraction	----	3	mg/kg	**8**	**9**	----	----	----
C29 - C36 Fraction	----	5	mg/kg	<5	<5	----	----	----
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**16**	**22**	----	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	----	----	----
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	----	----	----
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	----	----	----
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	----	----	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP106.0_L	KP106_U_A	----	----	----
			Sampling date / time	06-Jan-2022 00:00	06-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200550-012	EB2200550-013	--------	--------	--------
				Result	Result	----	----	----
EP080-SD: BTEXN - Continued								
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	----	----	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	----	----	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	----	----	----
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	----	----	----
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	----	----	----
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	----	----	----
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	----	----	----
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	----	----	----
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	----	----	----
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	----	----	----
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	----	----	----
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	----	----	----
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	----	----	----
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	----	----	----
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	----	----	----
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	----	----	----
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	----	----	----
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	----	----	----
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	----	----	----
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	----	----	----
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	----	----	----
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	----	----	----
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	----	----	----
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	----	----	----
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	----	----	----
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	----	----	----
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	----	----	----
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	----	----	----
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	----	----	----
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	----	----	----
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	----	----	----
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP106.0_L	KP106_U_A	----	----	----
			Sampling date / time	06-Jan-2022 00:00	06-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200550-012	EB2200550-013	--------	--------	--------
				Result	Result	----	----	----
EP131A: Organochlorine Pesticides - Continued								
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	----	----	----
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	----	----	----
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	----	----	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**87.5**	**90.0**	----	----	----
Toluene-D8	2037-26-5	0.2	%	**78.2**	**78.8**	----	----	----
4-Bromofluorobenzene	460-00-4	0.2	%	**90.3**	**92.0**	----	----	----
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**45.2**	**88.7**	----	----	----
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**46.6**	**45.2**	----	----	----
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**51.2**	**48.8**	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	EB	----	----	----	----
			Sampling date / time	06-Jan-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2200550-010	--------	--------	--------	--------
				Result	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	----	----	----	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ Total Xylenes	----	2	µg/L	<2	----	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**103**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**102**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**100**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP131A: Organochlorine Pesticides

(SOIL) EP131S: OC Pesticide Surrogate

(SOIL) EP131B: Polychlorinated Biphenyls (as Aroclors)

(SOIL) EP131T: PCB Surrogate

CERTIFICATE OF ANALYSIS

Work Order	: **EB2200737**	Page	: 1 of 16
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 12-Jan-2022 08:20
Order number	: ----	Date Analysis Commenced	: 13-Jan-2022
C-O-C number	: ----	Issue Date	: 28-Jan-2022 09:11
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 18		
No. of samples analysed	: 17		

Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2200737_002 (KP92-95_U_1) Shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP93-23_U' (EB2200737-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP120-6_U' (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- AES 6318477 T/O 6314877
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP120-6_U (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP92-95_U_1 (EB2200737-002) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EP071 (TRH Semivolatiles): Sample 'KP92-95_U_1' shows poor matrix spike recovery due to sample heterogeneity. Confirmed by re-extraction and re-analysis.
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.8	9.6	9.9	9.7	9.1
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.008	0.080	0.010	0.015	0.526
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	50	<10	<10	328
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	43.4	47.0	36.3	2.13	19.3
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	8680	9390	7250	425	3860
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	13.9	15.0	11.6	0.68	6.19
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	0.08	<0.02	<0.02	0.52
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	50	<10	<10	328
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	4	<1	<1	25
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	17.1	24.3	16.8	16.0	41.3
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	600	2620	760	340	9520
Iron	7439-89-6	50	mg/kg	8560	10700	10000	1680	29100
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	17.8	18.5	18.6	1.21	27.3
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	9.9	13.7	11.4	1.7	33.2
Copper	7440-50-8	1.0	mg/kg	<1.0	1.8	1.3	1.1	5.7
Cobalt	7440-48-4	0.5	mg/kg	1.2	2.5	1.4	<0.5	8.7
Lead	7439-92-1	1.0	mg/kg	2.4	3.8	2.7	24.1	10.6

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
Sampling date / time				08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
				EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**362**	**371**	**311**	<10	**173**
Nickel	7440-02-0	1.0	mg/kg	**1.7**	**3.7**	**2.3**	<1.0	**9.8**
Selenium	7782-49-2	0.1	mg/kg	**0.1**	**0.2**	**0.1**	<0.1	**0.6**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**1.8**	**5.1**	**2.8**	**1.6**	**17.2**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**60**	**160**	**60**	**50**	**210**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**315**	**283**	**312**	**44**	**210**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.04**	**0.60**	**0.05**	<0.02	**0.53**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	**3**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	**3**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	**3**	**3**	<3	**4**
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	**3**	**3**	<3	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ **Sum of Aldrin + Dieldrin**	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ **Total Polychlorinated biphenyls**	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**90.6**	**90.0**	**94.8**	**97.3**	**83.6**
Toluene-D8	2037-26-5	0.2	%	**81.0**	**84.0**	**82.3**	**89.3**	**77.6**
4-Bromofluorobenzene	460-00-4	0.2	%	**91.5**	**95.2**	**94.7**	**102**	**87.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**113**	**132**	**90.4**	**93.8**	**110**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**65.2**	**25.9**	**55.4**	**56.4**	**50.6**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**60.0**	**27.5**	**58.8**	**63.8**	**32.5**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.9**	**9.6**	**9.6**	**9.9**	**9.7**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.011**	**0.020**	**0.011**	**0.015**	**0.052**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	**13**	<10	<10	**33**
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**48.5**	**15.4**	**36.4**	**36.3**	**47.8**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**9700**	**3070**	**7280**	**7250**	**9560**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**15.6**	**4.92**	**11.7**	**11.6**	**15.3**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	**0.02**	<0.02	<0.02	**0.05**
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	**13**	<10	<10	**33**
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	**2**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**20.1**	**24.9**	**18.8**	**16.4**	**24.2**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**670**	**2430**	**2780**	**960**	**2670**
Iron	7439-89-6	50	mg/kg	**5540**	**18500**	**9710**	**10500**	**11800**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**12.8**	**14.6**	**12.6**	**19.8**	**18.3**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**6.4**	**15.6**	**13.3**	**15.0**	**16.4**
Copper	7440-50-8	1.0	mg/kg	<1.0	**2.1**	**2.0**	<1.0	**1.6**
Cobalt	7440-48-4	0.5	mg/kg	**0.9**	**3.0**	**2.8**	**1.4**	**2.4**
Lead	7439-92-1	1.0	mg/kg	**1.9**	**7.8**	**4.1**	**2.9**	**3.8**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	250	167	177	512	397
Nickel	7440-02-0	1.0	mg/kg	1.5	3.3	3.8	2.1	3.6
Selenium	7782-49-2	0.1	mg/kg	<0.1	0.2	0.2	0.1	0.2
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	1.3	6.5	7.6	1.7	5.4
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	90	240	170	50	140
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	346	340	262	247	335
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.06	0.14	0.11	0.05	0.12
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	10	6	<3	4
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	10	9	<3	4
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	3	4	4	3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	4	<3	4
C29 - C36 Fraction	----	5	mg/kg	<5	8	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	3	12	8	3	4
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**80.1**	**84.2**	**89.4**	**97.6**	**88.5**
Toluene-D8	2037-26-5	0.2	%	**70.2**	**76.8**	**81.4**	**88.9**	**82.6**
4-Bromofluorobenzene	460-00-4	0.2	%	**80.0**	**88.4**	**91.2**	**98.2**	**91.8**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**106**	**121**	**84.3**	**103**	**128**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**46.1**	**44.9**	**56.7**	**48.9**	**55.8**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**47.5**	**52.5**	**52.5**	**68.8**	**55.0**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.4	9.2	9.4	9.9	9.9
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.042	0.340	0.102	0.010	0.014
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	26	212	64	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	14.2	40.8	23.6	35.0	45.5
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	2830	8160	4720	6990	9090
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	4.54	13.1	7.56	11.2	14.6
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.04	0.34	0.10	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	26	212	64	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	2	16	5	<1	<1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	29.7	35.8	32.4	19.2	7.7
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	5840	6700	5590	720	760
Iron	7439-89-6	50	mg/kg	32300	24700	22200	7960	8110
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	11.0	26.6	20.5	19.6	16.5
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	28.5	27.8	37.0	9.3	11.6
Copper	7440-50-8	1.0	mg/kg	6.1	3.6	3.2	<1.0	<1.0
Cobalt	7440-48-4	0.5	mg/kg	4.2	7.0	5.9	1.1	1.2
Lead	7439-92-1	1.0	mg/kg	13.4	9.5	9.8	2.4	2.4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	102	156	212	228	316
Nickel	7440-02-0	1.0	mg/kg	5.3	7.6	6.5	1.7	1.9
Selenium	7782-49-2	0.1	mg/kg	0.3	0.4	0.3	0.1	0.1
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	10.2	12.1	11.0	1.6	1.8
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	110	40	60	60	80
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	181	27	35	292	355
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.15	0.56	0.20	0.04	0.06
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	4	3	4	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	4	3	4	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	3	<3	4	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	3	<3	7	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**62.9**	**62.8**	**65.4**	**70.9**	**73.7**
Toluene-D8	2037-26-5	0.2	%	**55.0**	**53.9**	**56.7**	**61.8**	**63.9**
4-Bromofluorobenzene	460-00-4	0.2	%	**64.3**	**70.2**	**74.9**	**79.0**	**84.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**78.4**	**90.8**	**127**	**127**	**81.1**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**60.5**	**59.5**	**55.1**	**37.7**	**65.4**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**62.5**	**65.0**	**62.5**	**50.0**	**63.8**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Sample ID*	**TB**	**FB**	**----**	**----**	**----**
			Sampling date / time	10-Jan-2022 00:00	10-Jan-2022 00:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB2200737-010**	**EB2200737-011**	--------	--------	--------
				Result	Result	----	----	----
EP071: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	50	µg/L	----	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	----	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	----	<50	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	----	<50	----	----	----
EP071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	100	µg/L	----	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	----	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	----	<100	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	----	<100	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ **Total Xylenes**	----	2	µg/L	<2	----	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**115**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**97.4**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**98.7**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP131A: Organochlorine Pesticides

(SOIL) EP131S: OC Pesticide Surrogate

(SOIL) EP131B: Polychlorinated Biphenyls (as Aroclors)

(SOIL) EP131T: PCB Surrogate

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<1
Analysis Date		29/10/2021	29/10/2021	29/10/2021	2/11/2021	2/11/2021	2/11/2021	2/11/2021	1/11/2021
File		21102902	21102902	21102902	21110201,1001,1701,1702		21110201,1201	21110201,1201	211101-11
OP1S	16/10/2021	<3	3	<2	9	120	0.9	0.2	2.7
OP1B	16/10/2021	12	7	15	14	100	0.4	<0.2	3.2
OP2S	16/10/2021	<3	3	<2	9	100	1.2	0.2	1.8
OP2B	16/10/2021	4	6	5	15	100	0.5	<0.2	4.1
OP3S	16/10/2021	<3	<2	<2	9	130	1.2	0.4	3.0
OP3B	16/10/2021	3	6	11	14	100	0.5	<0.2	2.6
OP4S	16/10/2021	<3	<2	<2	13	150	1.2	0.5	2.5
OP4B	16/10/2021	4	6	6	13	100	0.7	<0.2	2.0
OP5S	16/10/2021	7	2	<2	12	130	1.0	0.5	2.5
OP5B	16/10/2021	<3	5	3	14	140	1.1	<0.2	2.0
OP6S	16/10/2021	<3	3	<2	13	140	1.0	0.6	3.0
OP6B	16/10/2021	4	6	2	12	80	1.3	0.5	2.7
OP7S	17/10/2021	<3	3	<2	11	110	1.5	0.3	1.7
OP7B	17/10/2021	3	4	4	13	110	0.8	0.2	1.7
OP8S	17/10/2021	<3	3	<2	14	110	0.6	<0.2	2.0
OP8B	17/10/2021	<3	2	<2	13	110	0.8	<0.2	3.5
OP9S	17/10/2021	<3	4	<2	12	100	0.7	<0.2	2.6
OP9B	17/10/2021	6	4	9	12	110	1.0	<0.2	3.1
OP10S	17/10/2021	<3	6	<2	16	90	0.8	<0.2	8.6

Signatory: Jamie Woodward
Date: 19/11/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater
Research Laboratory
Environmental Science
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NATA
WORLD RECOGNISED ACCREDITATION

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WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD	Sampling	2000	4100	2100	4700	2700	3000	3000	2540D
SAMPLE CODE	Date	AMMONIA	ORTHO-P	NO3+NO2	TOTAL-P	TOTAL-N	CHLOROPHYLL'a'	PHAEOPHYTIN'a'	TSS
		µg.N/L	µg.P/L	µg.N/L	µg.P/L	µg.N/L	µg/L	µg/L	mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<1
Analysis Date		29/10/2021	29/10/2021	29/10/2021	2/11/2021	2/11/2021	2/11/2021	2/11/2021	1/11/2021
File		21102902	21102902	21102902	21110201,1001,1701,1702		21110201,1201	21110201,1201	211101-11
SG1S	18/10/2021	<3	5	<2	12	110	0.4	<0.2	2.6
SG1B	18/10/2021	<3	6	<2	13	120	0.3	<0.2	2.7
SG12S	18/10/2021	<3	6	<2	11	100	0.4	<0.2	5.8
SG12B	18/10/2021	13	4	12	14	120	0.5	<0.2	2.4
SG13S	18/10/2021	<3	6	<2	16	100	0.5	<0.2	2.1
SG13B	18/10/2021	<3	5	<2	13	100	0.5	<0.2	3.9
SG8S	18/10/2021	<3	9	<2	14	90	0.4	<0.2	3.0
SG8B	18/10/2021	<3	5	<2	14	110	0.4	<0.2	3.7
SG4S	18/10/2021	<3	6	<2	14	100	0.4	<0.2	2.7
SG4B	18/10/2021	5	6	<2	13	110	0.3	<0.2	4.4
OP10B	17/10/2021	4	8	4	17	110	0.6	0.3	7.7
SG7S	17/10/2021	<3	6	<2	13	100	0.5	<0.2	1.4
SG7B	17/10/2021	<3	6	<2	13	100	0.5	<0.2	4.8
SG11S	17/10/2021	<3	6	<2	14	110	0.2	<0.2	2.1
SG11B	17/10/2021	3	5	4	14	110	0.4	<0.2	3.8
Triplicate A	17/10/2021	<3	3	<2	10	100	0.8	<0.2	2.3
Triplicate B	17/10/2021	<3	3	<2	11	110	0.6	<0.2	2.1
Triplicate C	18/10/2021	<3	6	<2	13	110	0.4	<0.2	6.2
Triplicate D	18/10/2021	<3	6	<2	14	110	0.3	<0.2	5.7

Signatory: Jamie Woodward
Date: 19/11/2021

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WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	2000 AMMONIA µg.N/L	4100 ORTHO-P µg.P/L	2100 NO3+NO2 µg.N/L	4700 TOTAL-P µg.P/L	2700 TOTAL-N µg.N/L	3000 CHLOROPHYLL'a' µg/L	3000 PHAEOPHYTIN'a' µg/L	2540D TSS mg/L
Reporting Limit		<3	<2	<2	<5	<50	<0.1	<0.2	<1
Analysis Date		29/10/2021	29/10/2021	29/10/2021	2/11/2021	2/11/2021	2/11/2021	2/11/2021	1/11/2021
File		21102902	21102902	21102902	21110201,1001,1701,1702		21110201,1201	21110201,1201	211101-11
Field Blank	18/10/2021	<3	<2	4	<5	<50			
Equipment Blank	18/10/2021	4	<2	2	<5	<50	<0.1	<0.2	<0.5
Trip Blank		<3	<2	<2	<5	<50			

Note: For results for compliance purposes uncertainity of measurement (MU) will sometimes affect the interpretation whether the result passes or fails the compliance limit.
Tables for measurement uncertainity are available online at www.mafrl.murdoch.edu.au

Signatory: Jamie Woodward
Date: 19/11/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr	Filtered Co	Filtered Ni	Filtered Cu	Filtered Zn	Filtered As	Filtered Cd	Filtered Pb	Hg
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.1	<0.0001
Analysis Date		15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	29/10/2021
File		21111501	21111501	21111501	21111501	21111501	21111501	21111501	21111501	21102902
OP1S	16/10/2021	<0.2	<0.05	1.5	0.4	4	1.4	<0.1	0.2	<0.0001
OP1B	16/10/2021	0.2	<0.05	<0.3	0.4	9	1.9	<0.1	0.3	<0.0001
OP2S	16/10/2021	0.2	<0.05	<0.3	8.4	8	1.7	<0.1	0.8	<0.0001
OP2B	16/10/2021	<0.2	<0.05	<0.3	0.3	2	1.8	<0.1	<0.1	<0.0001
OP3S	16/10/2021	0.2	<0.05	<0.3	0.3	3	1.3	<0.1	0.3	<0.0001
OP3B	16/10/2021	<0.2	<0.05	<0.3	1.2	7	1.9	<0.1	0.1	<0.0001
OP4S	16/10/2021	0.2	<0.05	<0.3	0.5	2	1.4	<0.1	0.2	<0.0001
OP4B	16/10/2021	<0.2	<0.05	<0.3	0.4	2	1.9	<0.1	<0.1	<0.0001
OP5S	16/10/2021	0.2	<0.05	<0.3	0.5	8	1.3	<0.1	5.4	<0.0001
OP5B	16/10/2021	0.2	<0.05	<0.3	0.3	3	1.9	<0.1	0.2	<0.0001
OP6S	16/10/2021	<0.2	<0.05	<0.3	0.2	2	1.5	<0.1	0.3	<0.0001
OP6B	16/10/2021	<0.2	<0.05	<0.3	0.5	2	1.8	<0.1	<0.1	<0.0001
OP7S	17/10/2021	0.2	<0.05	<0.3	0.4	2	1.5	<0.1	<0.1	<0.0001
OP7B	17/10/2021	<0.2	<0.05	<0.3	0.4	2	1.8	<0.1	0.3	<0.0001
OP8S	17/10/2021	0.2	<0.05	<0.3	0.4	3	1.7	<0.1	0.1	<0.0001
OP8B	17/10/2021	<0.2	<0.05	<0.3	0.2	3	1.8	<0.1	0.3	<0.0001
OP9S	17/10/2021	<0.2	<0.05	<0.3	0.5	3	1.8	<0.1	0.2	<0.0001
OP9B	17/10/2021	<0.2	<0.05	<0.3	0.4	3	1.9	<0.1	<0.1	<0.0001
OP10S	17/10/2021	<0.2	<0.05	<0.3	0.3	1	1.9	<0.1	0.2	<0.0001

Signatory: Jamie Woodward
Date: 19/11/2021

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Marine and Freshwater Research Laboratory
Environmental Science
Tel: 08 93602907 Address: 90 South St, Murdoch, WA, 6150

Accreditation Number: 10603
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NATA
WORLD RECOGNISED ACCREDITATION

Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD	Sampling	MS001	MS001	MS001	MS001	MS001	MS001	MS001	MS001	ICP006
SAMPLE CODE	Date	Filtered Cr	Filtered Co	Filtered Ni	Filtered Cu	Filtered Zn	Filtered As	Filtered Cd	Filtered Pb	Hg
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.1	<0.0001
Analysis Date		15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	29/10/2021
File		21111501	21111501	21111501	21111501	21111501	21111501	21111501	21111501	21102902
SG1S	18/10/2021	<0.2	<0.05	<0.3	0.3	8	1.8	<0.1	0.2	<0.0001
SG1B	18/10/2021	<0.2	<0.05	<0.3	0.3	6	1.8	<0.1	0.1	<0.0001
SG12S	18/10/2021	<0.2	<0.05	<0.3	<0.2	7	1.8	<0.1	<0.1	<0.0001
SG12B	18/10/2021	<0.2	<0.05	<0.3	0.2	6	1.8	<0.1	0.1	<0.0001
SG13S	18/10/2021	<0.2	<0.05	<0.3	<0.2	2	1.9	<0.1	0.2	<0.0001
SG13B	18/10/2021	<0.2	<0.05	0.3	0.3	2	1.8	<0.1	<0.1	<0.0001
SG8S	18/10/2021	<0.2	<0.05	<0.3	0.3	3	1.9	<0.1	<0.1	<0.0001
SG8B	18/10/2021	<0.2	<0.05	<0.3	0.3	2	1.9	<0.1	<0.1	<0.0001
SG4S	18/10/2021	<0.2	<0.05	<0.3	<0.2	2	1.8	<0.1	<0.1	<0.0001
SG4B	18/10/2021	<0.2	<0.05	0.4	0.4	18	1.9	<0.1	0.3	<0.0001
OP10B	17/10/2021	<0.2	<0.05	<0.3	<0.2	2	1.9	<0.1	<0.1	<0.0001
SG7S	17/10/2021	<0.2	<0.05	<0.3	0.2	3	1.6	<0.1	0.4	<0.0001
SG7B	17/10/2021	<0.2	<0.05	<0.3	<0.2	8	1.7	<0.1	0.4	<0.0001
SG11S	17/10/2021	<0.2	<0.05	<0.3	0.4	2	1.8	<0.1	0.1	<0.0001
SG11B	17/10/2021	<0.2	<0.05	<0.3	0.3	3	1.6	<0.1	0.2	<0.0001
Triplicate A	17/10/2021	<0.2	<0.05	<0.3	0.3	2	1.9	<0.1	0.1	<0.0001
Triplicate B	17/10/2021	<0.2	<0.05	<0.3	0.3	5	1.9	<0.1	0.3	<0.0001
Triplicate C	18/10/2021	<0.2	<0.05	0.3	0.2	6	1.9	<0.1	<0.1	<0.0001
Triplicate D	18/10/2021	<0.2	<0.05	<0.3	<0.2	14	1.6	<0.1	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 19/11/2021

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Environmental Science
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Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	MS001 Filtered Cr µg/L	MS001 Filtered Co µg/L	MS001 Filtered Ni µg/L	MS001 Filtered Cu µg/L	MS001 Filtered Zn µg/L	MS001 Filtered As µg/L	MS001 Filtered Cd µg/L	MS001 Filtered Pb µg/L	ICP006 Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.1**	**<0.0001**
Analysis Date		**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**29/10/2021**
File		**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21102902**
Field Blank	18/10/2021	<0.2	<0.05	<0.3	<0.2	1	<0.5	<0.1	<0.1	<0.0001
Equipment Blank	18/10/2021	<0.2	<0.05	<0.3	<0.2	6	<0.5	<0.1	0.3	<0.0001
Trip Blank		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.1	<0.0001

Note: Samples supplied field filtered

Signatory: Jamie Woodward
Date: 19/11/2021

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WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.1**	**<0.0001**
Analysis Date		**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**29/10/2021**
File		**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21102902**
OP1S	16/10/2021	0.3	<0.05	<0.3	1.6	9	1.6	<0.1	0.2	<0.0001
OP1B	16/10/2021	0.2	<0.05	<0.3	0.4	4	1.9	<0.1	<0.1	<0.0001
OP2S	16/10/2021	0.2	<0.05	<0.3	0.3	2	1.7	<0.1	0.2	<0.0001
OP2B	16/10/2021	<0.2	<0.05	<0.3	0.3	2	1.8	<0.1	<0.1	<0.0001
OP3S	16/10/2021	0.2	<0.05	<0.3	0.6	1	1.8	<0.1	0.3	<0.0001
OP3B	16/10/2021	0.2	<0.05	<0.3	0.7	2	1.8	<0.1	<0.1	<0.0001
OP4S	16/10/2021	0.2	<0.05	<0.3	0.6	2	1.9	<0.1	0.2	<0.0001
OP4B	16/10/2021	0.2	<0.05	0.5	0.4	2	1.8	<0.1	0.1	<0.0001
OP5S	16/10/2021	<0.2	<0.05	<0.3	0.5	9	1.9	<0.1	1.4	<0.0001
OP5B	16/10/2021	0.2	<0.05	<0.3	0.3	1	1.9	<0.1	<0.1	<0.0001
OP6S	16/10/2021	<0.2	<0.05	<0.3	1.1	2	1.9	<0.1	0.3	<0.0001
OP6B	16/10/2021	0.2	<0.05	<0.3	0.5	2	1.9	<0.1	0.1	<0.0001
OP7S	17/10/2021	0.2	<0.05	<0.3	0.5	3	1.8	<0.1	0.1	<0.0001
OP7B	17/10/2021	<0.2	<0.05	<0.3	0.4	2	1.8	<0.1	0.3	<0.0001
OP8S	17/10/2021	<0.2	<0.05	<0.3	0.4	3	1.7	<0.1	<0.1	<0.0001
OP8B	17/10/2021	<0.2	<0.05	<0.3	0.5	2	1.9	<0.1	0.2	<0.0001
OP9S	17/10/2021	<0.2	<0.05	<0.3	0.5	2	1.9	<0.1	<0.1	<0.0001
OP9B	17/10/2021	<0.2	<0.05	<0.3	0.4	2	1.8	<0.1	<0.1	<0.0001
OP10S	17/10/2021	0.2	<0.05	<0.3	0.3	1	1.9	<0.1	0.2	<0.0001

Signatory: Jamie Woodward
Date: 19/11/2021

The results only apply to the sample as received and to the sample tested.
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Environmental Science
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Murdoch UNIVERSITY

WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.1	<0.0001
Analysis Date		15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	15/11/2021	29/10/2021
File		21111501	21111501	21111501	21111501	21111501	21111501	21111501	21111501	21102902
SG1S	18/10/2021	<0.2	<0.05	<0.3	0.3	2	1.9	<0.1	0.1	<0.0001
SG1B	18/10/2021	<0.2	<0.05	<0.3	0.2	<1	1.8	<0.1	<0.1	<0.0001
SG12S	18/10/2021	<0.2	<0.05	<0.3	0.5	2	1.9	<0.1	0.1	<0.0001
SG12B	18/10/2021	<0.2	<0.05	<0.3	0.2	1	1.8	<0.1	0.2	<0.0001
SG13S	18/10/2021	<0.2	<0.05	<0.3	0.4	2	1.9	<0.1	0.2	<0.0001
SG13B	18/10/2021	<0.2	<0.05	<0.3	0.4	2	1.9	<0.1	0.1	<0.0001
SG8S	18/10/2021	<0.2	<0.05	<0.3	0.3	<1	1.8	<0.1	<0.1	<0.0001
SG8B	18/10/2021	<0.2	<0.05	<0.3	0.3	1	1.9	<0.1	0.1	<0.0001
SG4S	18/10/2021	<0.2	<0.05	<0.3	0.3	1	1.9	<0.1	0.1	<0.0001
SG4B	18/10/2021	<0.2	<0.05	<0.3	0.2	1	1.7	<0.1	0.1	<0.0001
OP10B	17/10/2021	0.3	0.06	<0.3	<0.2	<1	1.7	<0.1	<0.1	<0.0001
SG7S	17/10/2021	<0.2	<0.05	<0.3	0.3	3	1.8	<0.1	0.3	<0.0001
SG7B	17/10/2021	<0.2	<0.05	<0.3	<0.2	<1	1.8	<0.1	0.1	<0.0001
SG11S	17/10/2021	<0.2	<0.05	<0.3	0.6	<1	1.8	<0.1	<0.1	<0.0001
SG11B	17/10/2021	<0.2	<0.05	<0.3	0.3	1	1.7	<0.1	0.2	<0.0001
Triplicate A	17/10/2021	0.2	<0.05	<0.3	0.6	4	1.9	<0.1	<0.1	<0.0001
Triplicate B	17/10/2021	0.3	<0.05	0.4	1.6	3	1.9	<0.1	<0.1	<0.0001
Triplicate C	18/10/2021	<0.2	<0.05	<0.3	<0.2	2	1.9	<0.1	<0.1	<0.0001
Triplicate D	18/10/2021									<0.0001

Signatory: Jamie Woodward
Date: 19/11/2021

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WATER QUALITY DATA

Contact: Natalie Robson
Customer: RPS Australia Asia Pacific
Address: Level 2, 27-31 Troode Street, West Perth WA 6005

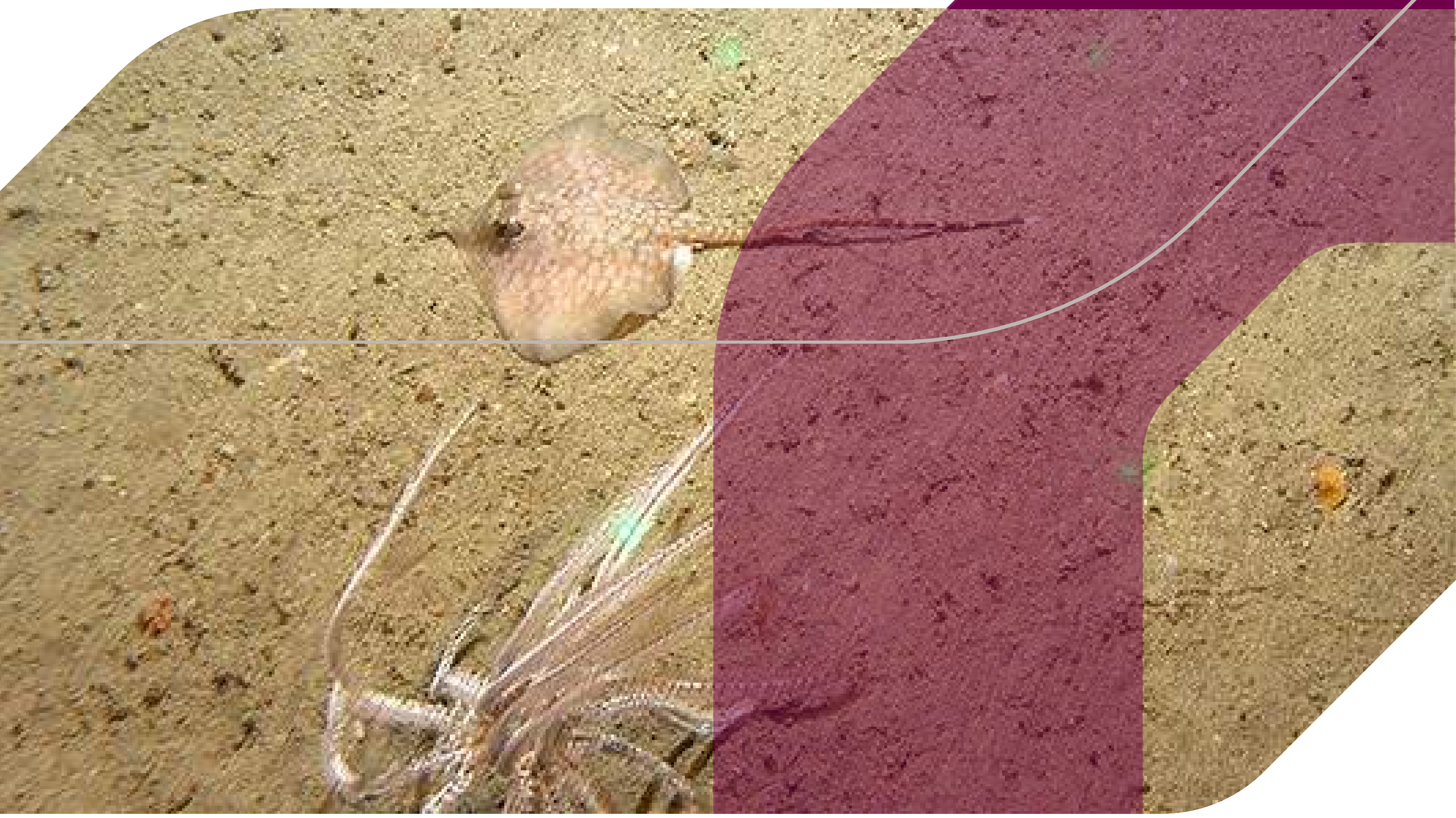
Date of Issue: 19/11/2021
Date Received: 25/10/2021
Our Reference: RPS21-3
Your Reference: AU213002038.001

METHOD SAMPLE CODE	Sampling Date	MS001 Unfiltered Cr µg/L	MS001 Unfiltered Co µg/L	MS001 Unfiltered Ni µg/L	MS001 Unfiltered Cu µg/L	MS001 Unfiltered Zn µg/L	MS001 Unfiltered As µg/L	MS001 Unfiltered Cd µg/L	MS001 Unfiltered Pb µg/L	ICP006 Total Ext Hg mg/L
Reporting Limit		**<0.2**	**<0.05**	**<0.3**	**<0.2**	**<1**	**<0.5**	**<0.1**	**<0.1**	**<0.0001**
Analysis Date		**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**15/11/2021**	**29/10/2021**
File		**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21111501**	**21102902**
Field Blank	18/10/2021	<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.1	<0.0001
Equipment Blank	18/10/2021	<0.2	<0.05	<0.3	<0.2	2	<0.5	<0.1	<0.1	<0.0001
Trip Blank		<0.2	<0.05	<0.3	<0.2	<1	<0.5	<0.1	<0.1	<0.0001

Signatory: Jamie Woodward
Date: 19/11/2021

The results only apply to the sample as received and to the sample tested.
Spare test items will be held for two months unless otherwise requested.

Appendix H
Laboratory sediment and water hydrocarbon, pesticides, tributyl tin and acid sulfate soils data



CERTIFICATE OF ANALYSIS

Work Order	: **ES2137956**	Page	: 1 of 13
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Sydney
Contact	: Natalie Robson	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: RPS Sediment & Water Quality	Date Samples Received	: 21-Oct-2021 06:30
Order number	: ----	Date Analysis Commenced	: 22-Oct-2021
C-O-C number	: ----	Issue Date	: 28-Oct-2021 13:54
Sampler	: Natalie Robson		
Site	: Timor Sea		
Quote number	: EP/145/21		
No. of samples received	: 45		
No. of samples analysed	: 45		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Surrogate recovery bias low due to sample matrix interferences, confirmed by re-extraction and re-analysis.

Analytical Results

Sub-Matrix: **SAND** (Matrix: **SOIL**)			*Sample ID*	**OP10**	**OP11**	**OP12**	**OP13**	**OP14**
			Sampling date / time	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES2137956-046**	**ES2137956-047**	**ES2137956-048**	**ES2137956-049**	**ES2137956-050**
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**29.3**	**30.5**	**30.0**	**26.6**	**25.3**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**76.3**	**92.3**	**99.8**	**101**	**100**
Toluene-D8	2037-26-5	0.2	%	**75.0**	**87.3**	**93.9**	**93.4**	**92.3**
4-Bromofluorobenzene	460-00-4	0.2	%	**77.4**	**80.6**	**84.6**	**82.3**	**84.7**

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	OP15	OP16	OP17	OP18	OP19
			Sampling date / time	15-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137956-051	ES2137956-052	ES2137956-053	ES2137956-054	ES2137956-055
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	30.8	33.5	32.1	38.2	35.4
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	97.5	102	92.4	90.5	86.6
Toluene-D8	2037-26-5	0.2	%	83.6	91.2	84.5	80.9	78.2
4-Bromofluorobenzene	460-00-4	0.2	%	87.2	82.2	79.4	73.5	73.7

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	OP20	OP21	OP22	OP23	OP24
			Sampling date / time	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	17-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137956-056	ES2137956-057	ES2137956-058	ES2137956-059	ES2137956-060
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	39.3	37.0	32.6	39.4	37.0
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	83.7	100	94.1	115	112
Toluene-D8	2037-26-5	0.2	%	79.2	91.2	74.2	89.0	89.5
4-Bromofluorobenzene	460-00-4	0.2	%	73.0	82.0	78.3	86.7	89.7

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	OP25	OP26	OP27	OP28	OP29
			Sampling date / time	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137956-061	ES2137956-062	ES2137956-063	ES2137956-064	ES2137956-065
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**37.6**	**41.1**	**43.8**	**39.0**	**38.4**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**107**	**80.6**	**75.6**	**96.6**	**97.0**
Toluene-D8	2037-26-5	0.2	%	**93.1**	**79.7**	**75.4**	**83.3**	**81.1**
4-Bromofluorobenzene	460-00-4	0.2	%	**89.7**	**80.3**	**98.4**	**84.0**	**83.2**

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	OP30	SG1	SG2	SG3	SG4
			Sampling date / time	17-Oct-2021 00:00	18-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137956-066	ES2137956-071	ES2137956-072	ES2137956-073	ES2137956-074
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	49.3	39.8	38.4	37.5	40.8
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	81.4	110	103	96.3	93.4
Toluene-D8	2037-26-5	0.2	%	75.9	90.9	81.6	79.8	76.0
4-Bromofluorobenzene	460-00-4	0.2	%	77.5	92.3	84.2	80.3	80.3

Analytical Results

Sub-Matrix: **SAND** (Matrix: **SOIL**)			*Sample ID*	**SG5**	**SG6**	**SG7**	**SG8**	**SG9**
			Sampling date / time	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES2137956-075**	**ES2137956-076**	**ES2137956-077**	**ES2137956-078**	**ES2137956-079**
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**36.3**	**38.8**	**37.4**	**40.5**	**38.5**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ **C10 - C36 Fraction (sum)**	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ **Total Xylenes**	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ **Sum of BTEX**	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**117**	**95.2**	**127**	**75.7**	**91.2**
Toluene-D8	2037-26-5	0.2	%	**116**	**81.0**	**123**	**57.2**	**74.5**
4-Bromofluorobenzene	460-00-4	0.2	%	**106**	**81.8**	**112**	**64.8**	**76.5**

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	SG10	SG11	SG12	SG13	Triplicate A
			Sampling date / time	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	15-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137956-080	ES2137956-081	ES2137956-082	ES2137956-083	ES2137956-084
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**36.8**	**35.1**	**37.0**	**38.0**	**27.0**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**86.6**	**85.6**	**102**	**115**	**107**
Toluene-D8	2037-26-5	0.2	%	**79.2**	**74.9**	**97.6**	**108**	**107**
4-Bromofluorobenzene	460-00-4	0.2	%	**77.4**	**73.1**	**86.8**	**99.8**	**94.8**

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	Triplicate B	Duplicate A	Triplicate C	Trip Blank	----
			Sampling date / time	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	18-Oct-2021 00:00	----
Compound	CAS Number	LOR	Unit	ES2137956-085	ES2137956-086	ES2137956-087	ES2137956-089	--------
				Result	Result	Result	Result	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	42.4	40.2	43.0	1.4	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	----
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	----
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	----
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	----
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	----
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	----
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	103	95.4	102	104	----
Toluene-D8	2037-26-5	0.2	%	105	95.3	101	105	----
4-Bromofluorobenzene	460-00-4	0.2	%	87.3	82.7	87.1	88.4	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	Triplicate A	Triplicate B	Triplicate C	Triplicate D	Equip Blank
			Sampling date / time	17-Oct-2021 00:00	17-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137956-067	ES2137956-068	ES2137956-069	ES2137956-070	ES2137956-088
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	----	<50	<50	----
C15 - C28 Fraction	----	100	µg/L	<100	----	<100	<100	----
C29 - C36 Fraction	----	50	µg/L	<50	----	<50	<50	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	----	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	----	<100	<100	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	<100	<100	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	<100	<100	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	----	<100	<100	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	----	<100	<100	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**131**	**107**	**131**	**131**	**120**
Toluene-D8	2037-26-5	2	%	**127**	**106**	**126**	**131**	**121**
4-Bromofluorobenzene	460-00-4	2	%	**118**	**101**	**118**	**119**	**113**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	Field Blank	----	----	----	----
			Sampling date / time	18-Oct-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	ES2137956-090	--------	--------	--------	--------
				Result	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ **Total Xylenes**	----	2	µg/L	<2	----	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**108**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**106**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**99.5**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SAND**

Compound	CAS Number	Recovery Limits (%) Low	Recovery Limits (%) High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	67	137
Toluene-D8	2037-26-5	74	134
4-Bromofluorobenzene	460-00-4	73	137

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	Recovery Limits (%) High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2137835**	Page	: 1 of 13
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Sydney
Contact	: Natalie Robson	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: RPS Sediment & Water Quality	Date Samples Received	: 21-Oct-2021 06:30
Order number	: ----	Date Analysis Commenced	: 22-Oct-2021
C-O-C number	: ----	Issue Date	: 28-Oct-2021 13:54
Sampler	: Natalie Robson		
Site	: Timor Sea		
Quote number	: EP/145/21		
No. of samples received	: 45		
No. of samples analysed	: 45		

NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	OP1	OP2	OP3	OP4	OP5
			Sampling date / time	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137835-038	ES2137835-039	ES2137835-040	ES2137835-041	ES2137835-042
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**27.2**	**28.2**	**37.9**	**28.4**	**26.6**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**104**	**99.9**	**90.3**	**104**	**91.4**
Toluene-D8	2037-26-5	0.2	%	**85.9**	**86.5**	**81.5**	**91.1**	**95.0**
4-Bromofluorobenzene	460-00-4	0.2	%	**79.8**	**73.8**	**81.6**	**81.8**	**85.1**

Analytical Results

Sub-Matrix: SAND (Matrix: SOIL)			Sample ID	OP6	OP7	OP9	----	----
			Sampling date / time	15-Oct-2021 00:00	15-Oct-2021 00:00	15-Oct-2021 00:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	ES2137835-043	ES2137835-044	ES2137835-045	--------	--------
				Result	Result	Result	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**30.2**	**28.8**	**32.6**	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	----	----
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	----	----
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	----	----
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	----	----
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	----	----
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	----	----
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	----	----
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	----	----
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	----	----
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	----	----
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	----	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**115**	**93.8**	**109**	----	----
Toluene-D8	2037-26-5	0.2	%	**105**	**90.6**	**96.3**	----	----
4-Bromofluorobenzene	460-00-4	0.2	%	**93.9**	**74.6**	**85.4**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	OP1S	OP1B	OP2S	OP2B	OP3S
			Sampling date / time	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137835-001	ES2137835-002	ES2137835-003	ES2137835-004	ES2137835-005
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**122**	**130**	**115**	**126**	**122**
Toluene-D8	2037-26-5	2	%	**114**	**117**	**106**	**118**	**105**
4-Bromofluorobenzene	460-00-4	2	%	**118**	**122**	**110**	**124**	**114**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	OP3B	OP4S	OP4B	OP5S	OP5B
			Sampling date / time	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00	16-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137835-006	ES2137835-007	ES2137835-008	ES2137835-009	ES2137835-010
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**120**	**111**	**126**	**123**	**126**
Toluene-D8	2037-26-5	2	%	**110**	**103**	**111**	**109**	**116**
4-Bromofluorobenzene	460-00-4	2	%	**112**	**107**	**113**	**111**	**122**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	OP6S	OP6B	OP7S	OP7B	OP8S
			Sampling date / time	16-Oct-2021 00:00	16-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*	ES2137835-011	ES2137835-012	ES2137835-013	ES2137835-014	ES2137835-015
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**128**	**115**	**124**	**124**	**126**
Toluene-D8	2037-26-5	2	%	**113**	**105**	**112**	**110**	**113**
4-Bromofluorobenzene	460-00-4	2	%	**116**	**107**	**115**	**109**	**115**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	OP8B	OP9S	OP9B	OP10S	OP10B
			Sampling date / time	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137835-016	ES2137835-017	ES2137835-018	ES2137835-019	ES2137835-020
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**117**	**128**	**129**	**118**	**126**
Toluene-D8	2037-26-5	2	%	**108**	**116**	**119**	**109**	**108**
4-Bromofluorobenzene	460-00-4	2	%	**110**	**120**	**121**	**111**	**108**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	SG1S	SG1B	SG12S	SG12B	SG13S
			Sampling date / time	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137835-021	ES2137835-022	ES2137835-023	ES2137835-024	ES2137835-025
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	----	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**123**	**116**	**114**	**117**	**114**
Toluene-D8	2037-26-5	2	%	**110**	**104**	**102**	**106**	**102**
4-Bromofluorobenzene	460-00-4	2	%	**108**	**103**	**102**	**103**	**98.4**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			*Sample ID*	**SG13B**	**SG8S**	**SG8B**	**SG4S**	**SG4B**
			Sampling date / time	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00	18-Oct-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES2137835-026**	**ES2137835-027**	**ES2137835-028**	**ES2137835-029**	**ES2137835-030**
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	<100
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**117**	**108**	**121**	**116**	**118**
Toluene-D8	2037-26-5	2	%	**106**	**96.4**	**111**	**104**	**107**
4-Bromofluorobenzene	460-00-4	2	%	**104**	**92.8**	**107**	**101**	**96.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	SG7S	SG7B	SG11S	SG11B	Trip Blank
			Sampling date / time	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	17-Oct-2021 00:00	18-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2137835-031	ES2137835-032	ES2137835-033	ES2137835-034	ES2137835-035
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	<100	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	<50	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	<50	<50	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	<100	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	<100	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	<100	<100	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	<100	<100	<100	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ **Total Xylenes**	----	2	µg/L	<2	<2	<2	<2	<2
^ **Sum of BTEX**	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**102**	**116**	**120**	**116**	**119**
Toluene-D8	2037-26-5	2	%	**89.4**	**104**	**108**	**111**	**107**
4-Bromofluorobenzene	460-00-4	2	%	**91.6**	**102**	**105**	**105**	**101**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	Equip Blank	Field Blank	----	----	----
			Sampling date / time	18-Oct-2021 00:00	18-Oct-2021 00:00	----	----	----
Compound	CAS Number	LOR	Unit	ES2137835-036	ES2137835-037	--------	--------	--------
				Result	Result	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	----	----	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	----	----	----
Toluene	108-88-3	2	µg/L	<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	----	----	----
^ Total Xylenes	----	2	µg/L	<2	<2	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**118**	**114**	----	----	----
Toluene-D8	2037-26-5	2	%	**112**	**105**	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**105**	**98.2**	----	----	----

Surrogate Control Limits

Sub-Matrix: **SAND**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	67	137
Toluene-D8	2037-26-5	74	134
4-Bromofluorobenzene	460-00-4	73	137

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2136788**	Page	: 1 of 49
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Sydney
Contact	: Natalie Robson	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: Sediment Quality	Date Samples Received	: 27-Oct-2021 07:00
Order number	: ----	Date Analysis Commenced	: 28-Oct-2021
C-O-C number	: ----	Issue Date	: 09-Nov-2021 16:51
Sampler	: Natalie Robson		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 54		
No. of samples analysed	: 54		

Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Evie Sidarta	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Franco Lentini	LCMS Coordinator	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW
Morgan Lennox	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Wisam Marassa	Inorganics Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP090 Organotins: High LCS recovery for MBT deemed acceptable as all associated analyte results are less than LOR.
- EP090-Organotins: High surrogate recovery for particular samples are deemed acceptable as all associated analyte results are less than LOR.
- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- EP131B : LOR is raised due to high amount of moistures is present.
- EG020: Poor precision was obtained for some elements on samples ES2136788 - #001, #011 and #32 due to sample heterogeneity. Results have been confirmed by re-extraction and reanalysis.
- EK067G: Poor spike recovery for Total Phosphorus due to matrix interferences.
- EG094: Results for sample ES2136788-#013 have been confirmed by re-digestion and reanalysis.
- EG020: Poor precision was obtained for Arsenic and Manganese on sample ES2136788-#001. Results have been confirmed by re-extraction and reanalysis.
- EG020: Poor precision was obtained for Chromium on samples ES2136788-#011 and #032. Results have been confirmed by re-extraction and reanalysis.
- ASS: EA037 (Rapid Field and F(ox) screening): pH F(ox) Reaction Rate: 1 - Slight; 2 - Moderate; 3 - Strong; 4 - Extreme
- EA037 ASS Field Screening: NATA accreditation does not cover performance of this service.
- EG093: Samples containing high levels of sulfate may precipitate barium under the acidic conditions of this method and may therefore bias results low.

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS13	HS12	HS11	HS10	HS09
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-001	ES2136788-002	ES2136788-003	ES2136788-004	ES2136788-005
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.5	8.3	8.5	8.4	8.5
ø pH (Fox)	----	0.1	pH Unit	6.9	7.3	7.9	8.5	8.5
ø Reaction Rate	----	1	-	2	4	4	4	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	32.7	33.2	31.1	30.3	28.6
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8700	8700	5700	6390	6400
Iron	7439-89-6	50	mg/kg	58100	57100	51700	55500	47100
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	0.61	0.86	0.97	0.90	0.95
Arsenic	7440-38-2	1.00	mg/kg	66.1	94.3	108	106	73.4
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	26.3	41.0	35.2	45.4	41.4
Copper	7440-50-8	1.0	mg/kg	2.5	3.0	2.3	2.4	3.2
Cobalt	7440-48-4	0.5	mg/kg	6.5	9.0	8.6	10.6	7.3
Lead	7439-92-1	1.0	mg/kg	7.9	14.8	11.0	11.7	11.9
Manganese	7439-96-5	10	mg/kg	304	392	632	616	475
Nickel	7440-02-0	1.0	mg/kg	6.0	8.4	7.0	8.0	6.0
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	9.8	13.8	12.3	14.5	11.7
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	360	290	270	330	300
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	661	1130	697	631	589
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.28	0.23	0.22	0.22	0.20
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	4	<3	8	6	12
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	4	<3	8	6	12

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS13	HS12	HS11	HS10	HS09
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-001	ES2136788-002	ES2136788-003	ES2136788-004	ES2136788-005
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**3**	<3	**6**	**4**	**9**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	<3	**6**	**4**	**9**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS13	HS12	HS11	HS10	HS09
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-001	ES2136788-002	ES2136788-003	ES2136788-004	ES2136788-005
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**100**	**79.6**	**99.5**	**105**	**122**
Toluene-D8	2037-26-5	0.2	%	**87.6**	**75.6**	**101**	**107**	**118**
4-Bromofluorobenzene	460-00-4	0.2	%	**86.0**	**77.2**	**98.3**	**97.7**	**114**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**96.2**	**124**	**89.4**	**37.4**	**81.3**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS13	HS12	HS11	HS10	HS09
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-001	ES2136788-002	ES2136788-003	ES2136788-004	ES2136788-005
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**58.0**	**42.9**	**44.6**	**48.4**	**58.8**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**72.5**	**54.4**	**56.2**	**58.1**	**55.6**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS08	HS07	HS06	HS05	HS04
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-006	ES2136788-007	ES2136788-008	ES2136788-009	ES2136788-010
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.4	8.6	8.3	8.5	8.2
ø pH (Fox)	----	0.1	pH Unit	7.1	7.1	7.5	6.7	6.8
ø Reaction Rate	----	1	-	4	4	4	2	2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	35.1	35.2	27.9	43.2	40.9
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	8640	9750	7770	12000	9340
Iron	7439-89-6	50	mg/kg	55200	56900	54300	35600	34000
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	0.89	1.07	0.80	0.67	<0.50
Arsenic	7440-38-2	1.00	mg/kg	84.3	85.7	74.4	22.6	26.4
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	35.9	73.4	42.7	29.7	18.1
Copper	7440-50-8	1.0	mg/kg	3.1	3.7	4.3	5.7	5.4
Cobalt	7440-48-4	0.5	mg/kg	8.9	10.9	9.1	6.2	7.2
Lead	7439-92-1	1.0	mg/kg	13.1	11.2	9.7	9.7	10.1
Manganese	7439-96-5	10	mg/kg	527	498	396	185	230
Nickel	7440-02-0	1.0	mg/kg	7.5	9.8	7.6	9.6	9.4
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	13.0	17.4	13.3	20.3	19.8
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	330	300	180	540	370
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	834	635	1120	416	297
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.24	0.24	0.21	0.55	0.46
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	5	6	9	5	8
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	5	6	9	5	8

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS08	HS07	HS06	HS05	HS04
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-006	ES2136788-007	ES2136788-008	ES2136788-009	ES2136788-010
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**3**	**4**	**7**	**4**	**5**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	**4**	**7**	**4**	**5**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT
(Matrix: SOIL)

			Sample ID	HS08	HS07	HS06	HS05	HS04
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-006	ES2136788-007	ES2136788-008	ES2136788-009	ES2136788-010
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**104**	**113**	**117**	**110**	**116**
Toluene-D8	2037-26-5	0.2	%	**107**	**114**	**119**	**113**	**118**
4-Bromofluorobenzene	460-00-4	0.2	%	**102**	**104**	**113**	**104**	**112**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**91.0**	**86.2**	**122**	**51.6**	**116**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS08	HS07	HS06	HS05	HS04
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-006	ES2136788-007	ES2136788-008	ES2136788-009	ES2136788-010
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	41.6	42.4	45.2	63.6	47.1
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	60.0	50.0	54.4	71.2	59.4

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS03	HS02	HS01	HS19	HS18
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-011	ES2136788-012	ES2136788-014	ES2136788-015	ES2136788-016
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.4	8.2	8.1	8.2	8.2
ø pH (Fox)	----	0.1	pH Unit	7.2	7.3	6.8	8.5	8.7
ø Reaction Rate	----	1	-	4	4	2	4	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	38.7	38.1	33.2	31.5	56.4
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	9740	10200	5380	9570	14500
Iron	7439-89-6	50	mg/kg	37800	43600	37900	43100	23300
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	0.64	<0.50	0.57	0.59	<0.50
Arsenic	7440-38-2	1.00	mg/kg	32.4	64.0	28.0	61.1	20.8
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	30.3	28.9	19.8	57.9	21.5
Copper	7440-50-8	1.0	mg/kg	6.5	5.2	3.2	4.0	4.6
Cobalt	7440-48-4	0.5	mg/kg	8.0	8.0	6.1	7.0	6.2
Lead	7439-92-1	1.0	mg/kg	10.6	9.4	7.2	9.4	7.1
Manganese	7439-96-5	10	mg/kg	344	437	202	323	401
Nickel	7440-02-0	1.0	mg/kg	7.4	7.9	4.9	7.8	8.5
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	16.9	15.0	11.3	15.3	18.6
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	380	350	280	260	480
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	540	428	549	626	696
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.26	0.34	0.36	0.19	0.14
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	8	6	9	4	6
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	8	6	9	4	6

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS03	HS02	HS01	HS19	HS18
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-011	ES2136788-012	ES2136788-014	ES2136788-015	ES2136788-016
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**6**	**5**	**7**	<3	**4**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**6**	**5**	**7**	<3	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS03	HS02	HS01	HS19	HS18
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-011	ES2136788-012	ES2136788-014	ES2136788-015	ES2136788-016
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**81.6**	**112**	**115**	**90.8**	**108**
Toluene-D8	2037-26-5	0.2	%	**74.3**	**97.2**	**100**	**92.4**	**95.7**
4-Bromofluorobenzene	460-00-4	0.2	%	**79.3**	**98.8**	**100**	**84.2**	**92.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**130**	**106**	**129**	**136**	**117**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS03	HS02	HS01	HS19	HS18
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-011	ES2136788-012	ES2136788-014	ES2136788-015	ES2136788-016
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**51.0**	**88.9**	**59.6**	**49.3**	**55.4**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**56.9**	**59.4**	**65.0**	**60.0**	**60.0**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	HS17	HS16	HS15	HS14	HS20
Sampling date / time				21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	20-Oct-2021 00:00
				ES2136788-017	ES2136788-018	ES2136788-019	ES2136788-020	ES2136788-021
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.2	8.4	8.1	8.4	8.4
ø pH (Fox)	----	0.1	pH Unit	8.9	6.9	7.0	6.8	7.6
ø Reaction Rate	----	1	-	4	2	2	2	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	30.8	32.4	33.4	36.8	27.7
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	6220	8620	9380	10200	6900
Iron	7439-89-6	50	mg/kg	45000	27500	39500	38600	43100
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	0.71	<0.50	<0.50	<0.50	0.68
Arsenic	7440-38-2	1.00	mg/kg	49.5	24.5	34.7	46.5	70.1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	39.0	22.3	41.5	31.4	19.1
Copper	7440-50-8	1.0	mg/kg	3.8	3.6	5.2	3.5	4.1
Cobalt	7440-48-4	0.5	mg/kg	6.6	4.8	5.7	7.3	8.5
Lead	7439-92-1	1.0	mg/kg	10.3	6.6	8.2	8.5	11.0
Manganese	7439-96-5	10	mg/kg	382	235	240	268	531
Nickel	7440-02-0	1.0	mg/kg	6.2	6.6	6.9	7.4	7.2
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	12.0	12.2	13.6	13.9	10.4
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	280	270	270	310	130
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	483	485	322	555	569
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.14	0.32	0.31	0.34	0.20
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	3	4	6	5	4
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	3	4	6	5	4

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			*Sample ID*	HS17	HS16	HS15	HS14	HS20
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	20-Oct-2021 00:00
Compound	*CAS Number*	*LOR*	*Unit*	ES2136788-017	ES2136788-018	ES2136788-019	ES2136788-020	ES2136788-021
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	**3**	**5**	**3**	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	**3**	**5**	**3**	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS17	HS16	HS15	HS14	HS20
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-017	ES2136788-018	ES2136788-019	ES2136788-020	ES2136788-021
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**105**	**111**	**130**	**119**	**117**
Toluene-D8	2037-26-5	0.2	%	**90.5**	**99.9**	**114**	**102**	**106**
4-Bromofluorobenzene	460-00-4	0.2	%	**90.2**	**95.3**	**111**	**99.7**	**99.8**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**144**	**138**	**127**	**111**	**113**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS17	HS16	HS15	HS14	HS20
			Sampling date / time	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	21-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-017	ES2136788-018	ES2136788-019	ES2136788-020	ES2136788-021
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	61.5	39.1	72.2	64.6	63.6
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	71.2	62.5	86.2	80.0	67.5

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS21	HS22	HS23	HS24	Duplicate A
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-022	ES2136788-023	ES2136788-024	ES2136788-025	ES2136788-026
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.5	8.7	8.4	8.5	8.5
ø pH (Fox)	----	0.1	pH Unit	8.9	9.0	7.2	7.5	7.1
ø Reaction Rate	----	1	-	4	4	4	4	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	29.8	12.5	33.5	24.7	33.7
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	6220	2790	5630	6360	6230
Iron	7439-89-6	50	mg/kg	24400	31900	19200	50900	22100
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	0.66	<0.50	1.02	<0.50
Arsenic	7440-38-2	1.00	mg/kg	37.5	58.0	28.1	80.9	27.9
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	17.2	45.8	13.8	45.6	21.1
Copper	7440-50-8	1.0	mg/kg	2.4	1.9	2.4	7.6	2.1
Cobalt	7440-48-4	0.5	mg/kg	4.9	4.5	4.0	9.6	3.8
Lead	7439-92-1	1.0	mg/kg	7.0	6.2	5.3	28.0	5.6
Manganese	7439-96-5	10	mg/kg	325	309	217	484	276
Nickel	7440-02-0	1.0	mg/kg	5.0	4.5	4.7	8.6	5.2
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	9.9	6.6	9.4	9.2	7.5
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	250	220	220	120	220
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	422	704	482	758	398
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.26	0.09	0.22	0.14	0.20
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	5	5	6	4	6
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	5	5	6	4	6

Analytical Results

Sub-Matrix: **SEDIMENT**
(Matrix: **SOIL)**

Compound	CAS Number	LOR	Unit	HS21	HS22	HS23	HS24	Duplicate A
Sampling date / time				20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
				ES2136788-022	ES2136788-023	ES2136788-024	ES2136788-025	ES2136788-026
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**4**	**4**	**4**	<3	**5**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**4**	**4**	**4**	<3	**5**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	----	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	----	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	----	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS21	HS22	HS23	HS24	Duplicate A
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-022	ES2136788-023	ES2136788-024	ES2136788-025	ES2136788-026
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**80.9**	**72.2**	**85.9**	**99.7**	**85.8**
Toluene-D8	2037-26-5	0.2	%	**86.8**	**76.6**	**91.4**	**104**	**89.3**
4-Bromofluorobenzene	460-00-4	0.2	%	**78.4**	**76.9**	**81.0**	**88.9**	**81.8**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**106**	**134**	**96.7**	----	**114**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS21	HS22	HS23	HS24	Duplicate A
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-022	ES2136788-023	ES2136788-024	ES2136788-025	ES2136788-026
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	53.6	37.8	44.7	43.4	53.8
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	51.2	68.8	53.8	47.5	71.2

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	Duplicate B	HS36	HS37	HS38	HS39
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-027	ES2136788-028	ES2136788-029	ES2136788-030	ES2136788-031
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.5	8.7	8.8	8.4	8.7
ø pH (Fox)	----	0.1	pH Unit	7.2	6.9	6.8	7.1	6.8
ø Reaction Rate	----	1	-	4	2	2	4	2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	24.9	16.0	12.0	27.5	10.1
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1800	1750	2630	3120	2090
Iron	7439-89-6	50	mg/kg	15100	11300	16900	22100	12000
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	28.8	28.4	34.8	24.0	21.6
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	11.9	9.6	12.0	16.2	11.1
Copper	7440-50-8	1.0	mg/kg	<1.0	<1.0	<1.0	1.3	<1.0
Cobalt	7440-48-4	0.5	mg/kg	2.2	2.0	2.2	2.2	1.6
Lead	7439-92-1	1.0	mg/kg	3.2	3.1	3.2	4.6	2.7
Manganese	7439-96-5	10	mg/kg	695	673	608	428	504
Nickel	7440-02-0	1.0	mg/kg	2.8	2.5	3.2	3.7	2.4
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	4.7	3.5	4.0	7.5	3.2
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	60	60	20	160	50
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	371	338	219	281	250
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.09	0.09	0.08	0.15	2.24
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	4	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	4	<3

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	Duplicate B	HS36	HS37	HS38	HS39
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-027	ES2136788-028	ES2136788-029	ES2136788-030	ES2136788-031
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	**3**	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	**3**	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	Duplicate B	HS36	HS37	HS38	HS39
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-027	ES2136788-028	ES2136788-029	ES2136788-030	ES2136788-031
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**99.0**	**114**	**87.6**	**108**	**119**
Toluene-D8	2037-26-5	0.2	%	**101**	**120**	**89.4**	**112**	**124**
4-Bromofluorobenzene	460-00-4	0.2	%	**91.3**	**105**	**84.1**	**97.9**	**109**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**116**	**120**	**130**	**135**	**143**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	Duplicate B	HS36	HS37	HS38	HS39
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-027	ES2136788-028	ES2136788-029	ES2136788-030	ES2136788-031
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	44.9	39.2	42.4	45.8	42.2
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	68.8	46.2	55.0	50.0	51.2

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)		Sample ID		HS40	HS41	HS42	HS43	HS44
		Sampling date / time		20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-032	ES2136788-033	ES2136788-034	ES2136788-035	ES2136788-036
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.5	8.2	8.0	8.3	8.6
ø pH (Fox)	----	0.1	pH Unit	6.9	7.9	7.0	7.2	6.9
ø Reaction Rate	----	1	-	2	4	2	4	2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	23.9	24.7	35.7	9.7	14.7
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2480	2290	8520	2060	1780
Iron	7439-89-6	50	mg/kg	18800	14200	16100	13900	11300
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	23.4	21.8	14.9	32.0	26.4
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	18.2	12.3	16.1	8.7	9.9
Copper	7440-50-8	1.0	mg/kg	1.3	<1.0	2.4	<1.0	<1.0
Cobalt	7440-48-4	0.5	mg/kg	2.0	1.8	3.5	2.5	2.0
Lead	7439-92-1	1.0	mg/kg	3.4	3.1	4.6	3.2	2.7
Manganese	7439-96-5	10	mg/kg	421	463	363	800	763
Nickel	7440-02-0	1.0	mg/kg	2.7	2.5	5.4	3.0	2.6
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	5.0	4.4	10.6	3.2	2.8
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	100	230	180	40	40
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	308	197	403	291	256
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.10	0.11	0.22	0.08	0.08
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	5	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	5	<3	<3

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS40	HS41	HS42	HS43	HS44
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-032	ES2136788-033	ES2136788-034	ES2136788-035	ES2136788-036
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	**4**	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	**4**	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS40	HS41	HS42	HS43	HS44
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-032	ES2136788-033	ES2136788-034	ES2136788-035	ES2136788-036
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	107	103	81.5	113	119
Toluene-D8	2037-26-5	0.2	%	104	110	80.8	115	121
4-Bromofluorobenzene	460-00-4	0.2	%	87.0	94.9	73.2	101	107
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	143	124	124	115	59.9

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS40	HS41	HS42	HS43	HS44
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-032	ES2136788-033	ES2136788-034	ES2136788-035	ES2136788-036
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**47.5**	**41.7**	**46.9**	**50.0**	**48.9**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**56.2**	**58.8**	**63.8**	**63.8**	**67.5**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS45	HS46	HS47	HS48	HS49
			Sampling date / time	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-037	ES2136788-038	ES2136788-039	ES2136788-040	ES2136788-041
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	**8.6**	**8.9**	**8.5**	**8.7**	**8.8**
ø pH (Fox)	----	0.1	pH Unit	**6.8**	**6.6**	**7.1**	**6.9**	**6.9**
ø Reaction Rate	----	1	-	**2**	**2**	**4**	**2**	**2**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**8.8**	**5.6**	**43.0**	**44.0**	**51.1**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**2610**	**1330**	**8120**	**9260**	**14600**
Iron	7439-89-6	50	mg/kg	**19100**	**8140**	**12200**	**17500**	**19900**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**23.5**	**15.8**	**8.27**	**11.0**	**9.86**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**22.2**	**6.9**	**13.0**	**18.4**	**24.9**
Copper	7440-50-8	1.0	mg/kg	**1.3**	<1.0	**2.5**	**2.7**	**4.6**
Cobalt	7440-48-4	0.5	mg/kg	**3.4**	**1.0**	**3.4**	**3.8**	**5.6**
Lead	7439-92-1	1.0	mg/kg	**3.1**	**1.6**	**4.8**	**5.6**	**7.2**
Manganese	7439-96-5	10	mg/kg	**416**	**264**	**281**	**248**	**273**
Nickel	7440-02-0	1.0	mg/kg	**4.5**	**1.6**	**5.2**	**5.9**	**9.5**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**3.9**	**2.0**	**10.4**	**12.3**	**17.7**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**40**	**30**	**270**	**300**	**470**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**212**	**200**	**353**	**310**	**341**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.08**	**0.08**	**0.17**	**0.35**	**0.51**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	**7**	**8**	**10**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	**7**	**8**	**10**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS45	HS46	HS47	HS48	HS49
			Sampling date / time	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-037	ES2136788-038	ES2136788-039	ES2136788-040	ES2136788-041
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	**6**	**6**	**8**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	**6**	**6**	**8**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS45	HS46	HS47	HS48	HS49
			Sampling date / time	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-037	ES2136788-038	ES2136788-039	ES2136788-040	ES2136788-041
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<6.2
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**98.9**	**108**	**100.0**	**91.6**	**111**
Toluene-D8	2037-26-5	0.2	%	**98.6**	**110**	**103**	**94.0**	**110**
4-Bromofluorobenzene	460-00-4	0.2	%	**91.7**	**95.2**	**94.6**	**84.5**	**97.4**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**109**	**110**	**109**	**65.0**	**122**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS45	HS46	HS47	HS48	HS49
			Sampling date / time	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00	19-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-037	ES2136788-038	ES2136788-039	ES2136788-040	ES2136788-041
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	55.7	44.8	57.4	51.1	43.9
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	67.5	62.5	70.0	71.2	58.8

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS25	HS26	HS27	HS31	HS70
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-042	ES2136788-043	ES2136788-044	ES2136788-045	ES2136788-046
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.7	8.6	8.6	8.5	8.6
ø pH (Fox)	----	0.1	pH Unit	8.9	7.7	7.9	7.7	7.1
ø Reaction Rate	----	1	-	4	4	4	4	4
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	23.2	27.5	28.3	19.1	28.7
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	5430	7870	4880	4610	7010
Iron	7439-89-6	50	mg/kg	28600	35400	29500	28400	22600
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	0.59	<0.50	0.51	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	42.4	39.4	32.6	25.4	25.1
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	60.4	30.9	29.1	114	19.4
Copper	7440-50-8	1.0	mg/kg	3.2	4.4	2.6	2.2	2.6
Cobalt	7440-48-4	0.5	mg/kg	5.3	6.0	5.4	2.4	4.2
Lead	7439-92-1	1.0	mg/kg	5.9	7.7	6.6	9.6	6.2
Manganese	7439-96-5	10	mg/kg	373	312	243	169	222
Nickel	7440-02-0	1.0	mg/kg	5.4	7.6	4.5	3.7	5.5
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	7.9	12.7	6.2	6.6	8.9
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	150	240	190	160	180
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	499	394	152	86	244
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.15	0.19	0.12	0.16	0.22
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	6	<3	4	5
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	6	<3	4	5

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS25	HS26	HS27	HS31	HS70
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-042	ES2136788-043	ES2136788-044	ES2136788-045	ES2136788-046
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	**4**	<3	<3	**4**
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	**4**	<3	<3	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	----	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	----	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	----	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS25	HS26	HS27	HS31	HS70
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-042	ES2136788-043	ES2136788-044	ES2136788-045	ES2136788-046
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**95.8**	**77.0**	**101**	**104**	**75.2**
Toluene-D8	2037-26-5	0.2	%	**84.4**	**82.8**	**114**	**115**	**79.8**
4-Bromofluorobenzene	460-00-4	0.2	%	**92.3**	**91.8**	**113**	**113**	**83.9**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	----	**89.0**	**114**	**99.1**	**97.5**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS25	HS26	HS27	HS31	HS70
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-042	ES2136788-043	ES2136788-044	ES2136788-045	ES2136788-046
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	56.4	49.7	74.9	42.3	51.6
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	67.5	57.5	58.8	58.8	62.5

Analytical Results

Sub-Matrix: SEDIMENT
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	HS74	HS75	HS77	HS32	HS33
Sampling date / time				20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
				ES2136788-047	ES2136788-048	ES2136788-049	ES2136788-050	ES2136788-051
				Result	Result	Result	Result	Result
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	**8.1**	**8.2**	**8.3**	**8.5**	**8.7**
ø pH (Fox)	----	0.1	pH Unit	**7.1**	**7.5**	**7.0**	**7.5**	**7.1**
ø Reaction Rate	----	1	-	**4**	**4**	**4**	**4**	**4**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**35.9**	**28.7**	**26.8**	**23.4**	**15.4**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**9010**	**5080**	**5330**	**2480**	**1890**
Iron	7439-89-6	50	mg/kg	**27200**	**15100**	**18000**	**14000**	**12000**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**22.1**	**19.1**	**18.9**	**29.6**	**22.5**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**19.6**	**14.1**	**20.6**	**17.9**	**10.4**
Copper	7440-50-8	1.0	mg/kg	**3.6**	**1.7**	**1.9**	**1.3**	<1.0
Cobalt	7440-48-4	0.5	mg/kg	**4.1**	**3.1**	**2.9**	**2.7**	**2.1**
Lead	7439-92-1	1.0	mg/kg	**5.9**	**3.8**	**4.7**	**3.3**	**3.2**
Manganese	7439-96-5	10	mg/kg	**419**	**261**	**336**	**751**	**586**
Nickel	7440-02-0	1.0	mg/kg	**5.6**	**3.9**	**4.1**	**3.5**	**2.6**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**9.5**	**6.7**	**9.5**	**5.1**	**3.3**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**380**	**240**	**410**	**80**	**110**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**508**	**553**	**270**	**331**	**344**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.18**	**0.19**	**0.21**	**0.09**	**0.11**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	**5**	**8**	**6**	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	**5**	**8**	**6**	<3	<3

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS74	HS75	HS77	HS32	HS33
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-047	ES2136788-048	ES2136788-049	ES2136788-050	ES2136788-051
				Result	Result	Result	Result	Result
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**3**	**6**	**5**	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	**6**	**5**	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SEDIMENT
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	HS74	HS75	HS77	HS32	HS33
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
				ES2136788-047	ES2136788-048	ES2136788-049	ES2136788-050	ES2136788-051
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	88.1	102	82.3	98.9	112
Toluene-D8	2037-26-5	0.2	%	96.6	108	91.9	101	122
4-Bromofluorobenzene	460-00-4	0.2	%	102	108	97.3	105	120
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	108	112	104	109	107

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS74	HS75	HS77	HS32	HS33
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00	20-Oct-2021 00:00
Compound	CAS Number	LOR	Unit	ES2136788-047	ES2136788-048	ES2136788-049	ES2136788-050	ES2136788-051
				Result	Result	Result	Result	Result
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**43.9**	**45.7**	**40.2**	**38.0**	**40.1**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**66.2**	**58.8**	**40.0**	**51.2**	**50.0**

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS34	HS35	Duplicate C	----	----
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	21-Oct-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	ES2136788-052	ES2136788-053	ES2136788-054	--------	--------
				Result	Result	Result	----	----
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.5	8.5	8.3	----	----
ø pH (Fox)	----	0.1	pH Unit	7.2	7.6	8.7	----	----
ø Reaction Rate	----	1	-	4	4	4	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	19.8	31.6	27.9	----	----
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1570	1970	3700	----	----
Iron	7439-89-6	50	mg/kg	13300	10300	25200	----	----
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	----	----
Arsenic	7440-38-2	1.00	mg/kg	26.5	18.8	28.2	----	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Chromium	7440-47-3	1.0	mg/kg	12.5	11.3	43.3	----	----
Copper	7440-50-8	1.0	mg/kg	<1.0	<1.0	2.1	----	----
Cobalt	7440-48-4	0.5	mg/kg	2.1	1.8	3.3	----	----
Lead	7439-92-1	1.0	mg/kg	3.0	3.0	5.6	----	----
Manganese	7439-96-5	10	mg/kg	738	589	339	----	----
Nickel	7440-02-0	1.0	mg/kg	2.7	2.5	3.6	----	----
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	----	----
Zinc	7440-66-6	1.0	mg/kg	3.8	4.1	6.5	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	90	180	270	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	408	317	319	----	----
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.08	0.13	0.22	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	----	----
>C16 - C34 Fraction	----	3	mg/kg	<3	4	4	----	----
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	----	----
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	4	4	----	----

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS34	HS35	Duplicate C	----	----
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	21-Oct-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	ES2136788-052	ES2136788-053	ES2136788-054	--------	--------
				Result	Result	Result	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions - Continued								
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	----	----
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	----	----
C10 - C14 Fraction	----	3	mg/kg	<3	<3	<3	----	----
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	----	----
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	----	----
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	<3	<3	----	----
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	----	----
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	----	----
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	----	----
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	----	----
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	----	----
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	----	----
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	----	----
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	----	----

Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)			Sample ID	HS34	HS35	Duplicate C	----	----
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	21-Oct-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	ES2136788-052	ES2136788-053	ES2136788-054	--------	--------
				Result	Result	Result	----	----
EP131A: Organochlorine Pesticides - Continued								
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	----	----
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
cis-Chlordane	5103-71-9	0.25	µg/kg	<0.25	<0.25	<0.25	----	----
trans-Chlordane	5103-74-2	0.25	µg/kg	<0.25	<0.25	<0.25	----	----
^ Total Chlordane (sum)	----	0.25	µg/kg	<0.25	<0.25	<0.25	----	----
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	----	----
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	----	----
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**87.9**	**107**	**93.0**	----	----
Toluene-D8	2037-26-5	0.2	%	**82.1**	**116**	**100**	----	----
4-Bromofluorobenzene	460-00-4	0.2	%	**92.2**	**121**	**106**	----	----
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**95.8**	**109**	**141**	----	----

Analytical Results

Sub-Matrix: **SEDIMENT** (Matrix: **SOIL**)			*Sample ID*	**HS34**	**HS35**	**Duplicate C**	**----**	**----**
			Sampling date / time	20-Oct-2021 00:00	20-Oct-2021 00:00	21-Oct-2021 00:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES2136788-052**	**ES2136788-053**	**ES2136788-054**	**--------**	**--------**
				Result	Result	Result	----	----
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**47.3**	**58.9**	**43.9**	**----**	**----**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**48.8**	**48.8**	**45.0**	**----**	**----**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	**Equipment Blank**	----	----	----	----
			Sampling date / time	21-Oct-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	**ES2136788-013**	--------	--------	--------	--------
				Result	----	----	----	----
EG035T: Total Mercury by FIMS								
Mercury	7439-97-6	0.00004	mg/L	<0.00004	----	----	----	----
EG094T: Total metals in Fresh water by ORC-ICPMS								
Arsenic	7440-38-2	0.2	µg/L	**2.3**	----	----	----	----
Chromium	7440-47-3	0.2	µg/L	**6.1**	----	----	----	----
Cobalt	7440-48-4	0.1	µg/L	**1.2**	----	----	----	----
Copper	7440-50-8	0.5	µg/L	**3.9**	----	----	----	----
Lead	7439-92-1	0.1	µg/L	**6.7**	----	----	----	----
Nickel	7440-02-0	0.5	µg/L	**3.8**	----	----	----	----
Zinc	7440-66-6	1	µg/L	**87**	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.01	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	----	----	----	----
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	----	----	----	----
^ **>C10 - C16 Fraction minus Naphthalene (F2)**	----	100	µg/L	<100	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	Equipment Blank	----	----	----	----
			Sampling date / time	21-Oct-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	ES2136788-013	--------	--------	--------	--------
				Result	----	----	----	----
EP080: BTEXN - Continued								
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ **Total Xylenes**	----	2	µg/L	<2	----	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**120**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**114**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**104**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SEDIMENT**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	67	137
Toluene-D8	2037-26-5	74	134
4-Bromofluorobenzene	460-00-4	73	137
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

Inter-Laboratory Testing

Analysis conducted by ALS Brisbane, NATA accreditation no. 825, site no. 818 (Chemistry) 18958 (Biology).

(SOIL) EP090: Organotin Compounds

(SOIL) EP090S: Organotin Surrogate

(SOIL) EP003: Total Organic Carbon (TOC) in Soil

(SOIL) EA037: Ass Field Screening Analysis

CERTIFICATE OF ANALYSIS

Work Order	: **EB2202010**	Page	: 1 of 6
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 25-Jan-2022 14:29
Order number	: ----	Date Analysis Commenced	: 28-Jan-2022
C-O-C number	: ----	Issue Date	: 07-Feb-2022 10:10
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 11		
No. of samples analysed	: 11		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Franco Lentini	LCMS Coordinator	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- **Analysis is conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93.8_U	KP93.8_L	KP102.7_U	KP102.7_L	KP103.1_U
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2202010-001	EB2202010-002	EB2202010-003	EB2202010-004	EB2202010-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	28.2	18.5	32.9	33.3	18.3
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	<5	<5	<5	<5
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	<5	<5	<5	<5
Acenaphthylene	208-96-8	4	µg/kg	<4	<4	<4	<4	<4
Acenaphthene	83-32-9	4	µg/kg	<4	<4	<4	<4	<4
Fluorene	86-73-7	4	µg/kg	<4	<4	<4	<4	<4
Phenanthrene	85-01-8	4	µg/kg	<4	<4	<4	<4	<4
Anthracene	120-12-7	4	µg/kg	<4	<4	<4	<4	<4
Fluoranthene	206-44-0	4	µg/kg	<4	<4	<4	<4	<4
Pyrene	129-00-0	4	µg/kg	<4	<4	<4	<4	<4
Benz(a)anthracene	56-55-3	4	µg/kg	<4	<4	<4	<4	<4
Chrysene	218-01-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	<4	<4	<4	<4
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(e)pyrene	192-97-2	4	µg/kg	<4	<4	<4	<4	<4
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	<4	<4	<4	<4
Perylene	198-55-0	4	µg/kg	<4	<4	<4	<4	<4
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	<4	<4	<4	<4
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	<4	<4	<4	<4
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	<4	<4	<4	<4
Coronene	191-07-1	5	µg/kg	<5	<5	<5	<5	<5
^ Sum of PAHs	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	5	5	5	5	5
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	10	10	10	10	10
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	77.2	108	92.1	96.2	85.6
Anthracene-d10	1719-06-8	10	%	81.8	108	102	97.7	98.3
4-Terphenyl-d14	1718-51-0	10	%	84.9	110	97.0	92.7	91.4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP103.1_L	KP103.5_U	KP104.9_U	KP106.0_U	KP106.0_L
			Sampling date / time	07-Jan-2022 00:00	07-Jan-2022 00:00	07-Jan-2022 00:00	06-Jan-2022 00:00	06-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2202010-006	EB2202010-007	EB2202010-008	EB2202010-009	EB2202010-010
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	22.4	25.5	37.0	27.7	34.9
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	<5	<5	<5	<5
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	<5	<5	<5	<5
Acenaphthylene	208-96-8	4	µg/kg	<4	<4	<4	<4	<4
Acenaphthene	83-32-9	4	µg/kg	<4	<4	<4	<4	<4
Fluorene	86-73-7	4	µg/kg	<4	<4	<4	<4	<4
Phenanthrene	85-01-8	4	µg/kg	<4	<4	<4	<4	<4
Anthracene	120-12-7	4	µg/kg	<4	<4	<4	<4	<4
Fluoranthene	206-44-0	4	µg/kg	<4	<4	<4	<4	<4
Pyrene	129-00-0	4	µg/kg	<4	<4	<4	<4	<4
Benz(a)anthracene	56-55-3	4	µg/kg	<4	<4	<4	<4	<4
Chrysene	218-01-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	<4	<4	<4	<4
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(e)pyrene	192-97-2	4	µg/kg	<4	<4	<4	<4	<4
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	<4	<4	<4	<4
Perylene	198-55-0	4	µg/kg	<4	<4	<4	<4	<4
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	<4	<4	<4	<4
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	<4	<4	<4	<4
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	<4	<4	<4	<4
Coronene	191-07-1	5	µg/kg	<5	<5	<5	<5	<5
^ Sum of PAHs	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	5	5	5	5	5
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	10	10	10	10	10
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	101	107	86.1	101	99.3
Anthracene-d10	1719-06-8	10	%	106	119	86.9	100.0	104
4-Terphenyl-d14	1718-51-0	10	%	103	119	81.6	103	99.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP106_U_A	----	----	----	----
			Sampling date / time	06-Jan-2022 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2202010-011	--------	--------	--------	--------
				Result	----	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	31.2	----	----	----	----
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	----	----	----	----
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	----	----	----	----
Acenaphthylene	208-96-8	4	µg/kg	<4	----	----	----	----
Acenaphthene	83-32-9	4	µg/kg	<4	----	----	----	----
Fluorene	86-73-7	4	µg/kg	<4	----	----	----	----
Phenanthrene	85-01-8	4	µg/kg	<4	----	----	----	----
Anthracene	120-12-7	4	µg/kg	<4	----	----	----	----
Fluoranthene	206-44-0	4	µg/kg	<4	----	----	----	----
Pyrene	129-00-0	4	µg/kg	<4	----	----	----	----
Benz(a)anthracene	56-55-3	4	µg/kg	<4	----	----	----	----
Chrysene	218-01-9	4	µg/kg	<4	----	----	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	----	----	----	----
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	----	----	----	----
Benzo(e)pyrene	192-97-2	4	µg/kg	<4	----	----	----	----
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	----	----	----	----
Perylene	198-55-0	4	µg/kg	<4	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	----	----	----	----
Coronene	191-07-1	5	µg/kg	<5	----	----	----	----
^ Sum of PAHs	----	4	µg/kg	<4	----	----	----	----
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	----	----	----	----
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	5	----	----	----	----
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	10	----	----	----	----
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	95.9	----	----	----	----
Anthracene-d10	1719-06-8	10	%	96.8	----	----	----	----
4-Terphenyl-d14	1718-51-0	10	%	94.1	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	High
EP132T: Base/Neutral Extractable Surrogates			
2-Fluorobiphenyl	321-60-8	55	135
Anthracene-d10	1719-06-8	70	136
4-Terphenyl-d14	1718-51-0	57	127

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP132B: Polynuclear Aromatic Hydrocarbons

(SOIL) EP132T: Base/Neutral Extractable Surrogates

(SOIL) EA055: Moisture Content (Dried @ 105-110°C)

CERTIFICATE OF ANALYSIS

Work Order	: **EB2202012**	Page	: 1 of 5
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 25-Jan-2022 14:34
Order number	: ----	Date Analysis Commenced	: 28-Jan-2022
C-O-C number	: ----	Issue Date	: 07-Feb-2022 10:12
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 8		
No. of samples analysed	: 8		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Inorganics, Smithfield, NSW
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

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Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- **Analysis is conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP119-7_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2202012-001	EB2202012-002	EB2202012-003	EB2202012-004	EB2202012-005
				Result	Result	Result	Result	Result
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	40.0	34.1	20.0	20.2	23.8
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	<5	<5	<5	<5
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	<5	<5	<5	<5
Acenaphthylene	208-96-8	4	µg/kg	<4	<4	<4	<4	<4
Acenaphthene	83-32-9	4	µg/kg	<4	<4	<4	<4	<4
Fluorene	86-73-7	4	µg/kg	<4	<4	<4	<4	<4
Phenanthrene	85-01-8	4	µg/kg	<4	<4	<4	<4	<4
Anthracene	120-12-7	4	µg/kg	<4	<4	<4	<4	<4
Fluoranthene	206-44-0	4	µg/kg	<4	<4	<4	<4	<4
Pyrene	129-00-0	4	µg/kg	<4	<4	<4	<4	<4
Benz(a)anthracene	56-55-3	4	µg/kg	<4	<4	<4	<4	<4
Chrysene	218-01-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	<4	<4	<4	<4
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	<4	<4	<4	<4
Benzo(e)pyrene	192-97-2	4	µg/kg	<4	<4	<4	<4	<4
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	<4	<4	<4	<4
Perylene	198-55-0	4	µg/kg	<4	<4	<4	<4	<4
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	<4	<4	<4	<4
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	<4	<4	<4	<4
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	<4	<4	<4	<4
Coronene	191-07-1	5	µg/kg	<5	<5	<5	<5	<5
^ Sum of PAHs	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	<4	<4	<4	<4
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	5	5	5	5	5
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	10	10	10	10	10
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	85.1	97.1	111	86.5	96.4
Anthracene-d10	1719-06-8	10	%	94.5	97.3	115	96.0	106
4-Terphenyl-d14	1718-51-0	10	%	87.4	94.0	117	95.7	110

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	----	----
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2202012-006	EB2202012-007	EB2202012-008	--------	--------
				Result	Result	Result	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	30.3	33.3	25.0	----	----
EP132B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	5	µg/kg	<5	<5	<5	----	----
2-Methylnaphthalene	91-57-6	5	µg/kg	<5	<5	<5	----	----
Acenaphthylene	208-96-8	4	µg/kg	<4	<4	<4	----	----
Acenaphthene	83-32-9	4	µg/kg	<4	<4	<4	----	----
Fluorene	86-73-7	4	µg/kg	<4	<4	<4	----	----
Phenanthrene	85-01-8	4	µg/kg	<4	<4	<4	----	----
Anthracene	120-12-7	4	µg/kg	<4	<4	<4	----	----
Fluoranthene	206-44-0	4	µg/kg	<4	<4	<4	----	----
Pyrene	129-00-0	4	µg/kg	<4	<4	<4	----	----
Benz(a)anthracene	56-55-3	4	µg/kg	<4	<4	<4	----	----
Chrysene	218-01-9	4	µg/kg	<4	<4	<4	----	----
Benzo(b+j)fluoranthene	205-99-2 205-82-3	4	µg/kg	<4	<4	<4	----	----
Benzo(k)fluoranthene	207-08-9	4	µg/kg	<4	<4	<4	----	----
Benzo(e)pyrene	192-97-2	4	µg/kg	<4	<4	<4	----	----
Benzo(a)pyrene	50-32-8	4	µg/kg	<4	<4	<4	----	----
Perylene	198-55-0	4	µg/kg	<4	<4	<4	----	----
Benzo(g.h.i)perylene	191-24-2	4	µg/kg	<4	<4	<4	----	----
Dibenz(a.h)anthracene	53-70-3	4	µg/kg	<4	<4	<4	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	4	µg/kg	<4	<4	<4	----	----
Coronene	191-07-1	5	µg/kg	<5	<5	<5	----	----
^ Sum of PAHs	----	4	µg/kg	<4	<4	<4	----	----
^ Benzo(a)pyrene TEQ (zero)	----	4	µg/kg	<4	<4	<4	----	----
^ Benzo(a)pyrene TEQ (half LOR)	----	4	µg/kg	5	5	5	----	----
^ Benzo(a)pyrene TEQ (LOR)	----	4	µg/kg	10	10	10	----	----
EP132T: Base/Neutral Extractable Surrogates								
2-Fluorobiphenyl	321-60-8	10	%	107	93.2	103	----	----
Anthracene-d10	1719-06-8	10	%	120	96.4	116	----	----
4-Terphenyl-d14	1718-51-0	10	%	119	97.5	111	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**

Compound	CAS Number	Recovery Limits (%) Low	High
EP132T: Base/Neutral Extractable Surrogates			
2-Fluorobiphenyl	321-60-8	55	135
Anthracene-d10	1719-06-8	70	136
4-Terphenyl-d14	1718-51-0	57	127

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP132B: Polynuclear Aromatic Hydrocarbons

(SOIL) EP132T: Base/Neutral Extractable Surrogates

(SOIL) EA055: Moisture Content (Dried @ 105-110°C)

CERTIFICATE OF ANALYSIS

Work Order	: **EB2200737**	Page	: 1 of 16
Client	: **RPS AAP Consulting Pty Ltd**	Laboratory	: Environmental Division Brisbane
Contact	: KAT THORNE	Contact	: Nick Courts
Address	: Level 2, 27-31 Troode St West Perth 6005	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Marine Sediment Sampling	Date Samples Received	: 12-Jan-2022 08:20
Order number	: ----	Date Analysis Commenced	: 13-Jan-2022
C-O-C number	: ----	Issue Date	: 28-Jan-2022 09:11
Sampler	: LUCIA & KATE		
Site	: ----		
Quote number	: EP/875/21_V3		
No. of samples received	: 18		
No. of samples analysed	: 17		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Edwandy Fadjar	Organic Coordinator	Sydney Organics, Smithfield, NSW
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Morgan Lennox	Senior Organic Chemist	Brisbane Organics, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Satishkumar Trivedi	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP080-SD: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- EP131A: Where reported, Total Chlordane (sum) is the sum of the reported concentrations of cis-Chlordane and trans-Chlordane at or above the LOR.
- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EB2200737_002 (KP92-95_U_1) Shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP93-23_U' (EB2200737-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T-Total Metals by ICP-AES: Sample 'KP120-6_U' (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- AES 6318477 T/O 6314877
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP120-6_U (EB2200737-014) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG020-SD (Total Metals in Sediments by ICP-MS): Sample KP92-95_U_1 (EB2200737-002) shows poor matrix spike recovery due to sample heterogeneity. Confirmed by visual inspection.
- EP071 (TRH Semivolatiles): Sample 'KP92-95_U_1' shows poor matrix spike recovery due to sample heterogeneity. Confirmed by re-extraction and re-analysis.
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.8	9.6	9.9	9.7	9.1
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.008	0.080	0.010	0.015	0.526
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	50	<10	<10	328
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	43.4	47.0	36.3	2.13	19.3
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	8680	9390	7250	425	3860
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	13.9	15.0	11.6	0.68	6.19
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	0.08	<0.02	<0.02	0.52
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	50	<10	<10	328
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	4	<1	<1	25
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	17.1	24.3	16.8	16.0	41.3
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	600	2620	760	340	9520
Iron	7439-89-6	50	mg/kg	8560	10700	10000	1680	29100
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	17.8	18.5	18.6	1.21	27.3
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	9.9	13.7	11.4	1.7	33.2
Copper	7440-50-8	1.0	mg/kg	<1.0	1.8	1.3	1.1	5.7
Cobalt	7440-48-4	0.5	mg/kg	1.2	2.5	1.4	<0.5	8.7
Lead	7439-92-1	1.0	mg/kg	2.4	3.8	2.7	24.1	10.6

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**362**	**371**	**311**	<10	**173**
Nickel	7440-02-0	1.0	mg/kg	**1.7**	**3.7**	**2.3**	<1.0	**9.8**
Selenium	7782-49-2	0.1	mg/kg	**0.1**	**0.2**	**0.1**	<0.1	**0.6**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**1.8**	**5.1**	**2.8**	**1.6**	**17.2**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**60**	**160**	**60**	**50**	**210**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**315**	**283**	**312**	**44**	**210**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.04**	**0.60**	**0.05**	<0.02	**0.53**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	<3	<3	<3	**3**
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	<3	<3	<3	**3**
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	**3**	**3**	<3	**4**
C15 - C28 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	<3	**3**	**3**	<3	**4**
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP93-23_U	KP92-95_U_1	KP92-85_U	KP112-4_U	KP119-7_L
			Sampling date / time	08-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00	06-Jan-2022 00:00	08-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-001	EB2200737-002	EB2200737-003	EB2200737-005	EB2200737-006
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**90.6**	**90.0**	**94.8**	**97.3**	**83.6**
Toluene-D8	2037-26-5	0.2	%	**81.0**	**84.0**	**82.3**	**89.3**	**77.6**
4-Bromofluorobenzene	460-00-4	0.2	%	**91.5**	**95.2**	**94.7**	**102**	**87.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**113**	**132**	**90.4**	**93.8**	**110**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**65.2**	**25.9**	**55.4**	**56.4**	**50.6**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**60.0**	**27.5**	**58.8**	**63.8**	**32.5**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	9.9	9.6	9.6	9.9	9.7
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.011	0.020	0.011	0.015	0.052
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	13	<10	<10	33
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	48.5	15.4	36.4	36.3	47.8
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	9700	3070	7280	7250	9560
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	15.6	4.92	11.7	11.6	15.3
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	<0.02	0.02	<0.02	<0.02	0.05
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	<10	13	<10	<10	33
Liming Rate excluding ANC	----	1	kg CaCO3/t	<1	<1	<1	<1	2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	20.1	24.9	18.8	16.4	24.2
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	670	2430	2780	960	2670
Iron	7439-89-6	50	mg/kg	5540	18500	9710	10500	11800
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	12.8	14.6	12.6	19.8	18.3
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	6.4	15.6	13.3	15.0	16.4
Copper	7440-50-8	1.0	mg/kg	<1.0	2.1	2.0	<1.0	1.6
Cobalt	7440-48-4	0.5	mg/kg	0.9	3.0	2.8	1.4	2.4
Lead	7439-92-1	1.0	mg/kg	1.9	7.8	4.1	2.9	3.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	250	167	177	512	397
Nickel	7440-02-0	1.0	mg/kg	1.5	3.3	3.8	2.1	3.6
Selenium	7782-49-2	0.1	mg/kg	<0.1	0.2	0.2	0.1	0.2
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	1.3	6.5	7.6	1.7	5.4
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	90	240	170	50	140
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	346	340	262	247	335
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	0.06	0.14	0.11	0.05	0.12
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	<3	10	6	<3	4
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	<3	10	9	<3	4
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	3	4	4	3	<3
C15 - C28 Fraction	----	3	mg/kg	<3	<3	4	<3	4
C29 - C36 Fraction	----	5	mg/kg	<5	8	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	3	12	8	3	4
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/50-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP92-85_L	KP120-5_U	KP110-4_U	KP92-75_U	KP92-95_U
			Sampling date / time	10-Jan-2022 00:00	08-Jan-2022 00:00	06-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-007	EB2200737-008	EB2200737-009	EB2200737-012	EB2200737-013
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	80.1	84.2	89.4	97.6	88.5
Toluene-D8	2037-26-5	0.2	%	70.2	76.8	81.4	88.9	82.6
4-Bromofluorobenzene	460-00-4	0.2	%	80.0	88.4	91.2	98.2	91.8
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	106	121	84.3	103	128
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	46.1	44.9	56.7	48.9	55.8
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	47.5	52.5	52.5	68.8	55.0

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**9.4**	**9.2**	**9.4**	**9.9**	**9.9**
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	<2	<2
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	<0.02	<0.02
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.042**	**0.340**	**0.102**	**0.010**	**0.014**
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**26**	**212**	**64**	<10	<10
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**14.2**	**40.8**	**23.6**	**35.0**	**45.5**
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**2830**	**8160**	**4720**	**6990**	**9090**
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**4.54**	**13.1**	**7.56**	**11.2**	**14.6**
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Net Acidity (sulfur units)	----	0.02	% S	<0.02	<0.02	<0.02	<0.02	<0.02
Net Acidity (acidity units)	----	10	mole H+ / t	<10	<10	<10	<10	<10
Liming Rate	----	1	kg CaCO3/t	<1	<1	<1	<1	<1
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.04**	**0.34**	**0.10**	<0.02	<0.02
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**26**	**212**	**64**	<10	<10
Liming Rate excluding ANC	----	1	kg CaCO3/t	**2**	**16**	**5**	<1	<1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	**29.7**	**35.8**	**32.4**	**19.2**	**7.7**
EG005(ED093)-SD: Total Metals in Sediments by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**5840**	**6700**	**5590**	**720**	**760**
Iron	7439-89-6	50	mg/kg	**32300**	**24700**	**22200**	**7960**	**8110**
EG020-SD: Total Metals in Sediments by ICPMS								
Antimony	7440-36-0	0.50	mg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Arsenic	7440-38-2	1.00	mg/kg	**11.0**	**26.6**	**20.5**	**19.6**	**16.5**
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	7440-47-3	1.0	mg/kg	**28.5**	**27.8**	**37.0**	**9.3**	**11.6**
Copper	7440-50-8	1.0	mg/kg	**6.1**	**3.6**	**3.2**	<1.0	<1.0
Cobalt	7440-48-4	0.5	mg/kg	**4.2**	**7.0**	**5.9**	**1.1**	**1.2**
Lead	7439-92-1	1.0	mg/kg	**13.4**	**9.5**	**9.8**	**2.4**	**2.4**

Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

Compound	CAS Number	LOR	Unit	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
				EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EG020-SD: Total Metals in Sediments by ICPMS - Continued								
Manganese	7439-96-5	10	mg/kg	**102**	**156**	**212**	**228**	**316**
Nickel	7440-02-0	1.0	mg/kg	**5.3**	**7.6**	**6.5**	**1.7**	**1.9**
Selenium	7782-49-2	0.1	mg/kg	**0.3**	**0.4**	**0.3**	**0.1**	**0.1**
Silver	7440-22-4	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	7440-66-6	1.0	mg/kg	**10.2**	**12.1**	**11.0**	**1.6**	**1.8**
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**110**	**40**	**60**	**60**	**80**
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	2	mg/kg	**181**	**27**	**35**	**292**	**355**
EP003: Total Organic Carbon (TOC) in Soil								
Total Organic Carbon	----	0.02	%	**0.15**	**0.56**	**0.20**	**0.04**	**0.06**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
>C16 - C34 Fraction	----	3	mg/kg	**4**	**3**	**4**	<3	<3
>C34 - C40 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
>C10 - C40 Fraction (sum)	----	3	mg/kg	**4**	**3**	**4**	<3	<3
>C10 - C16 Fraction minus Naphthalene (F2)	----	3	mg/kg	<3	<3	<3	<3	<3
EP080-SD / EP071-SD: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	3	mg/kg	<3	<3	<3	<3	<3
C10 - C14 Fraction	----	3	mg/kg	<3	<3	**3**	<3	<3
C15 - C28 Fraction	----	3	mg/kg	**3**	<3	**4**	<3	<3
C29 - C36 Fraction	----	5	mg/kg	<5	<5	<5	<5	<5
^ C10 - C36 Fraction (sum)	----	3	mg/kg	**3**	<3	**7**	<3	<3
EP080-SD / EP071-SD: Total Recoverable Hydrocarbons								
C6 - C10 Fraction	C6_C10	3	mg/kg	<3	<3	<3	<3	<3
C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	3.0	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0
EP080-SD: BTEXN								
Benzene	71-43-2	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	108-88-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Ethylbenzene	100-41-4	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP080-SD: BTEXN - Continued								
meta- & para-Xylene	108-38-3 106-42-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
ortho-Xylene	95-47-6	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
^ Total Xylenes	----	0.5	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
^ Sum of BTEX	----	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	91-20-3	0.2	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
EP090: Organotin Compounds								
Monobutyltin	78763-54-9	1	µgSn/kg	<1	<1	<1	<1	<1
Dibutyltin	1002-53-5	1	µgSn/kg	<1	<1	<1	<1	<1
Tributyltin	56573-85-4	0.5	µgSn/kg	<0.5	<0.5	<0.5	<0.5	<0.5
EP131A: Organochlorine Pesticides								
Aldrin	309-00-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-BHC	319-84-6	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-BHC	319-85-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
delta-BHC	319-86-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDD	72-54-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDE	72-55-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
4.4`-DDT	50-29-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of DDD + DDE + DDT	72-54-8/72-55-9/5 0-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Dieldrin	60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
alpha-Endosulfan	959-98-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
beta-Endosulfan	33213-65-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endosulfan sulfate	1031-07-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Endosulfan (sum)	115-29-7	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin	72-20-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin aldehyde	7421-93-4	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Endrin ketone	53494-70-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor	76-44-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Heptachlor epoxide	1024-57-3	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
Hexachlorobenzene (HCB)	118-74-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
gamma-BHC	58-89-9	0.25	µg/kg	<0.25	<0.25	<0.25	<0.25	<0.25
Methoxychlor	72-43-5	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
cis-Chlordane	5103-71-9	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
trans-Chlordane	5103-74-2	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Total Chlordane (sum)	----	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	KP120-6_U	KP119-7_U	KP119-8_U	KP92-75_L	KP92-85_U_1
			Sampling date / time	08-Jan-2022 00:00	08-Jan-2022 00:00	11-Jan-2022 00:00	10-Jan-2022 00:00	10-Jan-2022 00:00
Compound	CAS Number	LOR	Unit	EB2200737-014	EB2200737-015	EB2200737-016	EB2200737-017	EB2200737-018
				Result	Result	Result	Result	Result
EP131A: Organochlorine Pesticides - Continued								
Oxychlordane	27304-13-8	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
^ Sum of Aldrin + Dieldrin	309-00-2/60-57-1	0.50	µg/kg	<0.50	<0.50	<0.50	<0.50	<0.50
EP131B: Polychlorinated Biphenyls (as Aroclors)								
^ Total Polychlorinated biphenyls	----	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1016	12674-11-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1221	11104-28-2	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1232	11141-16-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1242	53469-21-9	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1248	12672-29-6	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1254	11097-69-1	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
Aroclor 1260	11096-82-5	5.0	µg/kg	<5.0	<5.0	<5.0	<5.0	<5.0
EP080-SD: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.2	%	**62.9**	**62.8**	**65.4**	**70.9**	**73.7**
Toluene-D8	2037-26-5	0.2	%	**55.0**	**53.9**	**56.7**	**61.8**	**63.9**
4-Bromofluorobenzene	460-00-4	0.2	%	**64.3**	**70.2**	**74.9**	**79.0**	**84.5**
EP090S: Organotin Surrogate								
Tripropyltin	----	0.5	%	**78.4**	**90.8**	**127**	**127**	**81.1**
EP131S: OC Pesticide Surrogate								
Dibromo-DDE	21655-73-2	0.50	%	**60.5**	**59.5**	**55.1**	**37.7**	**65.4**
EP131T: PCB Surrogate								
Decachlorobiphenyl	2051-24-3	0.5	%	**62.5**	**65.0**	**62.5**	**50.0**	**63.8**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	TB	FB	----	----	----
			Sampling date / time	10-Jan-2022 00:00	10-Jan-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2200737-010	EB2200737-011	--------	--------	--------
				Result	Result	----	----	----
EP071: Total Petroleum Hydrocarbons								
C10 - C14 Fraction	----	50	µg/L	----	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	----	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	----	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	----	<50	----	----	----
EP071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
>C10 - C16 Fraction	----	100	µg/L	----	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	----	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	----	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	----	<100	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	----	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ Total Xylenes	----	2	µg/L	<2	----	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**115**	----	----	----	----
Toluene-D8	2037-26-5	2	%	**97.4**	----	----	----	----
4-Bromofluorobenzene	460-00-4	2	%	**98.7**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: **SOIL**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080-SD: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	51	145
Toluene-D8	2037-26-5	42	144
4-Bromofluorobenzene	460-00-4	58	142
EP090S: Organotin Surrogate			
Tripropyltin	----	35	130
EP131S: OC Pesticide Surrogate			
Dibromo-DDE	21655-73-2	10	119
EP131T: PCB Surrogate			
Decachlorobiphenyl	2051-24-3	10	106

Sub-Matrix: **WATER**		Recovery Limits (%)	
Compound	*CAS Number*	*Low*	*High*
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	66	138
Toluene-D8	2037-26-5	79	120
4-Bromofluorobenzene	460-00-4	74	118

Inter-Laboratory Testing

Analysis conducted by ALS Sydney, NATA accreditation no. 825, site no. 10911 (Chemistry) 14913 (Biology).

(SOIL) EP131A: Organochlorine Pesticides

(SOIL) EP131S: OC Pesticide Surrogate

(SOIL) EP131B: Polychlorinated Biphenyls (as Aroclors)

(SOIL) EP131T: PCB Surrogate

Appendix 7: Marine Megafauna Noise Management Plan

BAS-210 0045

Santos

Darwin Pipeline Duplication (DPD) Project –Marine Megafauna Noise Management Plan (MMNMP)

PROJECT / FACILITY	Barossa DPD Project
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	Owner	Reviewer/s Managerial / Technical / Site	Approver
	Project Environmental Lead	Project HSE Manager	Project Director
F			

Any hard copy of this document, other than those identified above, are uncontrolled. Please refer to the Barossa Document Management System for the latest revision.

Rev	Rev Date	Author / Editor	Amendment
A	22/08/2022	RPS	Issued for Santos review
B	31/10/2022	RPS	Issued for Santos review
C	20/12/2022	RPS	Issued for Santos review
D	30/01/2023	RPS	Issued for Santos review
E	9/03/2023	RPS	Issued for Santos review
F	26/04/2023	RPS	Issued for NT EPA review

Santos

Contents

Acronyms, terms, units of measurement and definitions **6**

Abbreviations and acronyms 6

Glossary 7

Measurement units 9

1 Introduction **10**

1.1 Project overview 10

1.2 Purpose 12

1.3 Scope 12

1.4 Plan structure 14

1.5 Proponent 14

1.6 Document review, revision and availability 16

2 Detailed activity description **17**

2.1 Project Area 17

2.2 Construction activities 19

2.3 Indicative construction schedule 24

3 Legal and other obligations **26**

3.1 Barossa DPD Project approvals 26

3.2 Legislative framework 27

4 Environmental management framework **31**

4.1 Santos management system 31

4.2 Santos' Environment, Health and Safety Policy 31

4.3 DPD Project environmental management plans 31

5 Existing environment **32**

5.1 Physical environment 32

5.2 Marine megafauna 34

5.3 Sharks, rays and sawfishes 53

6 Noise assessment **54**

6.1 Underwater noise sources 54

6.2 Underwater noise thresholds 56

6.3 Underwater noise modelling 57

7 Impact assessment **72**

7.1 Conceptual site model 72

7.2 Impact assessment methods 72

7.3 Impact assessment summary 75

7.4 Assessment of potential for cumulative impacts 78

8 Environmental management strategy 79

8.1 NT EPA hierarchy 79

8.2 Environmental performance objectives and performance criteria 80

8.3 Adaptive management mechanism 80

8.4 Noise impact management actions 80

9 Environmental management implementation strategy 93

10 Stakeholder engagement and communications 94

11 References 95

Figures

Figure 1-1: DPD Project Location 11

Figure 1-2: Conceptual model of management plan geographical scopes 13

Figure 2-1: DPD Project Area (NT) 18

Figure 2-2: Indicative trench locations 20

Figure 5-1: Biologically important areas for the Indo-Pacific humpback dolphin 39

Figure 5-2: Biologically important areas for the Australian snubfin dolphin 41

Figure 5-3: Biologically important areas for the Indo-Pacific bottlenose dolphin 43

Figure 5-4: Flatback turtle biologically important areas and habitats critical to survival 49

Figure 5-5: Olive ridley turtle biologically important areas and habitats critical to survival 52

Figure 6-1: Noise modelling locations 60

Figure 6-2: Modelling location 3 – TSHD and CSD TTS and PTS contours for dolphins (MSL) 69

Figure 6-3: Modelling location 2 – TSHD behavioural contours for dolphins and sirenians (MSL) 70

Figure 6-4: Modelling location 3 – TSHD and CSD behavioural contours for dolphins and sirenians (MSL) 71

Figure 8-1: Marine megafauna observation and adaptive management protocol for routine construction operations including the use of Xcentric Ripper tool. 83

Figure 8-2: Marine megafauna observation and adaptive management protocol for contingency hydraulic hammering. 84

Tables

Table 1-1: Marine Megafauna Noise Management Plan Structure 14
Table 1-2: Proponent details for Barossa DPD Project's Pipeline licences 15
Table 2-1: Preliminary pre-lay, construction, installation, and pre-commissioning schedule for DPD 25
Table 3-1: International conventions, agreements, and guidelines relevant to the activity 27
Table 3-2: Commonwealth legislation, standards, and guidelines 28
Table 3-3: Northern Territory legislation, standards, plans, and guidelines 29
Table 5-1: Indicative noise levels from typical Darwin Harbour vessels and DPD Project trenching vessels 33
Table 5-2: Marine mammal species identified as known or likely to occur in the Project Area 36
Table 5-3: Threatened and migratory marine reptile species identified as habitat critical and as likely to occur in the Project Area. 45
Table 6-1: Noise impact thresholds for the marine fauna groups in Darwin Harbour 56
Table 6-3: Noise Modelling Locations and Scenarios 59
Table 6-4: Modelled noise source levels 59
Table 6-5: Tide heights within Darwin Harbour (Williams et al., 2006) 61
Table 6-6: PTS, TTS and Behavioural response threshold ranges for each fauna group for each modelled scenario/location at mean sea level 65
Table 6-7: Influence of BHD hydraulic hammering time on PTS and TTS ranges for each fauna group at mean sea level 66
Table 6-8: Quantitative behavioural disturbance threshold ranges for marine fauna across varying tidal states 68
Table 7-1: Consequence descriptors 73
Table 7-2: Summary environmental consequence descriptors 75
Table 7-3: Summary of underwater noise impact assessment outcome 76
Table 8-1: Environmental management strategy template 79
Table 8-2: Noise emissions EPOs and associated performance criteria 80
Table 8-3: Summary of management actions for noise emissions during routine construction including the use of an Xcentric Ripper tool 86
Table 8-4: Summary of additional environmental management actions for contingency rock breaking using hydraulic hammer 90

Appendices

Appendix 1: Santos Environment, Health and Safety Policies

Acronyms, terms, units of measurement and definitions

Abbreviations and acronyms

Acronym	Definition
ALARP	as low as reasonably practicable
AOO	area of occupancy
ASSDMP	acid Sulphate Soils and Dewatering Management Plan
BHD	backhoe dredge
BIA	biologically important area
BOM	Bureau of Meteorology
CEMP	Construction Environment Management Plan
CSD	cutter suction dredge
DAWE	Commonwealth Department of Agriculture, Water and the Environment
DENR	Northern Territory Department of Natural and Environmental Resources, now the Northern Territory Department of Environment, Parks and Water Security
DEPWS	Northern Territory Department of Environment, Parks and Water Security
DHAC	Darwin Harbour Advisory Committee
DITT	Northern Territory Department of Industry Tourism and Trade
DIPL	Northern Territory Department of Infrastructure, Planning and Logistics
DLNG	Darwin Liquified Natural Gas
DoE	Commonwealth Department of Environment
DP	dynamic positioning
DPD	Darwin Pipeline Duplication
EMP	environmental management plan
ENVID	environmental impact identification
EP Act	*Environmental Protection Act 2019*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GEP	gas export pipeline
HF	high frequency
HSEQ	health, safety, environment and quality
HSEQ-MS	health, safety, environment and quality management system
LAT	lowest astronomical tide
LF	low frequency

Acronym	Definition
MFO	marine fauna observer
MNES	matters of national environmental significance
MMNMP	Marine Megafauna Noise Management Plan
MFE	Mass flow excavation
NMR	North Marine Region
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NSW	New South Wales
NT	Northern Territory
NT EPA	Northern Territory Environmental Protection Authority
NW	North western
PMST	Protected Matters Search Tool
PPE	personal protective equipment
PTS	permanent threshold shift
ROV	remotely operated underwater vehicle
SEL	sound exposure level
SER	Supplementary Environmental Report
SHB	split hopper barge
SPL	sound pressure level
SPRAT	Species Profile and Threats Database
TSDMMP	Trenching and Spoil Disposal Management and Monitoring Plan
TSHD	trailer suction hopper dredge
TSSC	Threatened Species Scientific Committee
TTS	temporary threshold shift
TPWC	Territory Parks and Wildlife Conservation
WA	Western Australia

Glossary

Term	Definition
Biologically important area	Areas spatially defined and mapped by the Commonwealth Department of Environment (DoE) where aggregations of individuals of a species are known to display a biologically important behaviour such as breeding, foraging, resting or migration.
Cetacean	A marine mammal of the order Cetacea; a whale, dolphin, or porpoise.

Term	Definition
Consequence	Impact of an event or incident e.g. a loss, injury or concern. May be expressed qualitatively or quantitatively.
Effect	A change to the environment (including socio-economic changes) resulting from the DPD Project that may be positive or negative.
Environment	Consistent with the Envir*onment Protection and Biodiversity Conservation Act 1999*, the definition of environment encompasses physical, biological, heritage, cultural, social, health, safety and economic aspects.
Environmental Performance Standard	A statement of performance required of a management action.
Environmental Performance Objective	Measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks are of an acceptable level.
Impact	A positive or negative effect the DPD Project would have on the environment (including physical, ecological and socio-economic environments.
Listed species	Species of conservation importance listed under the Envir*onment Protection and Biodiversity Conservation Act 1999*, or *Territory Parks and Wildlife Conservation Act 1976*.
Measurement Criteria	A system of measurements that define whether a project is successful.
Performance Criteria	The standards by which success of management actions is evaluated.
Project Area	The Project Area is an area extending 500 m either side of the pipeline, within which the Construction Activity will take place.
Residual risk	Risk remaining after implementation of mitigation measures.
Risk	A combination of the potential consequence of an event occurring and the likelihood of the consequence occurring.
Sensitive receptor	A receptor that could be subject to adverse impacts from the DPD Project.
Significant impact	Under the Envir*onment Protection and Biodiversity Conservation Act 1999*, Significant Impact Guidelines 1.1, a 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment, which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts.
Target	Specific and measurable performance requirements to achieve Environmental Performance Objectives.

Measurement units

Measurement unit	Definition
°	degrees
µS	microSiemens
cm	centimetre
dB	decibels
dB(A)	a-weighted sound pressure level in decibels
Hz	hertz
kHz	kilohertz
km	kilometre
km^2	square kilometre
M	metre
m^2	square metre
mg/L	milligrams per litre
Nm	nautical mile (1.856 km)

1 Introduction

1.1 Project overview

Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the existing Bayu-Undan to Darwin Gas Export Pipeline (GEP) in the Timor Sea. The Bayu-Undan to Darwin GEP is a dry natural gas export pipeline transporting gas from the Bayu-Undan Field located in Timor-Leste waters to the Darwin liquefied natural gas (DLNG) facility at Wickham Point peninsula near Darwin, Northern Territory (NT), Australia. The Bayu-Undan to Darwin GEP has been operational since 2005. In anticipation of the end of the Bayu-Undan Field's commercial production in 2022 – 2023, the Barossa Field is being developed to supply gas to the DLNG. The supply of backfill gas to the DLNG facility was originally planned to be achieved through the installation of a 262 kilometre (km) Barossa GEP to a tie-in point on the existing Bayu-Undan to Darwin GEP.

In recognition of potential Carbon Capture and Storage opportunities at the Bayu-Undan Field, Santos has approved an alternative solution to transport backfill gas to the DLNG facility through the construction of an additional segment of pipeline to extend the Barossa GEP to the DLNG facility instead of tying into the existing Bayu-Undan to Darwin GEP. Construction of this segment of pipeline is referred to as the Darwin Pipeline Duplication (DPD) Project, as it will be installed parallel to the existing Bayu-Undan to Darwin GEP. The effective 'duplication' of the existing Bayu-Undan to Darwin GEP is considered the optimal route to minimise potential environmental and social impacts.

The pipeline will run from a location where the Barossa GEP approaches the existing Bayu-Undan pipeline and continue through Darwin Harbour into the DLNG facility at Wickham Point (**Figure 1-1**). Santos' DPD Project includes a ~23 km segment in Commonwealth waters and ~100 km segment in NT waters and lands adjacent to the existing Bayu-Undan to Darwin GEP. The DPD Pipeline (NT) will be located for the most part ~100 m from the existing Bayu-Undan to Darwin pipeline, to minimise potential environmental and social impacts. The Project Area for the DPD Project includes a 2 km buffer around the pipeline route in NT waters, the onshore construction area at the DLNG facility and an offshore spoil disposal ground for the trench spoil disposal (**Figure 1-1**).

Pre-lay trenching is required to meet a number of objectives, including providing pipeline protection and stability (in combination with rock installation), reducing pipeline spanning and ensuring compliance with shipping channel clear water requirements. Sections of the pipeline route within the harbour, with a combined length of up to ~12.8 km, will be trenched using various equipment with the remainder of the pipeline laid directly on the seabed. Rock sourced from a local quarry will be used to backfill for anchor protection in some areas where anchor protection or additional stabilisation is required.

Potential underwater noise impacts generated by the construction of the pipeline in NT waters is covered under this Marine Megafauna Noise Management Plan (MMNMP).

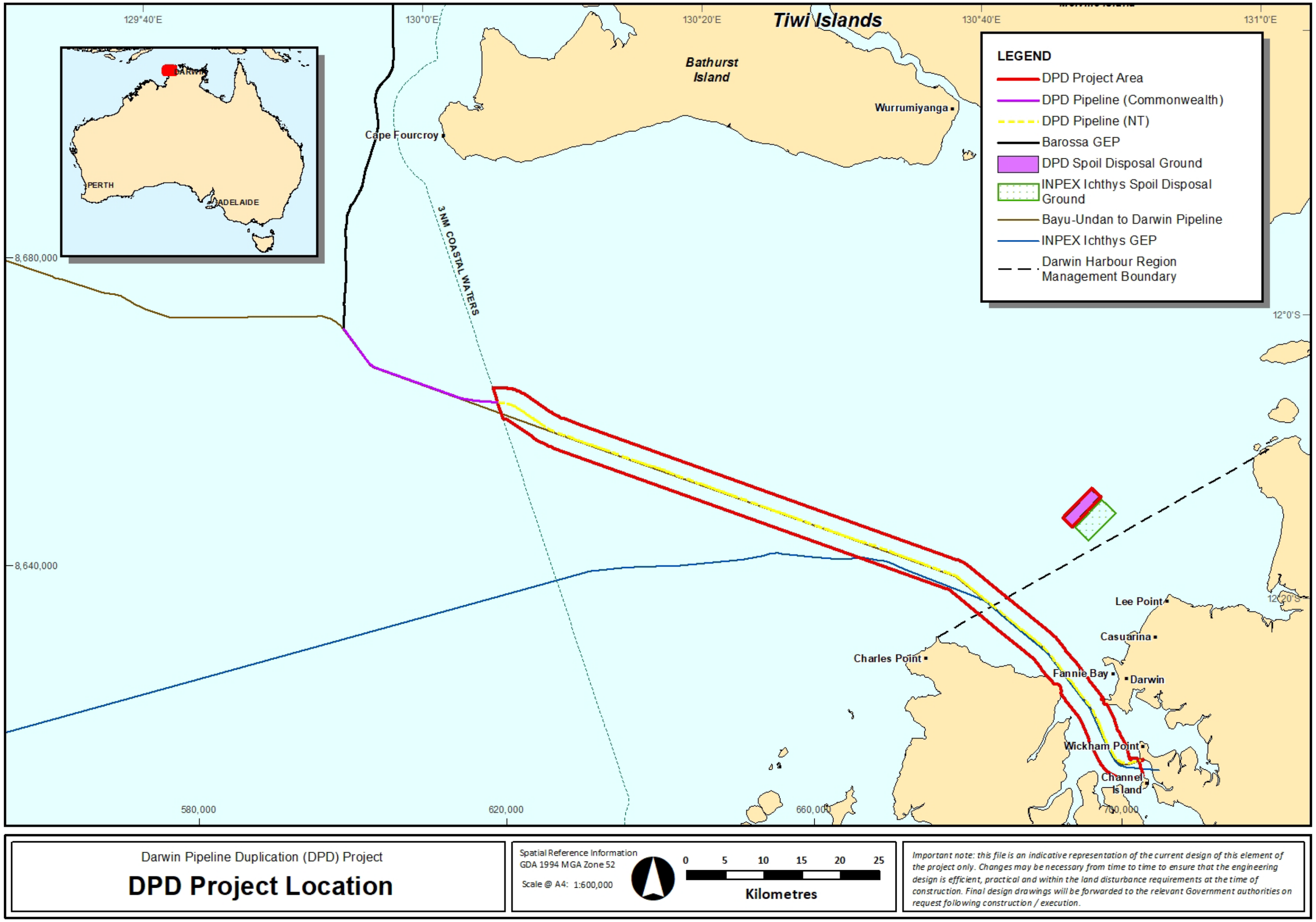


Figure 1-1: DPD Project Location

1.2 Purpose

This MMNMP details the likely impacts associated with underwater noise-generating activities during construction of the DPD pipeline in NT waters (DPD Pipeline (NT)), in particular trenching activities in Darwin Harbour. Assessment of these impacts is based on the results of project-specific underwater noise modelling undertaken during the environmental assessment phase of the DPD Project.

Further, this MMNMP identifies and details measures that will be implemented as required to manage and mitigate potential environmental impacts to marine megafauna due to underwater noise emissions from construction of the DPD Pipeline (NT).

The purpose of this MMNMP is to:

+ Demonstrate that all measures deemed reasonable and practicable will be implemented to manage underwater noise impacts and other potential environmental impacts to marine megafauna arising from the proposed DPD Project construction activities.
+ Prior to finalisation, demonstrate how the requirements of relevant conditions of approvals under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the NT *Environment Protection Act 2019* (EP Act) will be met.
+ Satisfy the Northern Territory Environmental Protection Authority (NT EPA) requirement for a draft marine megafauna management plan for construction activities that includes:
  - baseline (pre-construction) cumulative noise within the zone of influence of the proposal and relevant parameters to be monitored to detect impacts.
  - noise trigger levels for relevant parameters (and description of their derivation) corresponding to actions that must be taken in the event that monitoring indicates that construction activities are likely to impact protected species.
  - management actions to be applied if noise triggers are exceeded in accordance with the environmental decision-making hierarchy.
  - Santos has interpreted the latter two requirements as the application of management zones, as informed by noise modelling, and monitoring of sensitive fauna (using trained marine fauna observers (MFOs)) within these zones with associated management actions if sensitive fauna are observed.

1.3 Scope

This MMNMP addresses the noise generating activities during the construction of the ~100 km section of the DPD pipeline from the shore pull onshore termination point to the 3 nm Commonwealth/NT waters boundary (**Figure 1-2**).

The noise generating activities considered in the MMNMP, include:

+ Trenching along segments of the pipeline route within Darwin Harbour, with a combined length of up to ~16.5 km:
  - Sediment cutting using a cutter suction dredge (CSD)
  - Suction dredging using a trailer suction hopper dredge (TSHD)
  - Rock breaking (hydraulic tools; Xcentric Ripper or Hydraulic hammer tool) using a backhoe dredge (BHD)

- Excavation dredging using a BHD

+ Mass flow excavation (MFE)
+ Vessels (various, including the use of survey equipment)
+ Helicopters

This MMNMP forms part of a suite of environmental management plans (EMPs) under an overarching Santos Darwin Pipeline Duplication Project Offshore Construction Environmental Management Plan (Offshore CEMP; BAS-210 0024) which covers construction activities from the 3 nm Commonwealth/NT waters boundary to the shore pull onshore termination point. The construction of the remaining section of pipeline between the onshore termination point and the upstream weld of the beach valve will be subject to the DPD Project Onshore Pipeline CEMP (BAS-210 0025; Onshore CEMP) (**Figure 1-2**).

In addition to this MMNMP there are two further EMPs under the Offshore CEMP that address specific activities during construction (**Figure 1-2**). These are the:

+ Trenching and Spoil Disposal Monitoring and Management Plan (TSDMMP) (BAS-210 0023) that addresses all trenching and spoil disposal activities from the 3 nm Commonwealth/NT waters boundary to the shore pull onshore termination point
+ Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) (BAS-210 0049) that addresses all activities associated with acid sulfate soils (ASS) from lowest astronomical tide (LAT) to the upstream weld of the beach valve.

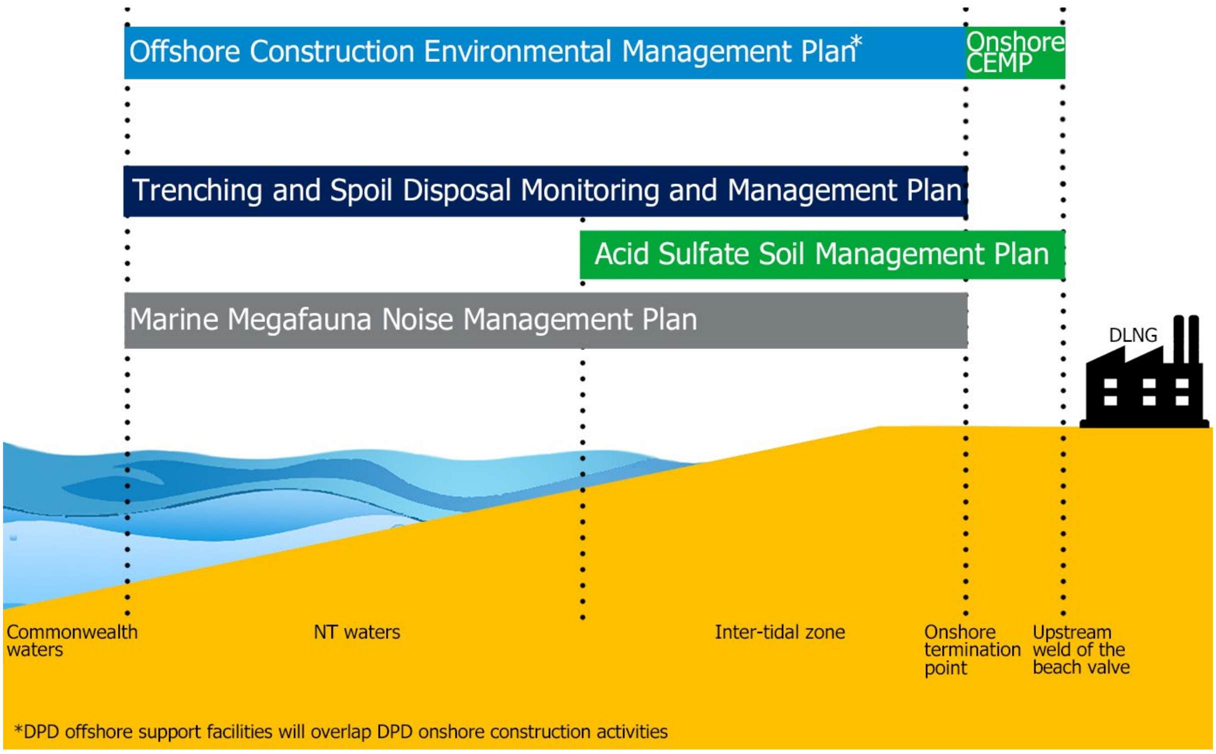


Figure 1-2: Conceptual model of management plan geographical scopes

1.4 Plan structure

This MMNMP has been prepared and structured in accordance with the Northern Territory Environment Protection Authority: Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015). The guideline requirements and where they have been addressed within the MMNMP are detailed in **Table 1-1**.

Table 1-1: Marine Megafauna Noise Management Plan Structure

Regulatory requirement Northern Territory Environment Protection Authority: Draft Guideline for the Preparation of an Environmental Management Plan 2015	Relevant MMNMP Section
Project Overview Proponent details Key contacts	**Section 1**: Introduction
Clear and comprehensive project description	**Section 2**: Detailed Activity Description
Legal and other obligations	**Section 3**: Legal and Other Obligation
Environmental management framework	**Section 4**: Environmental Management Framework
Existing environment	**Section 5**: Existing Environment
Conceptual Site Model Environmental risk assessment	**Section 6**: Noise Modelling Assessment **Section 7**: Environmental Impact Assessment The requirement for a conceptual site model is addressed within the impact assessment.
Environmental Management Strategies	**Section 8**: Environmental Management Strategies
Corrective actions and contingencies Auditing Reporting and Review Training and awareness Communication	**Section 9**: Implementation Strategy

1.5 Proponent

1.5.1 Details of the proponent

Santos, as the operator of the Barossa Joint Venture, has applied to the NT Department of Industry Tourism and Trade (DITT) for two pipeline licences for the DPD Pipeline (NT):

+ Coastal and Territorial Waters Licence for the section of the Pipeline under the jurisdiction of the *Petroleum (Submerged Lands) Act 1981* (i.e. between the NT Coastal Waters Limit and the Territorial Sea Baseline)

- Inland Waters Licence for the section of Pipeline under the jurisdiction of the *Energy Pipelines Act 1981* (i.e. between the Territorial Sea Baseline and the upstream weld of the beach valve).

Both licences are applicable to the section of Pipeline within the scope of the MMNMP. The proposed proponent details are provided in **Table 1-2**, with the nominated operator shown in bold.

Table 1-2: Proponent details for Barossa DPD Project's Pipeline licences

Title	Proponent (nominated operator in bold)	ABN	Interest	Titles
+ Coastal and Territorial Waters Licence + Inland Waters Licence	**Santos NA Barossa Pty Ltd**	109 974 932	25.0%	Business Address: Level 7, 100 St Georges Terrace, Perth, Western Australia, 6000 Telephone number: (08) 6218 7100 Fax number: (08) 6218 7200 Email address: barossa.regulatory@santos.com
	Santos Offshore Pty Ltd	158 702 071	25.0%	
	SK E&S Australia Pty Ltd	005 475 589	37.5%	Business Address: Level 6, 60 Martin Place, Sydney NSW 2000, Australia Telephone number: (02) 21213304 Fax number: None Email address: hyunjoon-kim@sk.com
	JERA Barossa Pty Ltd	18 654 004 387	12.5%	Business Address: Level 9 Brookfield Place, 125 St Georges Terrace, Perth, Western Australia, 6000

1.5.2 Details of nominated liaison person

Name: Dr Lachlan MacArthur

Title: Environmental Approvals Adviser

Business address: Level 7, 100 St Georges Terrace, Perth, WA 6000

Telephone number: (08) 6218 7100

Email: Barossa.regulatory@santos.com

1.5.3 Notification procedure in the event of changed details

If there is a change in the nominated operator or a change in the contact details for the operator or liaison person, Santos will notify the DITT and provide the updated details.

1.6 Document review, revision and availability

This MMNMP has been prepared for submission with the SER (BAS-210 0020) and other supporting documents to the NT EPA, under the EP Act and to DCCEEW under the EPBC Act, and will be updated to reflect any relevant regulatory conditions associated with the DPD Project approvals.

Santos will review and update the document as required based on regulatory feedback and any regulatory conditions on the DPD Project approval as applicable. The final MMNMP will be made publicly available on an Australian website.

2 Detailed activity description

For the DPD Project, Santos is preparing to develop a second pipeline to connect the Barossa GEP to the DLNG facility. The pipeline will run from where the Barossa GEP approaches the existing Bayu-Undan to Darwin GEP to the existing DLNG facility in Darwin Harbour. The DPD Pipeline (NT) will include a ~23 km segment in Commonwealth waters and ~100 km segment in NT waters and lands. This MMNMP addresses the section within NT waters to the onshore termination point at the shore crossing. For additional description of the activity, refer to Section 2 of the Offshore CEMP (BAS-210 0024).

2.1 Project Area

Santos has defined the Project Area as the DPD Project footprint and an area within which construction activity will take place. The Project Area extends nominally 2 km either side of the DPD pipeline route and additionally includes the spoil disposal ground (**Figure 2-1**).

The Project Area consists of the three key areas, being:

+ Offshore NT waters (i.e. NT waters outside Darwin Harbour). Note that this includes the proposed location for spoil disposal;
+ Darwin Harbour (i.e. waters within the Darwin Harbour Management Area); and
+ Shore crossing within the previously disturbed DLNG facility footprint.

The locations for activities along the DPD Pipeline are described using ‘kilometre points’ (KP), where KP0 is the beginning of the DPD Project pipeline from the “pipeline end termination point” (PLET) in Commonwealth waters. For the purposes of this MMNMP, the scope begins at the 3 nm Commonwealth/NT waters boundary at ~KP23, and terminates at the onshore termination point at KP122.484. The following sections present details of construction activities which have been considered in the MMNMP.

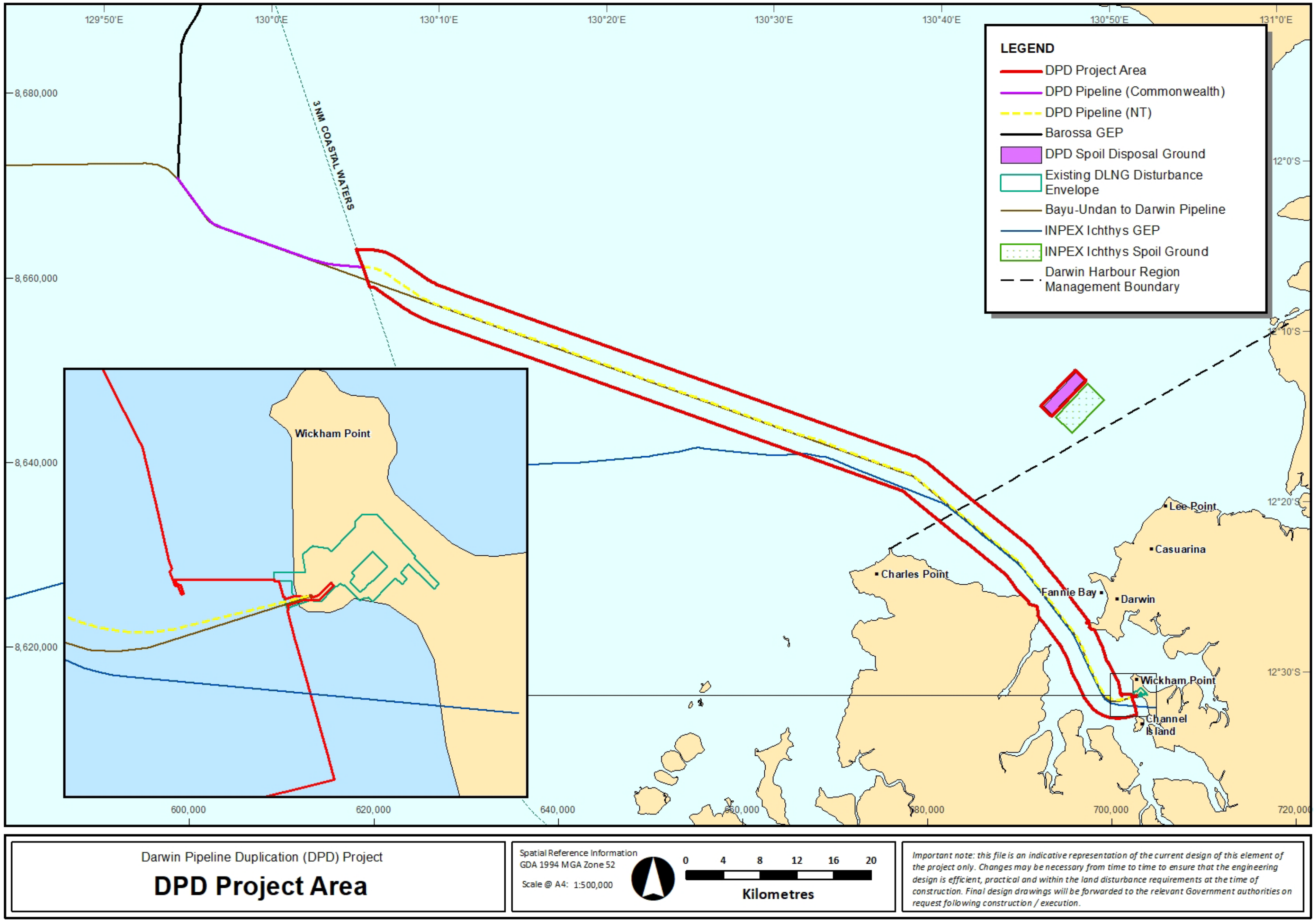


Figure 2-1: DPD Project Area (NT)

2.2 Construction activities

2.2.1 Pre-lay works

In water depths less than approximately 20 m the pipeline will require stabilisation due to exposure to waves, currents and tidal movement, and may need impact protection from third-party activities (i.e., anchors). As such, in some areas the pipeline will be installed and buried in a trench on the seafloor for stabilisation and protection. Some areas of seabed will also require intervention to reduce the potential for pipeline spanning.

2.2.1.1 Pipeline pre-lay trenching and spoil disposal

Trenching and backfill will be required in discrete sections of the pipeline route (with a combined length of up to ~12.8 km) within both nearshore DPD and shore crossing DPD locations. Locations of proposed trenching along the pipeline route are shown in **Figure 2-2**.

Offshore and within Darwin Harbour, the pre-lay trenching will involve the excavation of a trench (approximately 3 m width at its base) within an indicative trunkline corridor of 40 m width. Trailing Suction Hopper Dredge (TSHD), Cutter Suction Dredge (CSD) and a Backhoe Dredge (BHD) have been proposed for the pre-lay trenching works. Material will be excavated and disposed of at the spoil disposal ground, as shown in **Figure 2-1**.

The CSD will be used in conjunction with the TSHD in some areas. The CSD will crush harder seabed material, where required, and leave this in-situ with the TSHD dredging the material and storing spoil within its hopper. The TSHD will deposit spoil at the offshore spoil ground by opening the bottom doors of the hopper.

Closer to shore and at the shore crossing a BHD will be used. Hydraulic rock breaking tools may also be required in conjunction with the BHD for rock breaking. The base case is to use a Xcentric Ripper tool with a hydraulic hammer used as a contingency. The BHD will be supported in shallow waters on spuds and will empty spoil onto split hopper barges (SHBs). These barges will be self-propelled or towed to the spoil disposal ground, where barges 'split' and spoil is released.

At low tide, land-based excavators will also be used to trench at the shore crossing. Excavated spoil will be placed close to low tide allowing any spoil build up to be removed on high tides by the BHD.

A maintenance dredging campaign may be required to ensure the trench is in specification prior to pipe lay. Surveys prior to the pipelay campaign will indicate if maintenance trenching is required based on the level of sediment build-up. It would be expected that only a TSHD and /or BHD would be used for maintenance trenching.

The proposed spoil disposal ground for trenched material is located to the north of Darwin Harbour, within the Beagle Gulf, approximately 12 km north-west of Lee Point. The selected site is adjacent to the spoil disposal ground approved for use by INPEX for the Ichthys Gas Field Development Project (**Figure 2-1**).

Further detail on trenching activities is provided in the TSDMMP (BAS-210 0023).

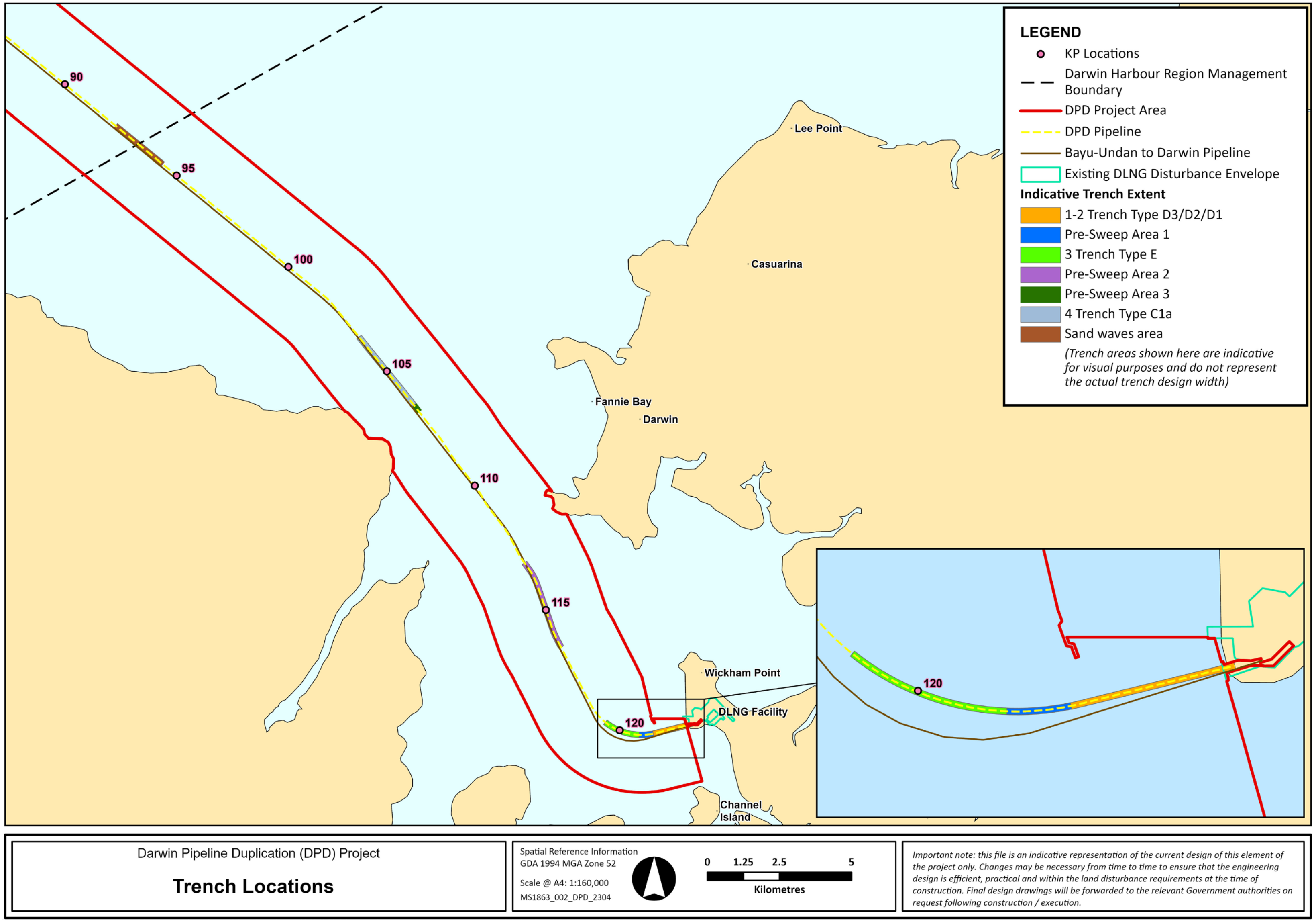


Figure 2-2: Indicative trench locations

2.2.1.2 Rock causeways

To aid in the trenching of the shore crossing, two temporary rock causeways are proposed to be installed either side of the trench in the intertidal zone. These will enable excavators to work further at low tides and provide a stable base for their operation.

2.2.1.3 Span rectification and foundation installation

Where the seabed is uneven a subsea pipeline may be left unsupported across spans between high points in the seabed. Where the spans are beyond acceptable limits and span rectification is required. One area of known sand waves (**Figure 2-2**) will be remediated by the TSHD. For other localised areas the following activities are proposed.

The use of mass flow excavation (MFE) has been identified as a potential method to reduce sediment high points (and therefore pipeline spanning) at 8 locations within two areas along the offshore pipeline route in NT waters. A MFE tool works by accelerating a mass flow of water to blow away sediments within a localised area and can be used to accurately remove sediment high points and reduce pipeline spanning.

MFE is currently the preferred alternative to the installation of numerous concrete mattresses or grout bags to rectify spanning.

The installation of concrete mattresses or grout bags may be used additional to MFE in instances where MFE proves not suitable (e.g., if consolidated sediments are encountered that cannot be removed by MFE) or as an adjunct to MFE if there is residual spanning requiring further rectification. A foundation may be installed for an in-line tee at KP62.8 during pre-lay activities. A construction vessel crane may be used to lift the mattresses or grout bags from the deck of the vessel onto the seabed. Each concrete mattress footprint is ~18 m^2 and may be installed in groups and stacked on top of each other to reach the desired height.

2.2.1.4 Equipment and methods

Trenching and spoil disposal for the DPD Project will be undertaken using the following equipment:

- Backhoe Dredge (BHD): For example "Pinochio/Hippopotous/Ambiorix", or similar (**Section 2.2.1.4.1**).
- BHD hydraulic rock breaking tools (if required): Xcentric Ripper tool (preferred) or hydraulic hammer (contingency) (refer to **Section 2.2.1.4.2**)
- Trailing Suction Hopper Dredge (TSHD): For example "Bonny River/Vox Amalia" or similar (**Section 2.2.1.4.3**)
- Cutter Suction Dredge (CSD): For example "Ambiorix/Athena" or similar (refer to **Section 2.2.1.4.4**)
- Split Hopper Barges (SHBs): For example "Pagadder/Sloeber/Jan Blanken" or similar (**Section 2.2.1.4.5**).
- Excavators (**Section 2.2.1.4.6**)
- Mass flow excavation will be undertaken with N-Sea Twin-prop and Quad-prop excavation tools or similar (**Section 2.2.1.4.7**)

2.2.1.4.1 Backhoe dredger

A BHD is a type of mechanical dredging equipment, consisting of a hydraulic arm and bucket system mounted on a turntable at the front of the pontoon with attached spud legs. Spud legs are driven into the seabed preventing movement due to wind, waves, and currents.

A BHD will be used to trench shallower sections of the DPD pipeline route near the shore crossing. The BHD will be towed to location and will begin operations once positioned and stationary. Trenched material will be lifted by the BHD bucket to an SHB for transport to the spoil disposal ground.

2.2.1.4.2 Hydraulic rock breaking tools

The use of a hydraulic rock breaking tools is required for hard material that the BHD cannot cut through. An Xcentric Ripper tool (preferred) or a hydraulic hammer tool (contingency) is mounted on the BHD in place of the usual bucket. Once the tool has fractured the hard rock the bucket is reattached to the BHD and the broken or fractured strata is dredged by the BHD and loaded into the SHB for transport to and discharge at the spoil disposal ground. This method will only be used when required at specific locations and is a discontinuous process.

2.2.1.4.3 Trailing suction hopper dredger

A TSHD is a type of hydraulic dredger that is a self-propelled sea-going vessel equipped with a hopper that can be loaded or emptied via a dredging installation. Dredging via TSHD is a cyclical process of loading (dredging), transporting, and discharging. TSHDs are the only non-stationary dredger and are not anchored by spud poles.

At the trenching location the TSHD vessel slows to approximately 2 to 3 knots, then one or more suction tubes with dragheads (suction mouths) are lowered to the seabed. Whilst on the seabed swell compensators control the contact between the draghead and the seabed. Pumps then suck the material (a mixture of soil and water) from the seabed into the hopper located within the TSHD.

After the hopper is filled with dredged material, the pumps are stopped, the suction pipes and draghead lifted on deck and the TSHD sails to the spoil disposal ground. At the spoil disposal ground the dredged material is discharged by opening the bottom doors of the hopper.

2.2.1.4.4 Cutter suction dredger

CSDs are stationary hydraulic dredgers that are equipped with a cutter head. The cutter head rotates excavating the seabed which can be sucked up by dredge pumps as a mixture of water and sediment (slurry). CSDs can also be used to break up harder material which is left in-situ for subsequent removal by a TSHD; this will be the mode of operation used for the DPD Project. Whilst operating the dredger moves around the spud pole via the pulling and slacking of two fore sideline wires. The CSD to be used will have barge loading facilities.

The CSDs utilised for this project will have self-propulsion, which will only be used during mobilisation between trench locations. Maximum dredge depth ranges between 31 m (Anthena) and 35 m (Ambiorix).

2.2.1.4.5 Split hopper barge

SHBs are utilised for transporting and discharging of material dredged by the BHD. For this project, it is expected that two SHBs will be used to maximise efficiency and will be either self-propelled, towed or pushed by barges. A third barge may be used to further increase efficiency.

2.2.1.4.6 Excavator

An excavator/s will be utilised to excavate onshore and intertidal material which will be disposed of adjacent to the trench as close to lowest astronomical tide (LAT) as possible. Where this spoil builds up, the BHD will remove the spoil to a SHB for disposal at the offshore spoil ground.

2.2.1.4.7 Mass flow excavation

MFE is expected to take an indicative 7 – 14 days to complete, with an estimated six hours of operation at each site. A MFE tool works by accelerating a mass flow of water to blow away sediments within a localised area and can be used to accurately remove sediment high points and reduce pipeline spanning. MFE is an alternative to the installation of numerous concrete mattresses or grout bags.

2.2.2 Pipeline installation and pre-commissioning

Pipeline installation and pre-commissioning will comprise the following activities:

+ Pipelay activities – The DPD pipeline (NT) will be installed using a continuous assembly pipe-welding installation method. In water deeper than ~20 m the pipeline will be installed using a deep-water dynamic positioning (DP) pipelay vessel. In shallower waters and all waters within the Darwin Harbour, a shallow water pipelay barge will be used and anchoring will be required.
+ In-line tee – The in-line tee (ILT) which can facilitate future pipeline tie-ins to the DPD Project pipeline will be installed in the offshore NT waters at KP62.8 by the deep-water DP pipelay vessel. If required, a foundation for the ILT will be pre-installed during pre-lay works.
+ Pipeline shore pull – Shore pull to bring the DPD Pipeline (NT) onshore, will use a conventional winch operation.
+ Trench backfill – Rock (sourced onshore) will be used where necessary for pipeline stabilisation and protection for sections within Darwin Harbour. Trench backfilling will be required nearshore and at the shore crossing to provide pipeline stability. The rock will likely be installed via a fall pipe vessel (FPV) or side dump vessel (SDV). Self-propelled DP vessels will be used to install rock on to the seabed, possibly with support barges used to transport rock. The volume of rock required is expected to be 200,000 tonnes and no more than 500,000 tonnes. Where possible for the shore crossing, the rock placement will be by shore-based excavators.
+ Post-lay span rectification – To provide pipeline stability, post-lay span rectification may be required to ensure the integrity of the pipeline and avoid failure through fatigue. Where required, spans will be rectified using ROVs to install grout bags that are then filled with grout.

2.2.3 Summary of vessel and support activities

Construction activities will include the operation of vessels, helicopters and ROVs. Vessel and support activities associated with the DPD Project will be undertaken throughout all phases of the DPD Project.

A number of vessel types will be required to complete the proposed activities, including:

+ Marine survey vessels – to support pre-lay and post-lay surveys of the Project pipeline, including verifying trench depth and rock placement, support pipeline and structure placement and monitor spoil ground.
+ Pipelay vessels (to install the pipeline) including: nearshore pipelay barge (shallow water pipelay vessel), dynamically positioned deep water pipelay vessel and pipe supply vessels.

+ Construction support vessels – to support installation of structures (i.e. installation of ILT protection frame, mattresses for scour protection, mechanical protection and stabilisation etc.) and use of MFE tools.
+ Rock installation vessels – including fall pipe vessel, side dump vessels and non-propelled barges
+ Trenching and spoil disposal vessels – including a cutter suction dredge (CSD), trailing suction hopper dredge (TSHD), backhoe dredge (BHD) and split hopper barges (SHB)
+ Survey vessels – to verify trench depth and rock placement and support pipeline and structure placement
+ Supply vessels – to provide general support and supplies to all offshore activities. Supply vessels are expected to operate from local regional ports (i.e. Darwin) to transport fuel, stores, waste and specialist supplies such as rock and pipe
+ Helicopters will be used for transporting passengers and/or urgent freight to/from during offshore installation and commissioning activities.

For trenching and spoil disposal activities, an expected 11 vessels will be required, for deep water and shallow pipelay activities an expected six and seven vessels, respectively, are expected to be involved, for rock installation an expected six vessels will be involved and for pre-commissioning an expected four vessels will be involved.

Supply vessels are expected to operate from local regional ports (i.e. Darwin) to transport fuel, stores, waste and specialist supplies such as rock, pipe etc.

Bunkering (re-fuelling) of the vessels may take place either at sea (i.e. if required for the pipelay vessel) or in port (support and other vessels).

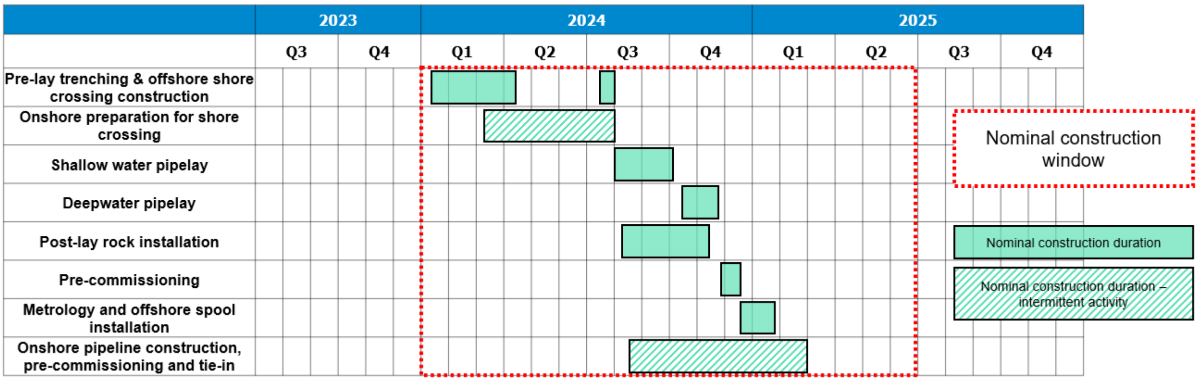
Vessels will vary in length and draft. They may anchor depending on water depth and activity type, with varying anchor requirement and disturbance footprints. Known sensitive areas will be avoided when anchoring.

Throughout the DPD Project, offshore activities will be supported by ROVs. The ROV can be fitted with various tools and camera systems that can be used to capture permanent records of the underwater operations and immediate surrounding environment.

2.3 Indicative construction schedule

Santos is targeting to have all DPD regulatory approvals in place by Q1 2024 to ensure construction activities do not delay Barossa first gas in the first half of 2025. A nominal DPD construction sequence and schedule is shown in **Table 2-1** representing a start of construction activities at the beginning of nominal construction window. The construction activities will span a nominal cumulative period of 15-months in the field. The actual construction sequence and schedule will be subject to the timely receipt of all regulatory approvals and drivers such as vessel availability, operational issues, and weather. Santos' regulatory approvals and stakeholder consultation consider construction activities at any time between Q1 2024 to mid-2025.

Table 2-1: Preliminary pre-lay, construction, installation, and pre-commissioning schedule for DPD



3 Legal and other obligations

The following sections describe the legislative framework governing the impacts from noise emissions during the construction of the DPD Pipeline (NT).

3.1 Barossa DPD Project approvals

This MMNMP has been prepared for submission to the NT EPA with approval documents including the SER (BAS-210 0020) and for submission to the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) as part of Preliminary Documentation (EPBC 2022-9372) for assessment under the EPBC Act. This MMNMP will also be submitted to DITT for approval under the *Petroleum (Submerged Lands) Act 1981* and *Energy Pipelines Act 1981*.

3.1.1 Commonwealth Environmental Approval

The DPD Project including the DPD Pipeline section in Commonwealth waters was referred to the DCCEEW under the EPBC Act on 7 October 2022 (EPBC 2022-9372). This MMNMP will be updated to reflect any relevant regulatory conditions associated with this approval. On 6 December the DPD Project was determined to be a Controlled Action requiring further assessment based on Preliminary Documentation. Further information was requested under section 95A(2) of the EPBC Act on 23 December 2022.

It was determined that the Project may have a significant impact on the following controlling provisions under the EPBC Act:

+ Listed threatened species and communities (sections 18 & 18A)
+ Listed migratory species (sections 20 & 20A)
+ Commonwealth marine areas (sections 23 & 24A)

The Preliminary Documentation is currently being prepared for submission to DCCEEW.

This MMNMP will be updated to reflect any relevant regulatory conditions associated with this approval.

3.1.2 Northern Territory Environmental Approvals

The DPD Project was referred to the NT EPA on 14 January 2022 under Section 55 of the *Environmental Protection Act 2019* (EP Act). The NT EPA determined the DPD proposal required assessment by Supplementary Environmental Report (SER) (Tier 2) in accordance with the Environment Protection Regulations 2020 (EP Regulations). The SER is required to address public submissions and include information additional to the referral document in relation to specific aspects of potential significance. This MMNMP will be updated to reflect any relevant regulatory conditions associated with this approval.

3.1.3 Regulatory requirements specific to noise emissions

The NT EPA considers that the DPD Project has the potential to have a significant impact on marine ecosystems. Marine ecosystems may be significantly impacted by disturbance of threatened species, recreationally or commercially significant species or maritime habitats during construction of the DPD Project.

The NT EPA requested the following additional information to support the SER and the Environmental Approval Process:

+ Provide interpreted outcomes of underwater noise modelling, including modelling of cumulative noise resulting from the proposal and existing activities at sensitive receptors.
+ Provide a draft marine megafauna management plan for construction activities that includes:
  - Baseline (pre-construction) cumulative noise within the zone of influence of the proposal and relevant parameters to be monitored to detect impacts
  - Trigger levels for relevant parameters (and description of their derivation) corresponding to actions that must be taken in the event that monitoring indicates that construction activities are likely to impact protected species
  - Management actions to be applied if triggers are exceeded in accordance with the environmental decision-making hierarchy.

This MMNMP has been prepared to address the relevant requests from NT EPA.

3.2 Legislative framework

Environmental legislative requirements governing DPD Project are described in the following sections. All activities will comply with legislative requirements established under relevant Commonwealth and Northern Territory legislation.

3.2.1 Relevant conventions, legislation, standards and guidelines

The following sections describe the conventions, legislation, standards, and guidelines applicable to noise emissions from construction activities and the impacts to marine megafauna.

3.2.1.1 International conventions, agreements, and guidelines

International conventions, agreements, and guidelines relevant to marine megafauna are presented in **Table 3-1**.

Table 3-1: International conventions, agreements, and guidelines relevant to the activity

Name	Description
United Nations Convention on Biological Diversity – 1992	An international treaty to sustain life on earth. Relevant as the activity may interact with MNES (threatened and migratory species) protected under the EPBC Act such as anthropogenic underwater noise.
Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention)	The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species. Relevant as the activity may interact with MNES (threatened and migratory species) protected under the EPBC Act. This includes development and implementation of the CMS Family Environmental Impact Assessment Guidelines for Noise-generating Offshore Industries.

3.2.1.2 Commonwealth legislation, standards, and guidelines

Commonwealth legislation, standards, and guidelines relevant to marine megafauna are presented in **Table 3-2.**

Table 3-2: Commonwealth legislation, standards, and guidelines

Name	Description
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The Act aims to: + Protect MNES; + Provide for Commonwealth environmental assessment and approval processes; + Provide an integrated system for biodiversity conservation and management of protected areas. The Threatened Species Scientific Committee (TSSC) was established under the EPBC Act which plays a critical role in protection and management of native species and ecological communities. The TSSC have published Approved Conservation Advice for important species relevant to this project including humpback whales, sei whales and fin whales.
Environment Protection and Biodiversity Conservation Regulations 2000 (EPBC Regulations)	The regulations are designed to provide a streamlined national environmental assessment and approvals process whilst enhancing the protection and management of the environment.
Marine Bioregional Plan for the North Marine Region (DSEWPAC, 2012)	The document describes the marine environment and conservation values (protected species, protected places and key ecological features) of the North Marine Region. It sets broad objectives for its biodiversity, identifies regional priorities, and outlines strategies and actions to achieve these.
National Guidance on the Management of Whale and Dolphin Incidents in Australian Waters (DSEWPAC, 2013)	The document outlines best practice guiding principles for the management of incidents where whales and dolphins are in distress (e.g. entangled or stranded). The Guidelines may be relevant in the event that a whale or dolphin is impacted by noise emissions from construction activities during the DPD Project that may result in animal distress and stranding.
Recovery Plan for Marine Turtles in Australia 2017-2027 (DoEE, 2017)	The document describes a long-term recovery plan for marine turtles in Australia. The main objective it to minimise anthropogenic threats to allows for the conservation status of marine turtles to improve so that they can be removed from the EPBC Act threatened species list.

3.2.1.3 Northern Territory legislation, standards, and guidelines

NT legislation, standards, and guidelines relevant to marine megafauna are presented in **Table 3-3**.

Table 3-3: Northern Territory legislation, standards, plans, and guidelines

Name	Description
Darwin Port Environmental Management Plan (EMP) (Darwin Port, 2020)	The EMP provides environmental standards which are to be adhered to within Darwin Port. It provides environmental information, targets, and management strategies to prevent adverse impacts to the environment (Darwin Port, 2020).
Darwin Harbour Strategy 2020 – 2025 (DHAC, 2020)	The Darwin Harbour Advisory Committee (DHAC) developed the Darwin Harbour Strategy 2020 – 2025 to act as a contemporary strategy for the sustainable management of the Darwin Harbour region. The strategy outlines goals, objectives and outcomes that will help guide sustainable management and planning in the region. The management strategy goals are: + Foster partnerships: To protect and enhance Darwin Harbour through integrated management and in a partnership between government, industry, and the community. + Protect and preserve: To protect and enhance the natural environment of Darwin Harbour. + Celebrate connection: To protect and enhance the cultural values and heritage of Darwin Harbour. + Maintain our unique lifestyle: To protect and enhance social, recreational and lifestyle use and enjoyment of Darwin Harbour in an ecologically sustainable manner.
Environmental Protection Act 2019	The objects of this Act are: (a) to protect the environment of the Territory; (b) to promote ecologically sustainable development so that the wellbeing of the people of the Territory is maintained or improved without adverse impact on the environment of the Territory; (c) to recognise the role of environmental impact assessment and environmental approval in promoting the protection and management of the environment of the Territory; (d) to provide for broad community involvement during the process of environmental impact assessment and environmental approval; and (e) to recognise the role that Aboriginal people have as stewards of their country as conferred under their traditions and recognised in law, and the importance of participation by Aboriginal people and communities in environmental decision-making processes.
Environmental Protection Regulations 2020	The regulations provide guidance and a legislative framework for environmental impact assessments and approval processes that involve the NT EPA.
Fisheries Act 1988	The Act makes it illegal to pollute waters where the effect of the substance is that fish or aquatic life are injured, detrimentally

Name	Description
	affected or the habitats, food or spawning grounds are detrimentally affected. Consideration of this Act is required in the assessment of potential impacts and mitigation measures for the construction of the pipeline.
Guidelines for Reporting of an Environmental Management Plan (NT EPA 2015)	The document provides project proponents with advice on when an EMP may be required and what is required in preparing an EMP for assessment by the NT EPA.
Guideline for Reporting on Environmental Monitoring (NT EPA 2016)	This guideline outlines the NT EPA's requirements for environmental monitoring reports – to establish a minimum standard and consistent approach. The guideline outlines how to report the information collected through monitoring to the NT EPA.
Northern Territory *Environment Protection Authority Act 2012*	This act aims to a) promote ecology sustainable development; b) to protect the environment, having regard to the need to enable ecologically sustainable development; (c) to promote effective waste management and waste minimisation strategies; and (d) to enhance community and business confidence in the environmental protection regime of the Territory.
Territory Parks and Wildlife Conservation Act 1976 (TPWC Act) and Regulations 2001	The Act forms a framework for the establishment and management of parks and reserves and declaration of protected wildlife. This Act has been considered with regard to the potential interactions with protected wildlife.

4 Environmental management framework

4.1 Santos management system

Santos's Management System (known as the SMS) exists to support its moral, professional, and legal obligations to undertake work in a manner that does not cause harm to people or the environment. The framework of policies, standards, processes, procedures, tools, and control measures that, when used together by a properly resourced and competent organisation, result in:

- A common HSE approach is followed across the organisation.
- HSE is proactively managed and maintained.
- The mandatory requirements of HSE management are implemented and are auditable.
- HSE management performance is measured, and corrective actions are taken.
- Opportunities for improvement are recognised and implemented.
- Workforce commitments are understood and demonstrated.
- The Implementation Strategy (**Section 9**) and Stakeholder Consultation (**Section 10**) align with the Management System structure and are designed to require that:
- environmental impacts and risks continue to be identified for the duration of the activity and reduced to ALARP
- controls are effective in reducing environmental impacts and risks to ALARP and acceptable levels
- environmental performance outcomes and standards set out in this MMNMP are met
- consultation with relevant and interested persons is maintained throughout the activity as appropriate.

4.2 Santos' Environment, Health and Safety Policy

Santos' Environment, Health and Safety Policy (**Appendix 1**) clearly sets out its strategic environmental objectives and the commitment of the management team to continuous environmental performance improvement. This EMP has been prepared in accordance with the fundamentals of this policy. By accepting employment with Santos, each employee and contractor is made aware during the recruitment process that he or she is responsible for the application of this policy.

4.3 DPD Project environmental management plans

There are a suite of environmental management plans covering DPD Project activities. The Offshore CEMP (BAS-210 0024) is an overarching management plan covering all activities from the 3 nm Commonwealth/NT waters boundary to the onshore termination point. The Onshore CEMP (BAS-210 0025) covers all activities to be completed from the onshore termination point to the upstream weld of the beach valve, except for support facilities for DPD Project offshore pipeline. The TSDMMP (BAS-210 0023), ASSDMP (BAS-210 0049) and MMNMP (BAS-210 0045) sit under these CEMPs and address specific activities. The activities for these management plans are outlined in **Section 1.3** and **Figure 1-2**.

5 Existing environment

This section describes the key physical and biological characteristics of Darwin Harbour and the offshore areas within and around the Project Area, including the DPD spoil disposal ground, as relevant to this MMNMP. Further detail on the physical, biological, cultural and socio-economic environment of the Project Area is provided in the Offshore CEMP (BAS-210 0024) and the DPD Project SER (BAS-210 0020).

5.1 Physical environment

5.1.1 Coastal morphology

Darwin Harbour is a large, drowned river system approximately 500 km^2 in extent. It is comprised of three arms (East Arm, West Arm, and Middle Arm) which along with the smaller Woods Inlet converge into a single unit before opening to the ocean and into Beagle Gulf in the north.

Freshwater inflow from the Elizabeth River into the East Arm and the Blackmore and Darwin rivers into the Middle Arm generally occurs between January and April creating more estuarine conditions.

Port Darwin's main channel is approximately 1,525 m wide and 15 – 25 m deep, with a maximum recorded depth of 36 m. The channel is generally deeper on the eastern side of the Harbour, while the western side is broader and shallower areas with intertidal flats and shoal being more extensive.

The channel extends into the East Arm with depths of more than 10 m LAT, the bathymetry of this area has been modified by dredging associated with the development of East Arm Wharf. A slightly deeper channel can be found in the Middle Arm extending up to the western side of Channel Island.

5.1.2 Oceanography

Darwin Harbour has a macrotidal (more than four metres) regime with tide range reaching 8 m which is considerable by world standards. Tides are generally semidiurnal (two highs and two lows each day) with some inequality between successive tides in a single day. Neap tides result in a two-day period where tidal conditions are nearly diurnal (one high and on low each day). There is a great degree of variation in daily tidal range with the presence of spring-neap tide cycle approximately every 15 days. The spring phase of the cycle has an average tidal range of 6 m, while the neap phase average tidal range is 3 m. Large tidal movements and to a lesser extent wind, drives rapid and regular exchange of large volumes of water between Darwin Harbour and Beagle Gulf.

Darwin Harbour is considered sheltered with tsunamis and swell waves unlikely to occur due to the harbour's orientation, shallow bathymetry and protection afforded by the Tiwi Islands. Most waves are generated within Darwin Harbour or Beagle Gulf and are well below 1 m with periods of 2 – 5 seconds, under non-cyclone conditions. Tropical cyclones can cause extreme wave conditions producing significant wave height of 4.5 m and approximate periods of 7.5 seconds at the entrance to Darwin Harbour. Inside the harbour waves heights are reduced by the bathymetry to approximately 0.7 m (GHDM, 1997).

5.1.3 Underwater noise

5.1.3.1 Darwin Harbour

Underwater noise within Darwin Harbour is influenced by the existing shipping traffic, biological sources, and weather. Natural prominent sources of noise include thunderstorms, lightning strikes, and heavy wet-season rains, which all generate noise at considerable intensities, although these natural sources of noise all occur seasonally. Vessel traffic in Darwin Harbour is a year-round source of noise with the Port of Darwin recording 1,510 vessels in the 2021 – 2022 financial year (Darwin Port, 2022). Large commercial vessels, such as cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels enter, exit and move around the harbour on a daily basis. Vessel movements are concentrated along designated shipping channels and around berthing and anchorage areas. The proposed DPD pipeline route and associated trenching areas are adjacent to these shipping channels.

Typical underwater noise emissions for the types of vessels using Darwin Harbour are provided in **Table *5-1*** along with typical source levels from the types of dredging vessels planned to be used for the DPD Project. Trenching vessels (BHD, CSD, TSHD) are expected to produce noise intensities and noise frequencies similar to large commercial vessels that use Darwin Harbour (**Table 5-1**).

Table 5-1: Indicative noise levels from typical Darwin Harbour vessels and DPD Project trenching vessels

Vessel Type	Source Level (dB)	Frequency	Reference
Tanker and Bulk Carriers	180-186	Low (10-30 kHz)	INPEX Browse, 2010
Offshore vessels (e.g. rig tender vessels)	177	Broadband	INPEX Browse, 2010
Powerboats with 80hp outboards (small recreational boats)	156-175	Broadband up to several kHz	INPEX Browse, 2010
Cutter Suction Dredge (CSD)	172-185	30Hz>-20kHz	Thomsen *et al.*, 2009
Trailing Suction Hopper Dredge (TSHD)	184-188	30Hz>-20kHz	de Jong *et al.*, 2010 Robinson *et al.*, 2011 Reine *et al.*, 2012
Backhoe Dredge (BHD)	175	30Hz>-20kHz	Reine *et al.*, 2012

Underwater noise measurements have been taken in Darwin Harbour by Salgado-Kent *et al.* (2015) during a period where dredging and piling activities were being conducted in East Arm for the INPEX Ichthys Project. Dredging noise measurements were taken in the vicinity of a Cutter Suction Dredge (CSD) cutting an area of hard rock known as Walker Shoal (Salgado-Kent *et al.*, 2015). These measurements revealed noise levels close to approximately 145 dB re 1 µPa at distances between 630 m and 680 m from the source, which were greater than the levels predicted by underwater noise modelling.

Given seabed hardness is expected to influence the level of noise emitted from a CSD while dredging, Santos commissioned an analysis of seabed hardness to be undertaken to determine if noise measurements from Walker Shoal would be applicable for the DPD Project. Fugro (2022) undertook a comparative analysis of Walker Shoal geology and seabed refractivity against the geology and seabed refractivity of a representative CSD trenching area between KP104 and KP105 along the DPD route. This assessment compared available refractivity and bore hole data at these locations and concluded that seabed materials at the representative DPD trenching location were significantly weaker than those encountered at Walker Shoal (Fugro, 2022). Interpreted compressional wave acoustic velocities (Vp) ranged between 1,700 m/s to 3,000 m/s for the DPD Project trenching location while for Walker

Shoal they ranged between 2,500 m/s and 4,000 m/s. Due the hardness of the rock at Walker Shoal and the fact that a specialised cutting tool was required to be used on the CSD for dredging in this area (INPEX Browse, 2011) it is unlikely that CSD noise measurements collected by Salgado-Kent *et al.* (2015) would be representative for DPD Project CSD trenching.

Salgado-Kent *et al.* (2015) found that in the absence of Ichthys project pile driving or dredging in East Arm, the most intense noises dominating the environment were from a range of vessel, and to a lesser extent machinery, operating in the area. Noise emissions from vessels were found to be broadband, with most energy ranging from tens of Hz to several kHz and often reaching 130 to 140 dB re 1 Pa. The study found intense broadband anthropogenic noise from vessels and machinery also occurred typically between 5 to 20 times per day throughout the recording period in the frequency band of approximately 10 Hz to 2 kHz with noise periods lasting from approximately 1 hour to 5 hours and with intensity levels reaching close to 160 dB re 1 µPa during some periods (Salgado Kent *et al.* 2015). Underwater noise measurements taken by SVT (2009) and provided within the Ichthys EIS (INPEX Browse 2010) also show relatively high measured background noise levels within East Arm of 150-170 dB re 1 µPa2/Hz.

Salgado-Kent *et al.* (2015) found that in comparison to East Arm, the ambient underwater noise levels in Middle Arm were on average lower, likely due to lesser vessel movements. It is also expected that, all other things being equal, received noise levels from vessel traffic will be lower in shallower areas of Darwin Harbour due to reduced sound propagation in shallow waters. This was found during surveys by SVT (2009) where measured ambient noise levels in the shallower Elizabeth River were lower than those for the broader East Arm.

When anthropogenic noise was not present, biological sounds such as fish and snapping shrimp were observed. While the program was aimed at detecting dolphins, they had a minor contribution to the soundscape and were detected infrequently. This suggests dolphins were either silent whilst travelling through the detection zone, spent limited time in the zone, or both (Salgado-Kent *et al.* 2015).

5.1.3.2 Offshore NT waters

There are no available ambient underwater noise monitoring data for the Project Area within offshore NT waters. It is expected that in the offshore NT waters ambient underwater noise would be minor, typically consisting of vessel noise from commercial fishers and shipping vessels.

5.2 Marine megafauna

The Darwin region supports marine megafauna including marine mammals, reptiles, sharks and birds. The EPBC Act Protected Matters Search Tool (PMST) has been used as a screening tool to determine EPBC Act listed marine megafauna that may occur within the DPD Project Area (with a 5 km buffer). Following the PMST screening, an assessment of likelihood of the species occurring within the DPD Project Area was determined based on documented records and the species habitat requirements with respect to habitat features within the Project Area.

The criteria applied to define the likelihood of occurrence for marine megafauna was:

+ **Unlikely**: the species has not been recorded within Darwin Harbour or surrounding waters; and/or its current known distribution does not encompass Darwin Harbour, and surrounding water; and/or suitable habitat is generally lacking from the Project Area.

- **Potential**: the species has not been recorded within Darwin Harbour or surrounding waters although species' distribution incorporates Darwin Harbour and surrounding waters; and potentially suitable habitat occurs in the Project Area.
- **Likely**: the species has been recorded within Darwin Harbour or surrounding waters in the past 10 years; and suitable habitat is present within the Project Area.
- **Known to occur**: the species has been recorded (directly by commissioned surveys or from database records) within the Project Area in the past 10 years.

The results of PMST searches and subsequent assessments of likelihood of occurrence within the Project Area have been presented in the DPD Project NT EPA referral, EPBC Act referral and DPD Project SER (BAA-201 0003; Santos, 2021a; BAA-201 0004; Santos, 2022; BAS-210 0020).

Those species known to occur or likely to occur within the Project Area relevant to this MMNMP are described in the following sections. The search identified species of diving birds as occurring or potentially occurring in the area but have not been discussed further due to low underwater noise impact.

5.2.1 Marine mammals

Five species of marine mammals are known to occur in the Project Area, including four listed as migratory under the Commonwealth EPBC Act (**Table 5-2**). None of these species are currently listed under the *Territory Parks and Wildlife Conservation Act.* Through further assessment as described above, the species determined likely to occur in the Project Area are described in the following sections.

Table 5-2: Marine mammal species identified as known or likely to occur in the Project Area

Species	EPBC Act (Cwth)	*Territory Parks and Wildlife Conservation Act 1976*	Likelihood of occurrence in Project Area	Biological Important Area (BIA) in Project Area
False killer whale[1] (*Pseudorca crassidens*)	N/A	-	Known to occur – This species has been recorded within the Darwin Harbour. Demographically independent population(s), year-round inhabits of coastal areas in Northern Australia	None
Australian humpback dolphin (*Sousa sahulensis*)	Migratory	-	Known to occur – Suitable habitat for the species is present. This species has been recorded within the Darwin Harbour.	Yes – The Project Area intersects the Indo-Pacific humpback dolphin BIA for breeding.
Australian snubfin dolphin (*Orcaella heinsohni)*	Migratory	-	Known to occur – Suitable habitat for the species is present. Individuals of the species have previously been recorded in the Darwin Harbour and near Catalina Island, located to the east of the Project Area.	Yes – The Project Area intersects the Australian snubfin dolphin BIA for breeding.
Indo-pacific bottlenose dolphin (Arafura/ Timor Sea populations) (*Tursiops aduncus*)	Migratory	-	Known to occur – Suitable habitat for the species is present. This species has been recorded within the Darwin Harbour.	Yes – The Project Area intersects the Indo-pacific bottlenose dolphin BIA for breeding.
Dugong (*Dugong dugon*)	Migratory	-	Known to occur – Individuals of this species are known to occur within the Darwin Harbour.	None

Notes:

1. The false killer whale was not identified in the PMST search, however the species has been recorded in Darwin Harbour and is therefore included in the below impact assessment.

5.2.1.1 False killer whale

False killer whales (*Pseudorca crassidens*) were not identified in the PMST search, however, they have been recorded in the Darwin Harbour and Beagle Gulf, therefore the species are briefly described here. False killer whales are found in all tropical and warm temperate oceans. They are typically pelagic but are also known to approach close to shore around oceanic islands. However, a recent study of 14 satellite tagged individuals has shown that the false killer whale population(s) in northern Australia are thought to be a demographically independent population and inhabit these shallow coastal waters year-round (Palmer *et al.*, 2022). Currently, there are no estimates of global populations available, but they appear to be uncommon throughout their range.

In the NT, eight sightings of false killer whale groups within the semi-closed harbours of Port Essington and Darwin have been recorded since 2007 as part of monthly surveys undertaken by the Coastal Dolphin Project (Palmer *et al.*, 2009). The most recent sightings within these NT harbours have been recorded during the wet season of 2018 (December – April) (ALA, 2018). The behavioural observations associated with these sightings suggest the false killer whales were foraging (i.e., chasing schools of fish). Therefore, the species is considered as known to occur in the area.

5.2.1.2 Inshore dolphin species

Three inshore dolphin species were identified in the PMST search: Indo-pacific bottlenose dolphin, Australian humpback dolphin and Australian snubfin dolphin.

These species were monitored in the Darwin Harbour region (comprising Bynoe Harbour, Darwin Harbour and Shoal Bay) between 2011 and 2019 by the Coastal Dolphin Monitoring Program (Griffiths *et al*., 2020). The monitoring program found that populations of coastal dolphin species occurred at low densities in the Darwin Harbour region, though were similar to average densities found across NT coastal waters, and individuals or pods exhibited fluctuating movement across sites. Griffiths *et al.*, (2020) noted that population sizes fluctuated over the monitoring period, however showed a general decline over time. The authors were unable to explain the reasons for year-to-year variation in abundance and declines, citing potential factors as population dynamics, environmental factors or anthropogenic factors (Griffiths *et al.*, 2020).

5.2.1.2.1 Australian humpback dolphin

Humpback dolphins (*Sousa sahulensis*) are found in tropical/subtropical waters of the Sahul Shelf from northern Australia to the southern waters of the island of New Guinea (Jefferson & Rosenbaum, 2014). In Australia, humpback dolphins are thought to be widely distributed along the northern Australian coastline from approximately the Queensland-NSW border to western Shark Bay, WA (Parra & Cagnazzi, 2016). Humpback dolphins are more likely to be found in relatively shallow and protected coastal habitats such as inlets, estuaries, major tidal rivers, shallow bays, inshore reefs and coastal archipelagos, rather than in open stretches of coastline (Parra & Cagnazzi, 2016). BIAs for the Australian humpback dolphin occur along the Kimberley coast in WA, in NT waters and down the Queensland coast from Cape York to Brisbane (DSEWPaC, 2012).

The species is widely distributed across the NT with populations considered in a heathy state as per the findings of a conservation assessment by the NT Department of Natural and Environmental Resources (DENR) conducted in 2017 based on 2014/2015 surveys (Palmer *et al.*, 2017). The Australian humpback dolphin was identified as having an area of occupancy (AOO) of 16,900 km^2 as well as a calculated extent of occurrence of 88% of NT coastal waters (Palmer *et al.*, 2017). Highest densities of sightings were from Groote Eylandt (500), English Company Islands, Kakadu National Park, Melville Island (Aspley Straight) (Palmer *et al*., 2017) which are located on northern and eastern coasts of NT, over ~150 km from the Project Area.

BIAs (foraging, feeding and breeding) have been designated for the Australian humpback dolphin in Darwin Harbour; Port Essington, Cobourg Peninsula; East Alligator River region and South Alligator River region (DSEWPaC, 2012). The Project Area overlaps the Darwin Harbour breeding BIA for Australian humpback dolphins (**Figure 5-1**). In the Darwin Harbour BIA, calving occurs in the months of October to April (Palmer, 2010). The proportion of dolphin calves sighted has varied considerably over the years with calving rates increasing from 3% in 2017 to 4% in 2018 for the Australian humpback dolphin, where over the previous years the rate has generally been low (Flora and Fauna Division, 2019).

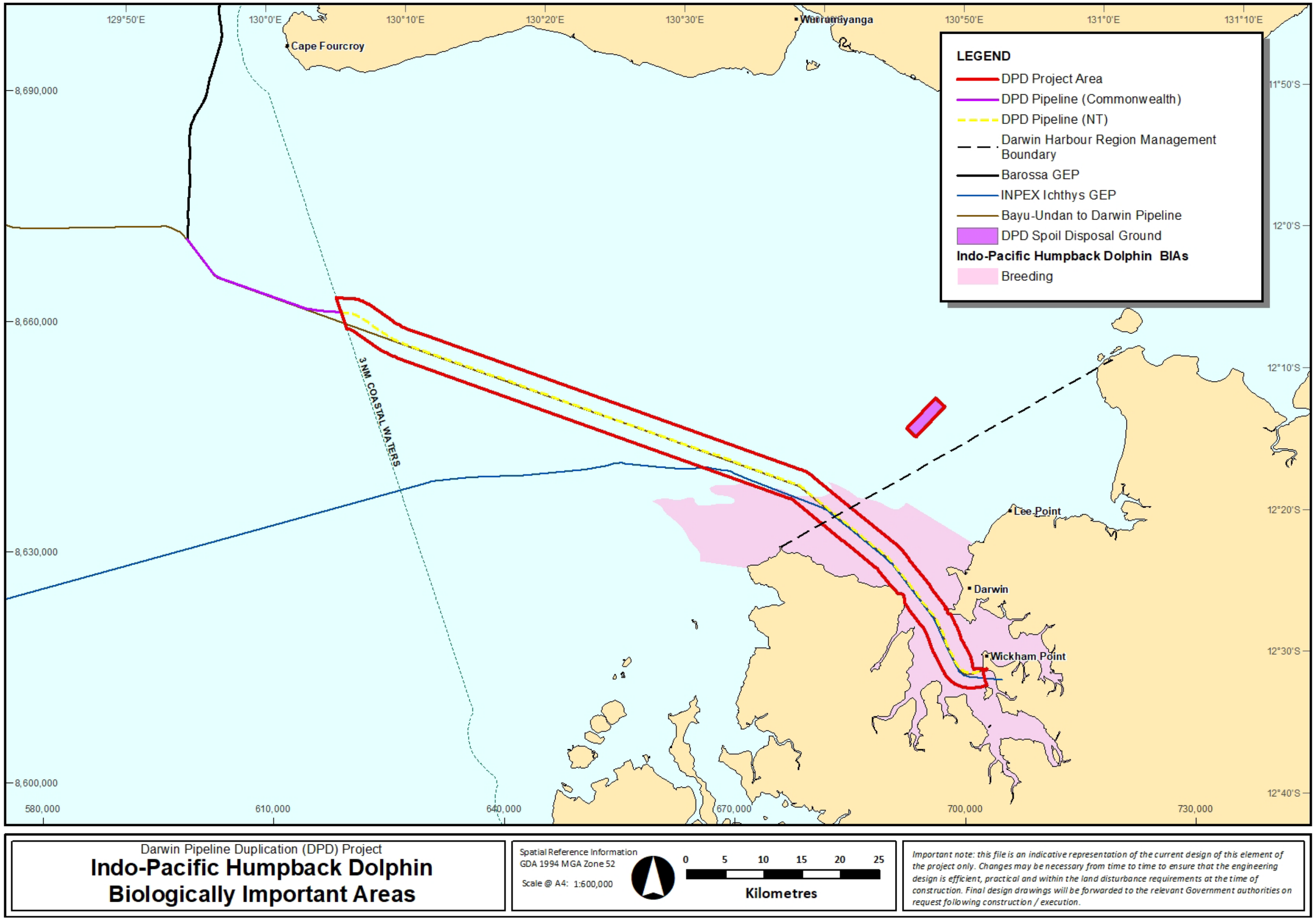


Figure 5-1: Biologically important areas for the Indo-Pacific humpback dolphin

5.2.1.2.2 Australian snubfin dolphin

The Australian snubfin dolphin (*Orcaella heinsohni*, hereafter, snubfin dolphin) was described as a separate species in 2005 and is endemic to the tropical waters of northern Australia and southern New Guinea (Beasley *et al.* 2005). Snubfin dolphins are typically found in shallow coastal waters (<20 m) and usually in proximity (<15 km) to freshwater inputs (Parra *et al.*, 2002, 2006a; Parra, 2006; Bouchet *et al.*, 2021). Previous research suggests they are intermittently distributed across their range as small local populations of 50 – 200 individuals (Parra *et al.*, 2006b; Palmer *et al.*, 2014b; Brown *et al.*, 2016; Brooks *et al.*, 2017; Bouchet *et al.*, 2021) that exhibit site fidelity (Parra, 2006; Brown *et al.*, 2016; D'Cruz *et al.*, 2022) and limited gene flow between populations (Brown *et al.*, 2014b, 2017). BIAs for Australian snubfin dolphins (breeding, foraging and resting) have been designated along the Kimberley coastline in WA and in NT waters.

The Australian snubfin dolphin is widely distributed across NT coastal waters, with populations considered in a heathy state, as per the findings of a conservation assessment by the NT DENR (Palmer *et al*., 2017). From aerial surveys undertaken in 2014 and 2015, the snubfin dolphin was identified as having an AOO of 24,900 km^2 and was calculated to occupy 89% of NT coastal waters (Palmer *et al.*, 2017). Highest densities of sightings were from Pellew Islands, Groote Eylandt, English Company Islands / Arnhem Bay and Fog Bay (Palmer *et al.*, 2017), with these sites primarily on the east coast of the NT.

The Project Area overlaps the Darwin Harbour breeding BIA for Australian snubfin dolphins (**Figure 5-2**). Limited data on breeding time are available for the Australian snubfin dolphin, however, the closely related irrawaddy dolphin is thought to mate from March to June (Ross, 2006) with calves born in August or September.

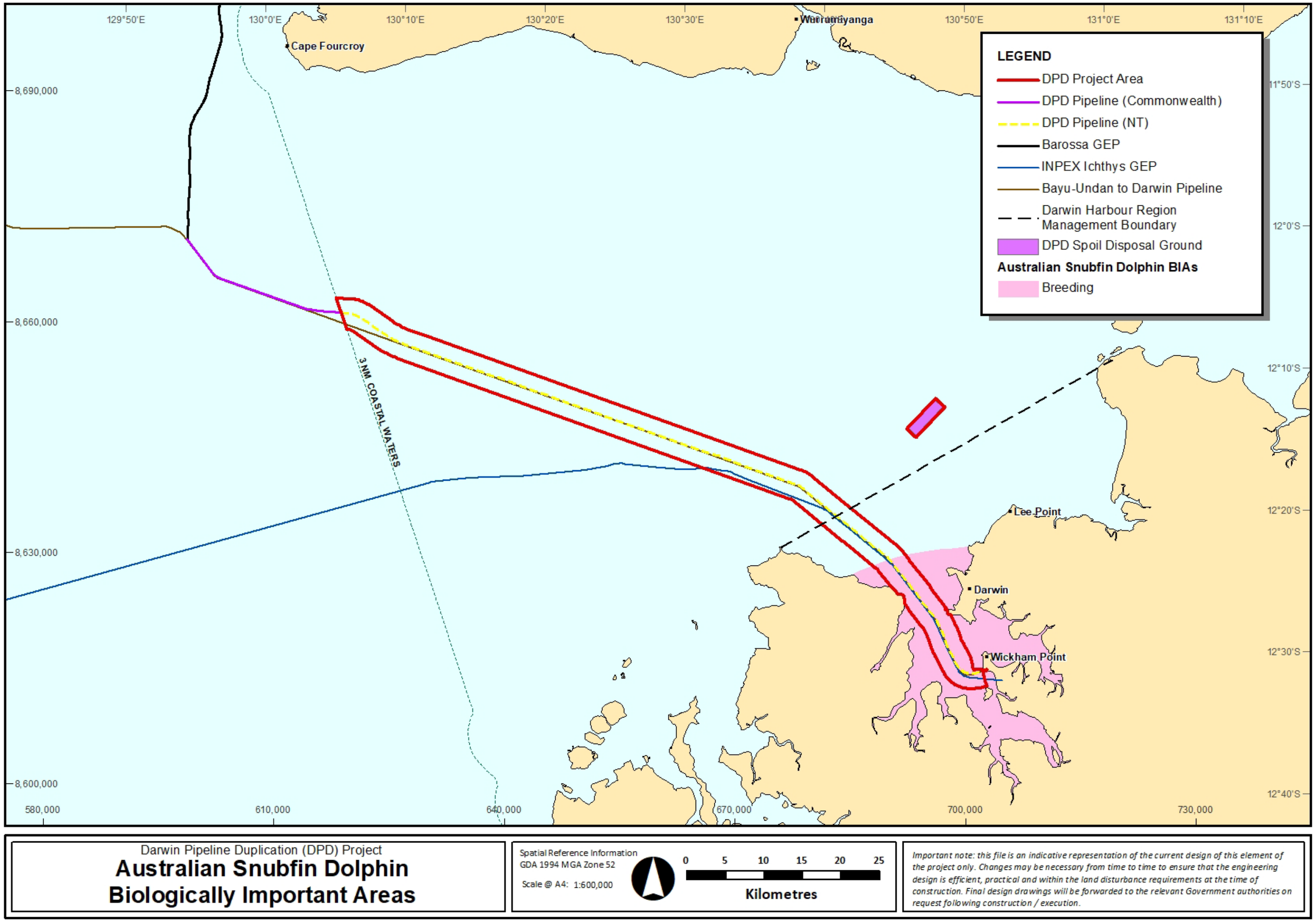


Figure 5-2: Biologically important areas for the Australian snubfin dolphin

5.2.1.2.3 Indo-Pacific bottlenose dolphin

Indo-pacific bottlenose dolphins (*Tursiops aduncas*) are found in tropical and sub-tropical coastal and shallow offshore waters of the Indian Ocean, Indo-Pacific Region and the western Pacific Ocean (Möller & Beheregaray 2001; Rice 1998; Ross & Cockcroft 1990; Wang *et al.*, 1999). The species has been recorded in waters of all Australian states/territories, and can be found in estuarine and coastal waters of eastern, western and northern Australia (Hale *et al.*, 2000; Möller & Beheregaray 2001; Ross & Cockcroft 1990). BIAs for the species have been designated along the Kimberley Coast in WA, in NT waters and down the entire east coast of Australia from Cape York to past the New South Wales (NSW) – Victorian border.

The species is widely distributed across the NT with populations considered in a heathy state as per the findings of a conservation assessment by the NT Department of Natural and Environmental Resources (DENR) based on 2014/2015 surveys (Palmer *et al*., 2017). The species was identified as having an area of occupancy (AOO) of 17,600 km^2 and occurred within 84% of NT coastal waters (Palmer *et al.*, 2017). Highest densities were recorded from Limmen Bight, Nhulunbuy, Caledon Bay, Maningrida, Fog Bay, Anson Bay and Cape Ford (Palmer *et al.*, 2017), which are distributed across west, north and east coasts of NT.

The Project Area overlaps with a breeding BIA in Darwin Harbour (**Figure 5-3).** Calving in the Darwin Harbour BIA occurs in the months of October to April (Palmer, 2010). The proportion of dolphin calves sighted has varied considerably over the years with calving rates decreasing from 12% in 2011 to 0% in 2017 and increasing to 4% in 2018 (Flora and Fauna Division, 2019).

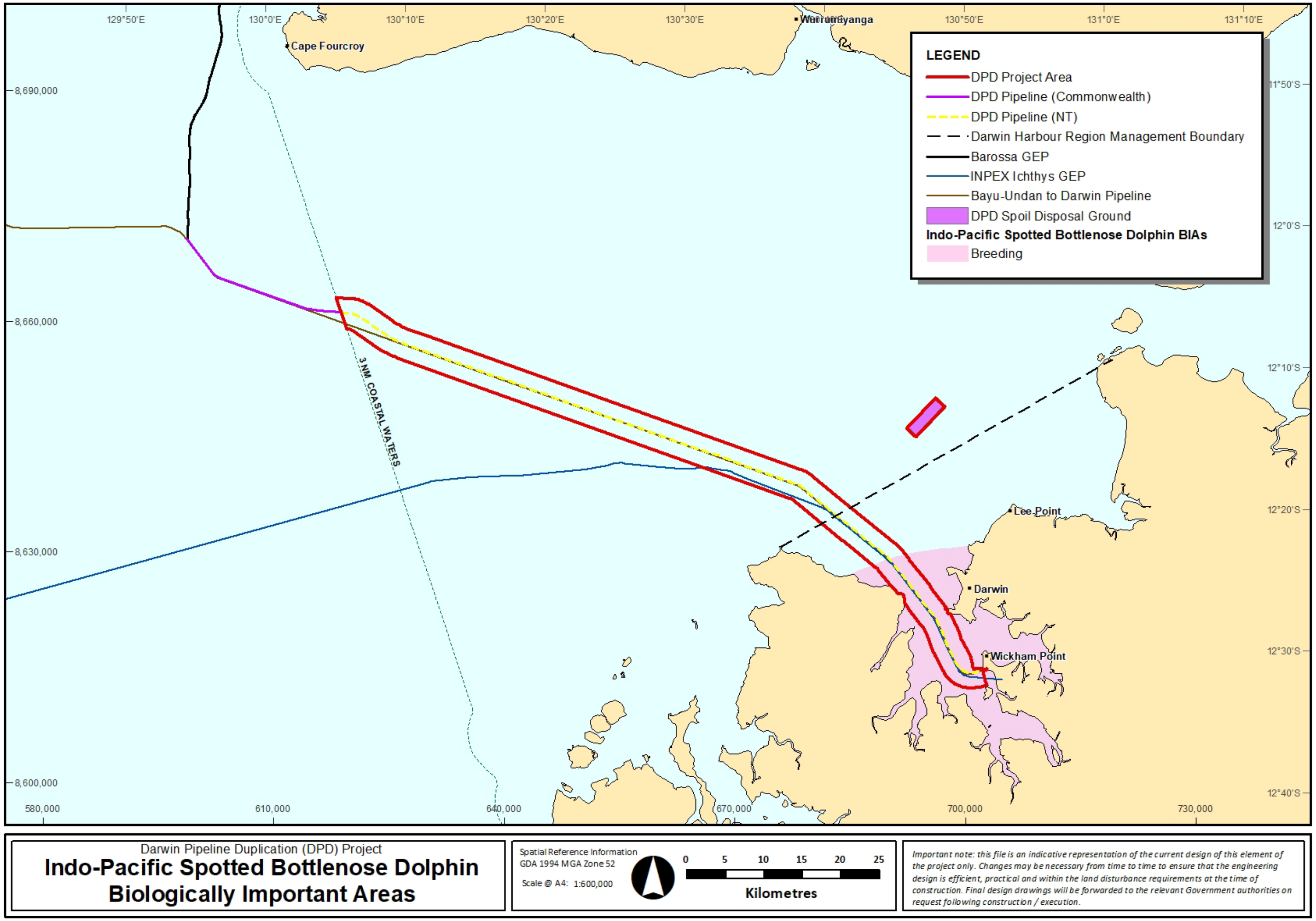


Figure 5-3: Biologically important areas for the Indo-Pacific bottlenose dolphin

5.2.1.2.4 Dugong

The Dugong (*Dugong dugong)* has a very large and fragmented Indo-West Pacific range that extends between about 26 – 27° north and south of the equator (Nishiwaki & Marsh, 1985), encompassing some 860,000 km² of shallow marine habitat across 128,000 km of coastline (Marsh *et al.*, 2011). In Australia, dugongs are known to occur in coastal and island waters from Shark Bay in WA, across the northern coastline to Moreton Bay in Queensland (Marsh *et al.*, 2002; 2011). The winter range includes about 24,000 km of Australia's coast, which represents about 19% of the global extent of occurrence along coastline habitats (Marsh *et al.*, 2011).

The NT supports a moderate population compared with the Torres Strait, which is the largest global population (Groom *et al.*, 2017). Specific areas supporting dugongs in the NT include: the northern coast from Daly River to Millingimbi, including Melville Island and Vernon Islands and the Darwin region; and the Gulf of Carpentaria, including the Sir Edward Pellew Group of Islands, the mouth of the Limmen Bight River, and the waters between Blue Mud Bay and Groote Eylandt (Marsh *et al.*, 2008; Grech *et al.*, 2011). The distribution and abundance of dugongs is generally associated with extensive seagrass and algal habitats, and they are usually found in coastal areas such as shallow protected bays, mangrove areas and leeward of large inshore islands where seagrass grows (O2 Marine, 2019). Aerial surveys conducted by Groom *et al.* (2017) in 2015 found that the Sir Edward Pellew Island Group and Limmen Bight on the east coast of the NT have the highest population estimates for dugongs in NT consistent with earlier survey results from 2007 and 2014.

Dugong monitoring was undertaken as part of the Ichthys Nearshore Environmental Monitoring Program from 2012 to 2014 across three areas (blocks), representing Bynoe Harbour, Darwin Harbour/Hope Inlet and Vernon islands and surrounds. Population estimates ranged from approximately 120 to 300 individuals (calculated from post-dredging phase monitoring) with a clear preference for shallow waters (0 – 10 m) and with far fewer sightings in the inner Darwin Harbour (demarcated as a line from Mandorah to East Point) than in the outer Darwin Harbour (Cardno, 2015a). Highest dugong abundances from these surveys were recorded in seagrass meadows at Casuarina Beach and Lee Point in the outer Darwin Harbour and outside of the Project Area. Within the inner harbour, dugongs were observed in highest abundance (n = 19) at Weed Reef (Cardno, 2015a).

Cardno (2015a) found that sightings and densities of dugongs increased from May to October, when overall sightings were greatest. This is consistent with seasonal increase in seagrass extent and density (Cardno, 2015b). There are no BIAs for dugongs in the Marine Bioregional Plan for the North Marine Region (DSEWPaC, 2012), however the species is known to regularly occur in Darwin Harbour.

5.2.2 Marine reptiles

There are six species of marine turtle known to occur in NT waters that are either known to occur or have the potential to occur within the Project Area (**Table *5-3***). Of these only the green, hawksbill, flatback and olive ridley turtle are known to inhabit Darwin Harbour (BAA-201 0003; Santos, 2021a; BAA-201 0004; Santos, 2022). Through further assessment as described above, the species determined likely to occur in the Project Area are described in the following sections.

Marine turtle aerial surveys undertaken for the INPEX nearshore environmental monitoring program (NEMP) estimated a population size of between 500 and 1,000 for the Darwin region (Buckee *et al.*, 2014). Turtles were primarily observed in shallow waters (<10 m), with the highest densities recorded between East Point and Lee Point, and near Gunn Point (Cardno, 2015a). Turtles were also sighted throughout Darwin Harbour, although at lower densities. It is likely that the majority of turtles observed in the harbour during these surveys were green turtles, as they accounted for 74% of sightings during fine scale land-based observations (INPEX Browse Ltd, 2018).

In addition to marine turtles, the salt water crocodile is known to occur in the Project Area.

Table 5-3: Threatened and migratory marine reptile species identified as habitat critical and as likely to occur in the Project Area.

Species	EPBC Act (Cwth)	*Territory Parks and Wildlife Conservation Act 1976*	Likelihood of occurrence in Project Area	BIA and habitat critical in Project Area
Loggerhead turtle (*Caretta caretta*)	Endangered Migratory	Vulnerable	Potential – Possibly infrequent users of Darwin Harbour but more likely to occur in surrounding oceanic areas.	None
Green turtle (*Chelonia mydas*)	Vulnerable Migratory	-	Known to occur – Suitable habitat for the species is present. This species is known to occur within the Darwin Harbour.	None
Hawksbill turtle (*Eretmochelys imbricata*)	Vulnerable Migratory	Vulnerable	Known to occur – Suitable habitat for the species is present. This species is known to occur within the Darwin Harbour.	None
Flatback turtle (*Natator depressus*)	Vulnerable Migratory	-	Known to occur – Suitable habitat for the species is present. This species is known to occur within the Darwin Harbour.	Yes – The Project Area intersects the flatback turtle habitat critical and BIA critical for survival (inter-nesting).
Leatherback turtle (*Dermochelys coriacea*)	Endangered Migratory	Critically endangered	Potential – Preferred habitat for this species is open ocean. Likely to occur in the oceanic waters outside Darwin Harbour.	None
Olive ridley turtle (*Lepidochelys olivacea*)	Endangered Migratory	Vulnerable	Known to occur – Suitable habitat for the species is present. This species is known to occur within the Darwin Harbour.	None – Habitat critical and BIA critical for the survival of the olive ridley turtle (inter-nesting) is present

Species	EPBC Act (Cwth)	*Territory Parks and Wildlife Conservation Act 1976*	Likelihood of occurrence in Project Area	BIA and habitat critical in Project Area
				to the north and south of the Project Area.
Salt-water Crocodile (*Crocodylus porosus*)	Migratory	-	Likely – The species has been recorded within Darwin Harbour or surrounding waters in the past 10 years; and suitable habitat is present.	None – no important habitat for the species located within the Project Area.

5.2.2.1 Loggerhead turtle

The loggerhead turtle (*Caretta caretta*) has a worldwide distribution, living and breeding in subtropical to tropical locations (Limpus, 2009). Loggerhead turtles are known to forage in subtidal and intertidal coral and rocky reefs and seagrass meadows in inshore waters, as well as in deeper soft-bottomed habitats. Females can migrate up to 2,600 km from feeding areas to traditional nesting beaches.

In Australia, they occur in coral reefs, seagrass beds and muddy bays and estuaries in tropical and warm temperate waters off the coast of Queensland, NT, WA and NSW. The current area of occurrence is estimated to be ~1.5 million km^2.

Breeding aggregations in Australia occur on both the east coast (Queensland and NSW) and the west. Based on the percentage of nesting females per year, approximately 2 – 4% of the total global population of loggerhead turtles occur in Australia, with the majority occurring in eastern and western Australia. There are no known nesting areas in NT. The annual nesting population in WA is thought to be 3,000 females annually (Baldwin *et al*., 2003), and this is considered to support the third-largest population in the world (Limpus, 2009). Loggerhead turtles have one genetic breeding stock within WA (Commonwealth of Australia, 2017).

Loggerhead turtles are known to forage in the Oceanic Shoals Marine Park, the Arafura Sea and the Gulf of Carpentaria; however, they have not been observed breeding in the region (DEWHA, 2008a). Loggerhead turtles are expected to be infrequent users of the Darwin Harbour (Whiting, 2003). The loggerhead turtle is more likely to occur in oceanic areas outside the Darwin Harbour. Benthic surveys undertaken in October/November 2021 and June 2022 found epibiota density did increase towards the shallow inner Darwin Harbour area outside the Project Area (RPS, 2022). However, there is unlikely to be suitable habitat for loggerhead turtles throughout the Project Area due to the large areas of bare silty sand with sparse epibiota. There are no BIAs for loggerheads in the Project Area and there is no evidence to suggest the species will use beaches within the Darwin Harbour for nesting.

5.2.2.2 Green turtle

Green turtles are found in tropical and subtropical waters throughout the world. The global population of green turtles is estimated to be very large (~2 million). Green turtles spend their first five to ten years drifting on ocean currents (pelagic phase). They then settle in shallow benthic foraging habitats such as tropical tidal and sub-tidal coral and rocky reef habitat or inshore seagrass beds. The shallow foraging habitat of adults contains seagrass beds or algae mats on which green turtles mainly feed. Green turtles can migrate more than 2,600 km between their feeding and nesting grounds.

Green turtles nest, forage and migrate across tropical northern Australia. The total Australian population of green turtles is estimated to be more than 70 000 individuals, distributed across seven regional populations that nest in different areas; the southern Great Barrier Reef, the northern Great Barrier Reef, the Coral Sea, the Gulf of Carpentaria, Western Australia's north-west shelf, the Ashmore and Cartier Reefs and Scott Reef. The Gulf of Carpentaria has two main nesting areas, the Wellesley Island Group, with major rookeries at Bountiful, Pisonia and Rocky Islands, and the Eastern Arnhem Land, Groote Eylandt and Sir Edward Pellew Islands area. Nesting occurs year-round, with a mid-year peak in nesting activity.

The key nesting and inter-nesting areas (where females live between laying successive clutches in the same season) are Coburg Peninsula (~125 km from the Project Area), between Nhulunbuy and northern Blue Mud Bay (East Arnhem Land), Groote Island, offshore islands including Crocker Island, Goulburn Island, Sir Edward Pellew Islands, Bathurst and Melville Islands, Wessel and English Islands, and Rocky Island.

There are no defined or evidence of nesting or inter-nesting areas within the Project Area, however, within Darwin Harbour, it is not known if the green turtle use Casuarina Beach, Cox Peninsula Beaches and Mandorah Beach for nesting (~10 km from the Project Area) due to low survey effort, low reporting effort and low levels of turtle nesting effort in the area. Incidental sightings from other surveys indicate green turtle are present within Darwin Harbour (Pendoley, 2022; Whiting, 2001). The Project Area contains rocky reef and algae habitat (e.g. weed reef), therefore it is likely that green turtles feed in the Project Area.

5.2.2.3 Hawksbill turtle

Hawksbill turtles (*Eretmochelys imbricata*) have a global distribution throughout tropical and subtropical marine waters. The total population of hawksbill turtles in Australia is unknown. Hawksbill turtles are largely concentrated on the North West Shelf (Dampier Archipelago) of WA (Limpus, 2009), however a second major population of hawksbill turtles, which is genetically isolated from the North West Shelf population is located along the NT coast and north-eastern Queensland (Northern Territory Government, n.d).

In the NT nesting is reported to occur from July to December (Chatto, 1997; 1998). Adults tend to forage in tropical tidal and subtidal coral and rocky reef habitat where they feed on an omnivorous diet of sponges, algae, jelly fish and cephalopods (DSWEPaC, 2012a).

Incidental sightings suggest hawksbill turtles utilise Darwin Harbour regularly but occur in lower abundances compared to the green turtle (Whiting, 2001; 2003). In the Darwin Harbour, immature and adult sized hawksbill turtles were found to use the rocky reef habitat at Channel Island, and may also utilise other habitats (Whiting, 2001). Soft coral and sandy habitats are widely present throughout the Project Area within Darwin Harbour, providing suitable foraging habitat for the hawksbill turtle.

5.2.2.4 Flatback turtle

The flatback turtle (*Natator depressus*) is found only in the tropical waters of northern Australia, Papua New Guinea and Irian Jaya and is one of only two species of sea turtle without a global distribution.

There are no estimates of population size for the species and it is currently listed as 'data deficient' by the IUCN. Flatback turtles feed in the northern coastal regions of Australia, extending as far south as the Tropic of Capricorn. Their feeding grounds also extend to the Indonesian archipelago and the Papua New Guinea coast. Post-hatchling flatback turtles do not have an oceanic dispersal phase, this species remains within the relatively shallow Australian continental shelf waters (Salmon *et al.*, 2009).

Flatback turtles are the most widely spread nesting marine turtle species in the NT, nesting on a wide variety of beach types around the entire coastline. Flatback turtles have a preference for shallow, soft-bottomed seabed habitats away from reefs; consistent with the habitat in the Project Area. A study conducted on Field Island in the Van Diemen Gulf (~100 km from the Project Area) recorded a total of 257 individuals nesting on the island from 2002 to 2013 (Groom *et al.* 2017). The study estimated the abundance of nesting flatback turtles at Field Island and found it varied over time and ranged from 97 to 183. Peak internesting for flatback turtles in the NT occurs between June-September (DoEE, 2017a).

As shown on **Figure 5-4**, the Project Area intersects 'Habitat Critical to the survival of the flatback turtle species'. This habitat was mapped by consensus of a panel of experts in marine turtle biology and according to the EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance, is defined as areas necessary:

+ For activities such as breeding or dispersal.
+ For the long-term maintenance of the species.
+ To maintain genetic diversity and long-term evolutionary development.
+ For the reintroduction of populations or recovery of the species.

Habitat Critical to the survival of flatback turtles includes at least 70% of nesting habitat for the stock (i.e. these marine areas are extensive). The Project Area also overlaps a flatback turtle BIA (inter-nesting), which further supports the species assessment as known to occur in the Project Area.

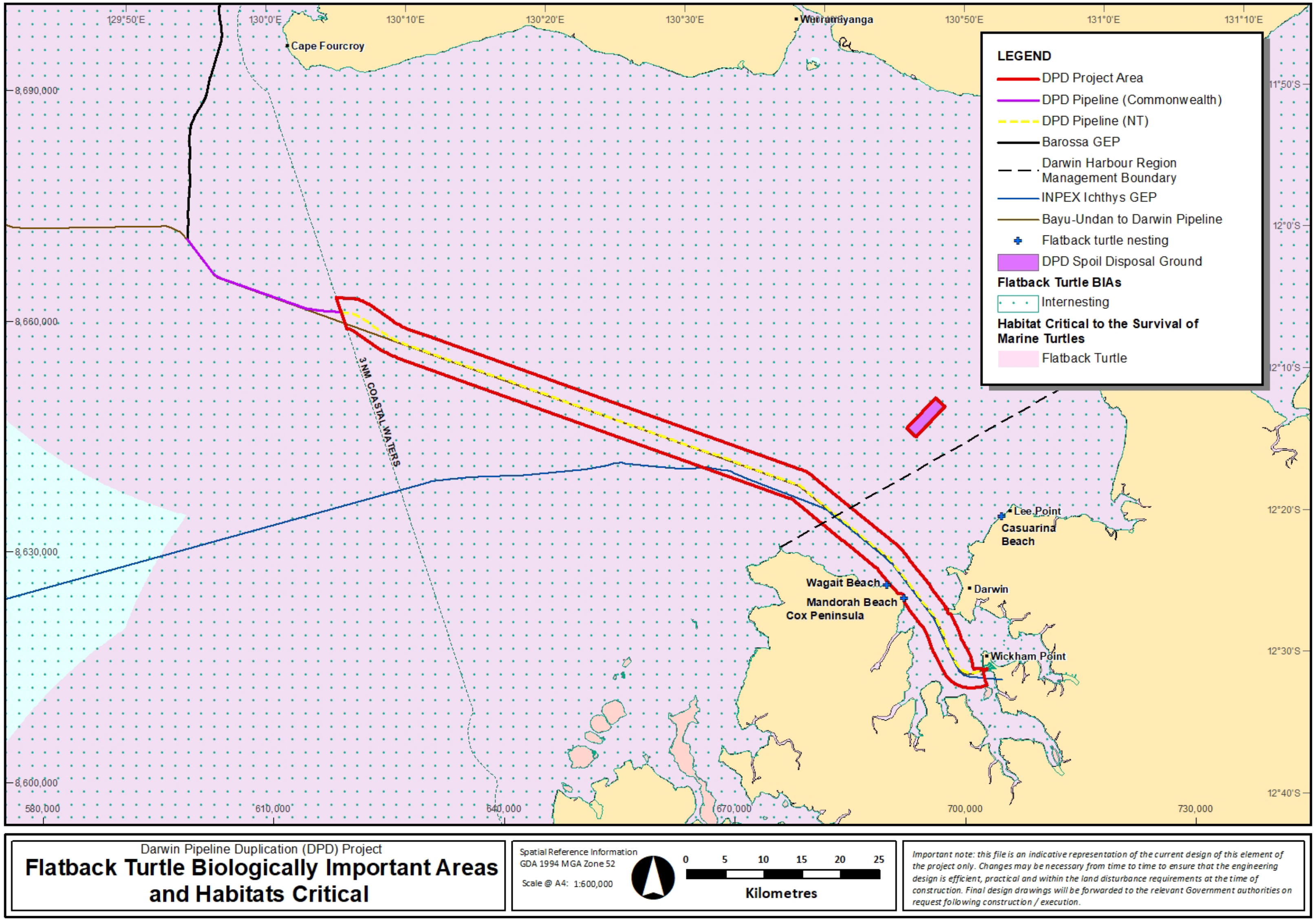


Figure 5-4: Flatback turtle biologically important areas and habitats critical to survival

5.2.2.5 Leatherback turtle

The leatherback turtle *(Dermochelys coriacea*) has the widest distribution of any marine turtle and can be found from tropical to temperate waters throughout the world. The leatherback turtle is a pelagic feeder, found in tropical, subtropical and temperate waters throughout the world. Although this species has an unusually wide latitudinal range as adults can withstand cold (10 °C) water. Leatherback turtles are presumed to migrate to Australian waters from nesting populations in Indonesia, Papua New Guinea and the Solomon Islands.

The species has been recorded feeding in the coastal waters of all Australian States (Hamann *et al.*, 2006). The species is most commonly reported from coastal waters in central eastern Australia (from the Sunshine Coast in southern Queensland to central NSW); south-east Australia (from Tasmania, Victoria and eastern South Australia) and in south-western WA. It is regularly seen in southern Australian waters. The current area of occurrence in Australia is estimated to be ~6 million km². No estimates of the numbers of leatherback turtles that forage in Australian waters are available.

There are no known major leatherback turtle nesting sites in Australia, although scattered isolated nesting (one to three nests per year) occurs in southern Queensland and the NT (Limpus & McLachlin, 1994). Nesting sites have been found at Cobourg Peninsula, Manangrida and Croker Island (200 – 250 km from the Project Area) in the NT. Only very small numbers of nests are laid per year in the NT and thus would only be a minor contributor to the global population. The species is unlikely to use beaches within the Darwin Harbour for nesting (Whiting, 2001).

The leatherback turtle is considered to be an oceanic species, which is unlikely to occur within the Darwin Harbour (Whiting, 2001).

5.2.2.6 Olive ridley turtle

The olive ridley turtle has a worldwide tropical and subtropical distribution, including northern Australia. The current area of occurrence is estimated to be in excess of 10 million km². Olive ridley turtles typically occur in shallow soft-bottomed habitats of protected waters. In Australia, they occur along the coast from southern Queensland and the Great Barrier Reef, northwards to Torres Strait, and across to the Joseph Bonaparte Gulf in WA.

A substantial part of the immature and adult population forage over shallow benthic habitats, though large juvenile and adult olive ridley turtles have been recorded in both benthic and pelagic foraging habitats. Foraging habitat can range from depths of several metres to over 100 m. A 'Habitat Critical to the survival of the olive ridley turtle species' occurs around the south-western side of Bathurst Island, extending 20 km seaward and approximately 5 – 10 km north of the Project Area (**Figure 5-5**).

An olive ridley turtle BIA inter-nesting area is located south-east of Darwin Harbour, approximately 10 km from the Project Area (**Figure 5-5**). This BIA is near the turtle nesting sites of Bare Sand Island, Quail Island and Indian Island, located near the mouth of Bynoe Harbour (~50 km from Darwin), however these sites are not considered significant on a regional scale with infrequent nesting recorded (Chatto and Baker, 2008). Within the Darwin Harbour, Casuarina Beach, Cox Peninsula Beaches and Mandorah Beach are infrequently used for nesting. In Northern Australia nesting occurs all year round, although most nesting occurs during the dry season from April to August. Hatchlings emerge from the nests about two months after laying (DoEE, 2017a).

There are no nesting beaches or defined inter-nesting area within the Project Area. However, Habitat Critical to the survival of olive ridley turtles and a BIA (inter-nesting) occur outside to the north and south of the Project Area respectively. Therefore, olive ridley turtles are likely to occur in waters outside Darwin Harbour and may transit through the Project Area.

Santos

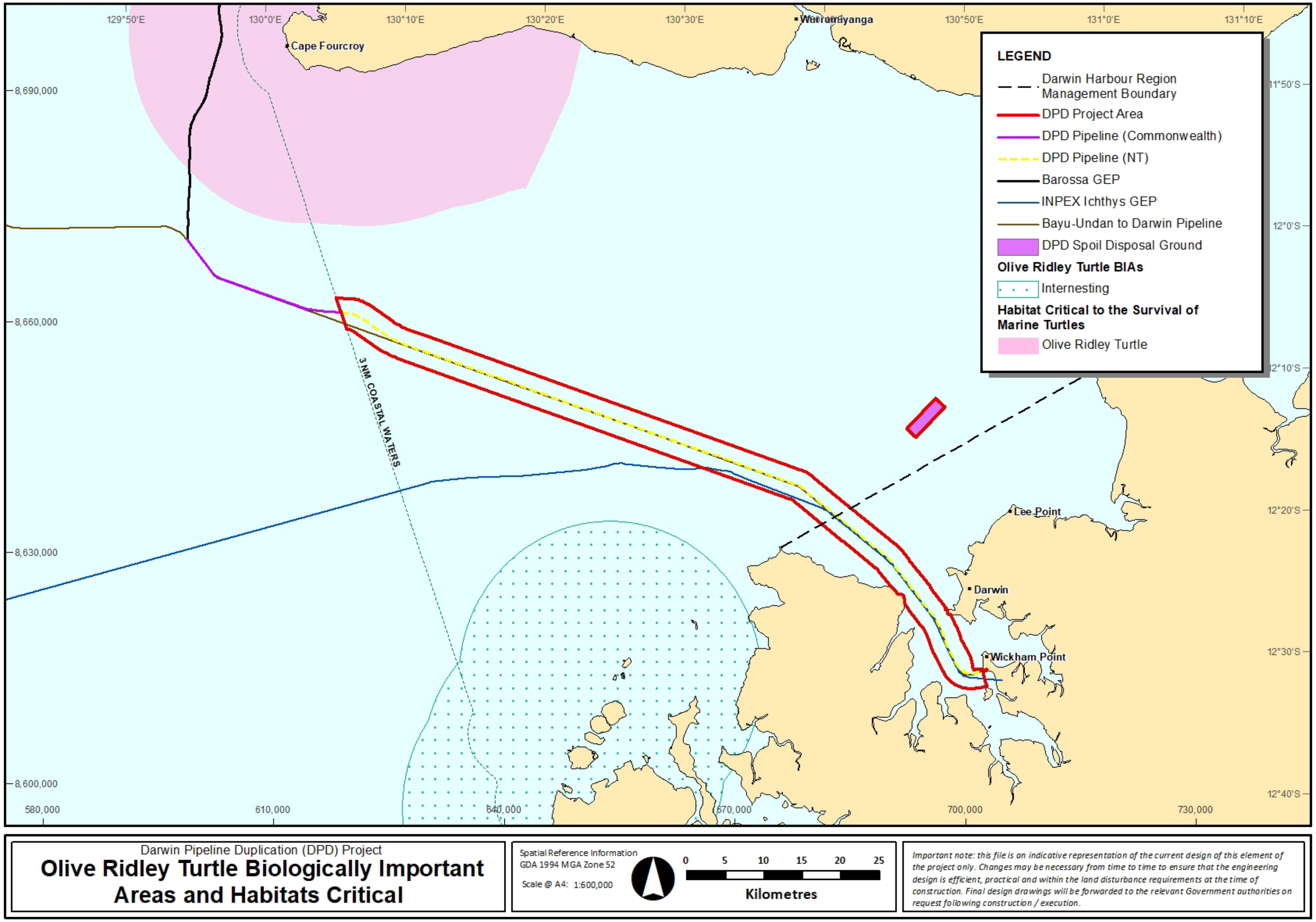


Figure 5-5: Olive ridley turtle biologically important areas and habitats critical to survival

5.2.2.7 Saltwater crocodile

The saltwater crocodile (*Crocodylus porosus*) is primarily found in inland waterways, tidal creeks, coastal floodplains and channels, billabongs and swamps across northern Australia (DoEE, 2019). The species' recognised distribution extends from Rockhampton in Queensland to King Sound in WA (DoEE, 2019). There are no identified BIAs or EPBC-listed critical habitat within the NMR for saltwater crocodiles. In the NT, saltwater crocodiles can be found in almost any type of water body, including fresh or saline, within their range (Saalfeld *et al.*, 2016). In the NT, most breeding sites are found on riverbanks or floating rafts of vegetation.

Within the NMR, the saltwater crocodile's distribution is thought to have expanded since its protection in the early 1970s, with individuals occurring up to 150 km inland, further than any historical records or knowledge (DEWHA, 2008b). Although the species is considered recovered and no longer threatened, it is recognised that strict regulation is required to avoid the population becoming depleted again (DoEE, 2019). Saltwater crocodiles breed during the wet season between October and May. Preferred nesting habitat of the saltwater crocodile includes elevated, isolated freshwater swamps that do not experience the influence of tidal movements (Saalfeld *et al.* 2016). Nesting occurs in freshwater swamps that have little tidal movement between December and March, with a peak period between January and February (DEWHA, 2008b).

The saltwater crocodile is common throughout the Darwin region and could occur in the Project Area. In 2019/2020 a total of 249 'problem crocodiles' were removed from NT waters with nearly all of these being caught within Darwin Harbour area (DEPWS, 2021).

The saltwater crocodile is commonly recorded in the Darwin Harbour, with sightings of individuals on boat ramps near the Project Area.

5.3 Sharks, rays and sawfishes

The EPBC Act PMST (BAA-201 0003; Santos, 2021a; BAA-201 0004; Santos, 2022) identified 13 species of sharks, rays and sawfishes listed as threatened and/or migratory under the EPBC Act. Through further likelihood assessment all are considered unlikely to occur within the Project Area BAA-201 0003; Santos, 2021a; BAA-201 0004; Santos, 2022).

6 Noise assessment

6.1 Underwater noise sources

There will be a period of increased noise emissions during construction activities due to the operation of vessels, survey and positioning equipment, trenching equipment and helicopters. Underwater noise emissions will be temporary and will take place for a relatively short period of time in any one location.

Research has found that the noise levels at which physiological or behavioural impacts to marine fauna occur is dependent on whether the noise being generated is classed as impulsive or non-impulsive:

+ **Impulsive** – sounds produced are typically transient, brief (less than one second), broadband and consist of high peak pressure with rapid rise time and rapid decay (NOAA, 2019). This noise source is associated with activities such as pile driving, seismic activities and underwater blasting and results in some of the most powerful sounds produced underwater (Yelverton et al., 1973; Young, 1991).
+ **Non-impulsive** – sounds produced can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have the high peak sound pressure with rapid rise / decay times that impulsive sounds do (NOAA, 2019). This type of noise source is associated with activities such as dredging, vessel noise, drilling and some construction activities.

The following sections describe the potential noise generating activities and noise sources during the DPD Project. The noise sources that were modelled were determined based on the activities with the highest risk of causing underwater noise impacts and the best possible match to the activities and equipment provided at the time of assessment.

6.1.1 Vessels

Noise associated with vessel activity that could impact marine megafauna includes noise generated by vessel thrusters, engines and propellers, as well as noise emitted onboard which is converted to underwater noise through the hull (i.e., from heavy machinery) (Abrahamsen, 2012). These are considered non-impulsive noise sources. The main source of vessel noise will be from propellers or dynamic positioning (DP) thrusters. Noise will also be generated during vessel transit within the Project Area. Noise from DP systems is predominately generated from water rushing through the thruster tunnel on vessels and typically ranges between 200 Hz and 1.2 kHz in frequency. Surveys measuring underwater noise from DP vessels holding station reported maximum source levels of approximately 182 dB re 1 µPa at 1 m (McCauley, 1998). Levels emitted from vessels during activities are expected to be no higher than these reported levels.

Of the vessels used for DPD Project activities, vessels undertaking trenching activities are considered to have the highest potential noise emissions and have been modelled.

6.1.2 Trenching vessels

Depending upon the trenching area, trenching will be completed using different trenching vessels, including a BHD, a TSHD and a CSD. These are considered non-impulsive noise sources. Previous studies of underwater noise have recorded that source levels for general marine dredging operations range from 160 – 180 dB (re 1 µPa at 1 m) for 1/3 octave bands, with peak intensities between 50 and 500 Hz (Greene & Moore, 1995; Thomsen *et al.*, 2009; CEDA, 2011; WODA, 2013). Received sound levels from some large trailer suction hopper dredges operating in rocky areas have been recorded greater than

150 dB (re 1 µPa at 1 km), while large CSDs can emit strong tones from the water pumps that are audible to 20 – 30 km ranges (Richardson *et al.*, 1995; Dames & Moore, 1996; Robinson *et al.*, 2011). Operating dredges will emit sound at their maximum source levels, which are in the 180 to 190 dB (re 1 µPa at 1 m) range (Richardson *et al.*, 1995; Simmonds, Dolman & Weilgart, 2004; Thomsen *et al.*, 2009; CEDA, 2011; WODA, 2013).

6.1.3 Rock breaking tools (Xcentric Ripper and hydraulic hammer)

An Xcentric Ripper (preferred) or a hydraulic hammer are BHD tools that may be required to break up rocky material during the trenching activities. For the purposes of modelling, the Xcentric Ripper is considered a non-impulsive noise source and the hydraulic hammer an impulsive noise source Connell *et al.* (2003).

Underwater measurements of an Xcentric Ripper XR-60 have been used to inform an appropriate source level for the purposes of underwater noise modelling. Connell et al. (2023) used underwater noise measurements taken by Lawrence (2016) to calculate a source level of 184.8 dB re 1 μPa^2 s m^2.

In order to determine an appropriate source level for modelling the effects of a hydraulic hammer (Epiroc HB 10000), Connell *et al.* (2023) used a source-level spectra corresponding to Down-The-Hole (DTH) hydro-hammering as a proxy. DTH hydro-hammering is a percussive rotating drilling technique appropriate for hard rock formations. The proxy DTH levels used correspond to a Numa Patriot 180 hammer as detailed in Denes *et al.* (2016). The source level used to represent hydraulic hammering was determined to be 192 dB 1 μPa^2s m^2.

6.1.4 Survey equipment

Commercial survey vessels (multibeam echosounder (MBES), side scan sonar (SSS), long baseline acoustic positioning system (LBL) / ultra-short baseline system (USBL)) use a variety of sonar (e.g., depth sounders) that emit underwater noise (150 – 235 dB) but tend to use a higher frequency (>70 kHz). They are generally pointed directly towards the bottom in a narrow beam limiting horizontal noise propagation and are considered impulsive noise sources. Side scanning sonars (e.g., seafloor mapping) are the exception as noise is propagated horizontally (Weilgart, 2007). Most SSS and MBES operate in the frequency range of 100 kHz to 500 kHz (MacGillivary *et al*., 2014; Ruppel *et al*., 2022).

6.1.5 Noise generated by helicopters

Helicopters will also generate noise, with the main source of noise being the engines and the rotor blades. Sound traveling from a helicopter to a receiver underwater is affected by both in-air and underwater propagation processes, and processes occurring at the air seawater surface interface (e.g., wind and waves). The level of noise received underwater depends on source altitude and lateral distance, receiver depth, water depth, and other variables.

Helicopter engine noise is emitted at various frequencies however, the dominant tones are generally of a low frequency (LQ) below 500 Hz (Richardson *et al.*, 1995) and is considered an impulsive noise source. Sound pressure in the water directly below a helicopter is greatest at the surface and diminishes with increasing receiver depth. Noise also reduces with increasing helicopter altitude, but the duration of audibility often increases with increasing altitude, with sound penetrating water at angles <13°.

It is expected the duration of helicopter operations within close proximity to the marine environment is limited and intermittent. Further, helicopter operations are expected to result in received underwater noise levels lower than those associated with vessel operations.

6.2 Underwater noise thresholds

Available threshold criteria associated with behavioural and physiological impacts for sensitive marine fauna have been derived from a number of sources (NMFS, 2018; NMFS, 2014; Popper *et al.*, 2014; Southall *et al.*, 2019). These thresholds have been used to assess modelling results and determine potential impacts to marine fauna from permanent threshold shift (PTS) and temporary threshold shift (TTS) as well as to determine potential behavioural effects.

6.2.1 Noise thresholds for marine mammals

The potential impacts of anthropogenic noise on marine mammals, specifically cetaceans, have been the subject of considerable research. Current data and predictions show that marine mammal species differ in their hearing capabilities, in absolute hearing sensitivity, as well as frequency band of hearing (Richardson *et al.*, 1995; Wartzok and Ketten, 1999; Southall *et al.*, 2007). To better reflect the auditory similarities between phylogenetically closely related species, but also significant differences between species groups among the marine mammals, Southall *et al.* (2007) assigned the extant marine mammal species to functional hearing groups based on their hearing capabilities and sound production. More recently, U.S. Navy technical reports by Finneran (2015, 2016) proposed new auditory weighting functions and the U.S. NMFS (2014, 2018) undertook a comprehensive review of PTS and TTS dual metric criteria for marine mammals and revised the threshold criteria for each frequency-weighted functional hearing category of cetacean. The only marine mammals likely to occur in the waters of Darwin harbour are dolphins (high frequency functional hearing category) and dugong and the noise effect threshold for these receptors are in **Table 6-1**.

6.2.2 Noise thresholds for marine reptiles

Marine turtles are considered to be less sensitive to noise than marine mammals as they do not have an external hearing organ but can detect sound through bone-conducted vibration in the skull with their shell providing a receiving surface (Lenhardt *et al.*, 1985). Morphological studies of green and loggerhead turtles (Ridgway *et al.*, 1969; Wever, 1978; Lenhardt *et al.*, 1985) found that the turtle ear is similar to other reptile ears but has adaptations for underwater listening.

Most studies researching the effect of seismic noise on sea turtles focused on behavioural responses, as physiological impacts are more difficult to observe in living animals. Turtles avoid low-frequency sounds (Lenhardt, 1994) and sounds from seismic surveys (O'Hara and Wilcox, 1990), but these reports did not note received sound levels. In another study, caged green and loggerhead turtles increased their swimming activity in response to an approaching airgun when the received SPL was above 166 dB (re 1 µPa) (McCauley *et al.*, 2000).

There are no known studies that have investigated the effects of noise on crocodiles so the thresholds for turtles have been applied to crocodiles and these are presented in **Table *6-1***.

Table 6-1: Noise impact thresholds for the marine fauna groups in Darwin Harbour

Marine fauna type	Marine hearing group	Hearing bandwidth	Noise type	SEL24hour (Weighted) dB (re 1µ Pa2.s)		SPL Possible Behavioural Disturbance dB (re 1µ Pa)
				TTS	PTS	
Dolphins			Non-Impulsive[1]	178	198	120

Marine fauna type	Marine hearing group	Hearing bandwidth	Noise type	SEL24hour (Weighted) dB (re 1µ Pa2.s)		SPL Possible Behavioural Disturbance dB (re 1µ Pa)
				TTS	PTS	
	High Frequency (HF)	150 Hz to 160 kHz	Impulsive[1]	170	185	160
Sirenians (Dugong)	SI	100 Hz to 50 kHz	Non-Impulsive[1]	186	206	120
			Impulsive[1]	175	190	160
Turtles and crocodiles	N/A	100 Hz to 2 kHz	Non-Impulsive[1]	200	220	Relative risk[2]
			Impulsive[1]	189	204	166

Note:

1. Thresholds are derived from Southall et al. (2019); NMFS (2018); NOAA (2019); Finneran et al. (2017); McCauley et al. 2000 and Popper et al. (2014).
2. Relative risk levels of Low, Moderate and High have been developed by Popper *et al*. (2014) for behavioural effect on turtles exposed to non-impulsive noise. Risk rankings from Popper *et al*. (2014) for 'Shipping and Other Continuous Noise' have been applied to non-impulsive noise for behavioural response. Risk rankings are provided in context of distance of Near (N) (10s of metres), Intermediate (I) (100s of metres) and Far (F) (1,000s of metres)

6.3 Underwater noise modelling

6.3.1 Overview

Of the activities and noise sources detailed in **Section 6.1**, and in discussion with underwater noise modeller, trenching activities using a combination of TSHD, CSD and BHD (including rock breaking using hydraulic tools) were considered the most significant sources of Project underwater noise. These activities have been modelled to quantify noise emissions and marine fauna exposures to inform impact assessment and marine fauna noise management measures included herein. An overview of the modelling approach is presented below with the full technical reports presented as attachments to the SER.

Underwater noise modelling initially conducted for the Project (Talis Consultants, 2023) included for dredging vessel noise emissions (TSHD, CSD and BHD), vibratory hammer (sheet piling) noise emissions and hydraulic hammer (BHD rock breaking) noise emissions. Since completion of that modelling, further definition of the Project scope was developed by Project contractors, including removal of the need to construct a cofferdam (and associated sheet piling) and further detail made available on the type and specification of rock breaking tools. For rock breaking from the BHD, the quieter Xcentric Ripper tool is considered the base case, and likely the most effective option, with a hydraulic hammer proposed as a contingency only.

To better represent underwater noise emissions and fauna exposure from the use of BHD rock breaking tools, additional underwater modelling was undertaken for an Xcentric Ripper (Xcentric Ripper XR-60) and a hydraulic hammer (Epiroc HB 10000) (Connell *et al.*, 2023). The results presented below for an Xcentric Ripper and a hydraulic hammer have been taken from that modelling. Since sheet piling is no longer required for the Project, the vibratory hammer modelling results included in Talis Consultants (2023) have not been presented below.

6.3.2 Modelling scenarios

DPD Project underwater noise modelling scenarios were discussed initially at a workshop with the Project team, environmental advisers and a noise modelling consultant. Noise activity scenarios were identified for modelling on the basis of those with the greatest potential for environmental impact (i.e., greatest noise generating activities in proximity to species of concern).

The following Project underwater noise sources/scenarios have been modelled:

+ **Trenching**: trenching will be undertaken using a combination of a TSHD, a CSD and a BHD. The following indicative 24-hour cycle times for each type of trenching vessel were modelled:
    - **TSHD** – The TSHD will alternate between trenching activities and spoil disposal at the offshore spoil ground. Cycle times are dependent on distance from spoil ground but nominally have been modelled as 3 hours trenching noise (non-impulsive noise, continuous noise) and 2 hours transit to spoil ground and back (i.e. 'no noise' period) repeated over period of 24 hours. The average time for transit is 102mins with the longest transit time at ~140 minutes (pre-sweep area 1) and the shortest at ~64 minutes (sand waves area)
    - **CSD** – 10 hours cutting (non-impulsive, continuous noise), 2 hours downtime over 12 hours (2x 12-hour cycles per 24h).
    - **CSD + TSHD** – The cycles for TSHD and CSD were applied at the same trenching location to conservatively assess cumulative effects of these vessels if they were operating in the same location.
    - **BHD** (in an area requiring rock breaking) - 4 hours of rock breaking modelled using an Xcentric Ripper (non-impulsive, continuous noise) and a hydraulic hammer (impulsive noise), 4 hours no noise (switching between rock breaking tool and excavating tool) and 4 hours digging (non-impulsive, continuous noise) over a 12-hour period and repeated (2x 12-hour cycles per 24h) i.e., cumulative total of 8 hours each of rock breaking, digging and no noise.
    - **BHD** (hydraulic hammer sensitivity analysis) **-** In addition to modelling a Xcentric Ripper and a hydraulic hammer noise for 8 hours per 24 hours, a sensitivity analysis on the effect of reducing operation time for the hydraulic hammer was undertaken, since the modelled PTS/TTS ranges for this tool were relatively large. The sensitivity analysis modelled reduced operation times of 6, 4 and 2 hours per 24 hours for the hydraulic hammer.

Trenching scenarios have been modelled at three representative locations (**Figure 6-1**):

+ Location 1 - BHD excavating and rock breaking (Xcentric Ripper or hydraulic hammer) in an area of hard rock;
+ Location 2 - TSHD operating at a middle harbour trenching zone. This area was also relatively close to Weed Reef compared to other trenching zones. Weed Reef is a known hard reef area supporting greater diversity of biota (including hard corals) and may support higher marine fauna abundance.
+ Location 3 - TSHD (alone) and TSHD/ CSD (operating together) operating in an outer harbour trenching zone. This zone was relatively close to Cox Peninsula shallow water and shorelines which support a higher diversity of biota and may support higher marine fauna abundance.

The sound source locations and levels used for each modelling scenario are shown in **Figure 6-1**, **Table 6-3** and **Table 6-4** respectively.

Table 6-2: Noise Modelling Locations and Scenarios

Location	Scenario	Easting (GDA94, MGA Zone 52) (m)	Northing (GDA94, MGA Zone 52) (m)	Recurring Cycle Time over 24 Hours
1	BHD (Excavating)	701 366	8 614 382	Two x 4 hours of digging over 24 hours.
	BHD (Rock breaking)			Two x 4 hours rock breaking over 24 hours.
2	TSHD	696 636	8 620 225	3 hours trenching and 2 hours transit/ spoil dump.
3	TSHD	692 710	8 625 712	3 hours Trenching and 2 hours transit/ spoil dump
	Concurrent operations – TSHD and CSD			TSHD (3 hours trenching and 2 hours transit/ spoil dump). CSD (10 hours of cutting and 2 hours downtime).

Table 6-3: Modelled noise source levels

Source type	Source Level
TSHD	184 dB re 1µPa @1m (based on Reine et al., 2012)
CSD	182 dB re 1µPa @1m (based on Thomsen et al., 2009)
BHD (excavating)	175 dB re 1µPa @1m (based on Reine et al., 2012)
BHD (Xcentric ripper)	184.8 dB re 1 $\mu Pa^2 \cdot s$ m^2 (based on Lawrence, 2016)
BHD (hydraulic hammer)	192.4 dB re 1 $\mu Pa^2 \cdot s$ m^2 (based on Denes et al., 2016)

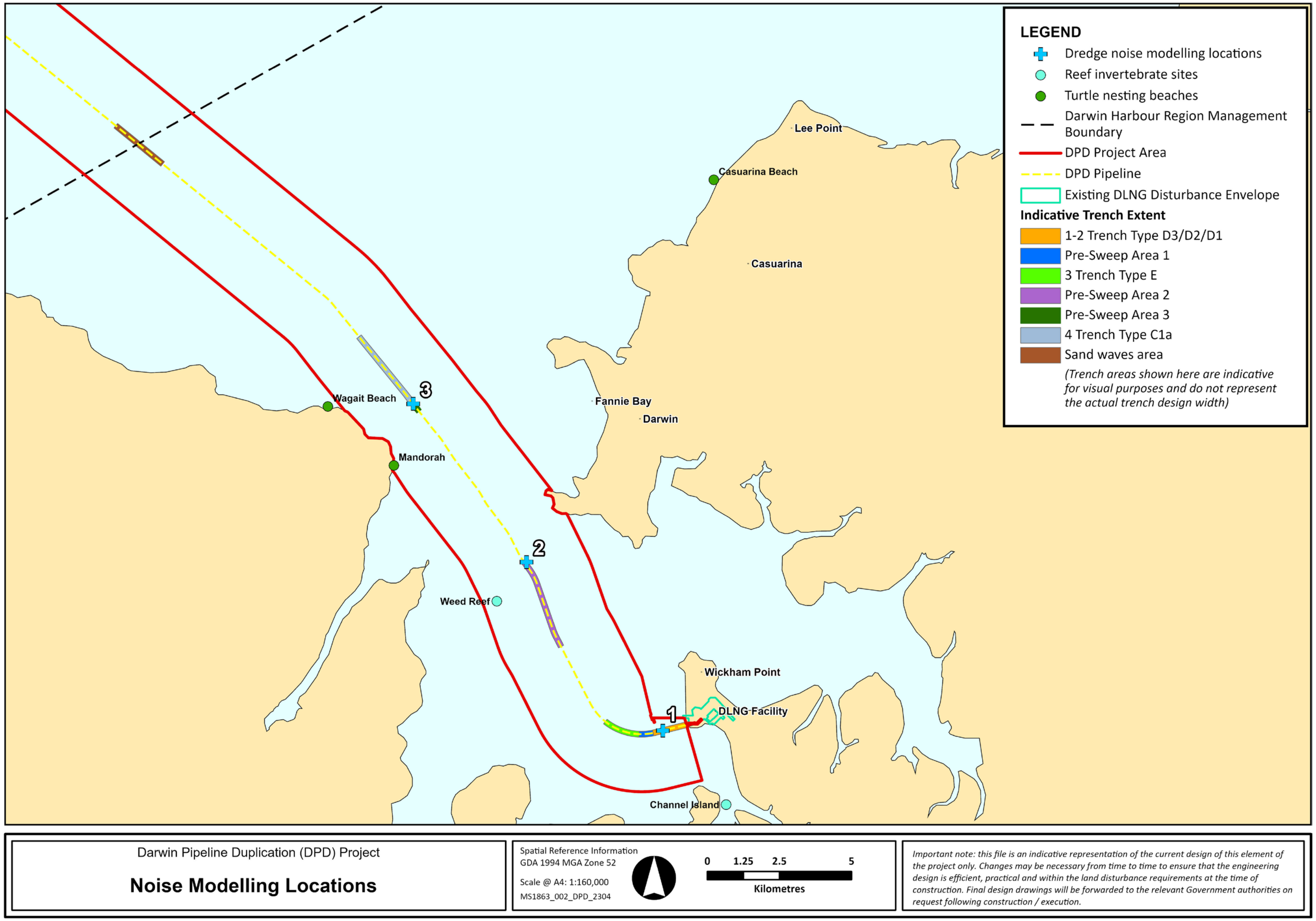


Figure 6-1: Noise modelling locations

Modelling of 24-hour sound exposure level ($SEL_{24\ hour}$) was conducted for each scenario to provide a conservative determination of PTS and TTS ranges from the cumulative effect of noise to marine fauna of interest over a 24-hour period. This modelling method is considered industry leading practice and is a conservative way of estimating potential effect ranges, as $SEL_{24\ hour}$ assumes the receptor (i.e., fauna) is stationary within the noise field of the noise source. In reality, the marine fauna of interest are highly mobile species which move naturally throughout the harbour and are capable of moving away from a noise source.

$SEL_{24\ hour}$ modelling presented here is based on a mean sea level (MSL) over a 24-hour period to represent average water level throughout the daily tidal cycle. This was considered the most appropriate approach for $SEL_{24\ hour}$ modelling (in comparison to presenting LAT or HAT results) since tide state varies significantly between low and high tide over a 24-hour period in Darwin Harbour (up to an 8 m range) and low and high tides are not representative of water level over a duration of 24 hours (rather they represent extreme water levels present for short periods of time).

Modelling of sound pressure level (SPL) which represents an instantaneous level of noise (in contrast to SEL) has been used for determining behavioural impact ranges to fauna. For SPL modelling, modelled results at high and low tide (as well as MSL) are considered appropriate given SPL is an instantaneous level. Highest astronomical tide (HAT) and Lowest astronomical tide (LAT) were conservatively used as water levels to represent high and low tide states, respectively, although these extremes are rarely reached. Between LAT of 0.0 m and a HAT of 8.0 m, low and high tides are on average (mean level) 2.2 m and 5.9 m, respectively as shown in **Table 6-5** (Williams *et al.*, 2006).

Table 6-4: Tide heights within Darwin Harbour (Williams *et al.*, 2006)

Tide type	Height
Highest Astronomical Tide (HAT)	8.0 m
Mean High Water Springs	6.9 m
Mean High Water	5.9 m
Mean High Water Neaps	4.9 m
Mean Sea Level (MSL)	4.0 m
Mean Low Water Neaps	3.1 m
Mean Low Water	2.2 m
Mean Low water Springs	1.2 m
Lowest Astronomical Tide (LAT)	0.0 m

Further description of the modelling inputs, including bathymetry, seabed types and sound profiles and further description of the noise sources used is presented in Talis Consultants (2023) and Connell *et al.* (2023) (attached to the DPD Project SER).

6.3.3 Results

To evaluate the potential for impact to different marine fauna, the estimated distances from the sound source at which the behavioural and physiological thresholds (as listed in **Table 6-1**) were predicted to be exceeded are presented below for each location and activity.

Table 6-6 presents the threshold ranges at mean sea level (MSL) between the noise source and the modelled PTS, TTS and behavioural response thresholds for each fauna group for each of the modelled scenarios. Equivalent figures plotting the threshold contours for TSHD, CSD and BHD trenching (non-impulsive noise) are provided in Talis Consultants (2023) with worst-case ranges illustrated in **Figure 6-2** to **Figure 6-4**. Equivalent threshold contour figures for Xcentric Ripper and hydraulic hammer are provided in Connell *et al.* (2023).

For all scenarios and fauna groups, PTS $SEL_{24\ hour}$ threshold ranges were below 50 m with the exception of the BHD impulsive noise (hydraulic hammering) scenario where PTS threshold ranges were 130, 160 and 100 m for dolphins, dugongs and turtles, respectively (**Table 6-6**). Given the mobility of these species, and the threshold ranges for behavioural response being greater than the PTS range for all species, it is unlikely that these species would remain within the predicted PTS ranges for a period of 24 hours. Permanent threshold shift (PTS) injury is therefore considered unlikely for dolphins, dugongs and turtles from Project trenching activities.

TTS $SEL_{24\ hour}$ threshold ranges at mean sea level varied across scenarios and fauna groups (**Table 6-6**). For continuous noise source scenarios of TSHD, CSD and BHD trenching and BHD rock breaking using an Xcentric Ripper, TTS threshold ranges varied between 40 m and 350 m and were highest for dolphins (100 – 350 m), followed by dugongs (70 – 210 m) and then marine turtles (40 - 160m) (**Table 6-6**).

For the BHD hydraulic hammering scenario, TTS threshold ranges were significantly larger than those predicted for the other modelled scenarios; threshold ranges for dolphins, dugongs and turtles were predicted to be 1,830 m, 2,500 m and 950 m, respectively (**Table 6-6**). Given the relatively large size of these ranges and the fact that behavioural response thresholds were predicted to be within these ranges, it is possible that dolphins, dugongs and turtles could remain within the threshold TTS ranges for a period of 24 hours and receive TTS impact, if management measures were not in place to prevent this from occurring.

Given the above, further investigation was undertaken by Connell *et al.* (2023) to determine the effect of reducing BHD hydraulic hammering time on the size of PTS and TTS threshold ranges. A summary of this analysis at MSL is presented in **Table 6-7**. PTS and TTS threshold ranges decreased as hammering time decreased. For dolphins, PTS/TTS ranges dropped from 130 m/1,830 m for 8 hours hammering time (per 24 hours) to 30 m/670 m for 2 hours hammering time. For dugongs PTS/TTS ranges dropped from 160 m/2,500 m for 8 hours hammering time to 50 m/840 m for 2 hours hammering time while for turtles, PTS/TTS ranges dropped from 100 m/950 m for 8 hours hammering time (per 24 hours) to 30 m/380 m for 2 hours hammering time. While reducing operation time had a significant effect on reducing PTS/TTS ranges for the hydraulic hammer, the ranges modelled for 2 hours of operation time per 24 hours were still significantly larger that for the Xcentric Ripper tool operated for 8 hours per 24 hours (**Table 6-6, Table 6-7**).

For behavioural response thresholds, ranges for marine mammals (dolphins and dugongs) varied from 100s of metres to 10s of kilometres for scenarios modelled at MSL with the highest range being for the Xcentric Ripper tool (14 km for both dolphins and dugongs) (**Table 6-6**). A quantitative threshold for marine turtles was only considered applicable for impulsive noise (i.e. BHD hydraulic hammer scenario). The range for this threshold at MSL was predicted to be 270 m (**Table 6-6**). For non-impulsive noise from TSHD, CSD and BHD trenching and use of Xcentric Ripper, the relative risk levels for marine turtle behavioural effect are taken from Popper *et al.* (2014) which are high risk in the near field (scale of 10s of metres), moderate risk at intermediate ranges (scale of 100s of metres) and low risk in the far field (scale of 1000s of metres). Behavioural effect in Popper *et al.* (2014) is defined as a substantial change in behaviour for the animals exposed to the sound.

In addition to ranges at MSL, quantitative behavioural threshold ranges were also modelled across LAT and HAT (**Table 6-8**). The effect of water level on range size was not consistent between modelling studies (Talis Consultants, 2023; Connell *et al.*, 2023). The greatest marine mammal (dolphin and dugong) behavioural response ranges for each scenario were: 909 m at HAT for BHD digging; 14,700 m at LAT for BHD Xcentric ripper use; 270 m at LAT for BHD hydraulic hammering; 20,000 m at HAT for the TSHD at Location 2; 17,878 m at HAT for the TSHD at Location 3 and 20,000 m at HAT for the TSHD and CSD operating at the same location (Location 3) (**Table 6-8**). A quantitative behavioural threshold for marine turtles was only considered applicable for impulsive noise. The largest behavioural response threshold range for marine turtles for BHD hydraulic hammering was 90 m at LAT (**Table 6-8**).

6.3.4 Marine megafauna impact discussion

The potential for physiological impacts to EPBC Act listed marine megafauna (dolphins, dugong and turtles), in the form of PTS and TTS was determined through modelling for the highest underwater noise generating activities associated with the DPD Project, i.e. the operation of trenching vessels, including the use of rock breaking tools. PTS $SEL_{24\ hour}$ threshold ranges of <50 m to 160 m were determined, with range sizes varying across species and modelled scenarios. PTS impact within these ranges requires marine fauna to be within the range for 24 hours. Given the likely behavioural response to avoid the area prior to entering into a PTS zone, and the known mobility of these species, it is unlikely that these species would remain within these ranges for long enough for PTS injury to occur. Nevertheless, the monitoring of observation and exclusion zones around trenching vessels, and appropriate adaptive management measures to cease trenching if fauna enter exclusion zones will be adopted for the Project to prevent this occurrence (**Section 8.4**).

For the continuous (non-impulsive) noise sources of TSHD, CSD and BHD trenching, and the use of an Xcentric Ripper tool for rock breaking, modelled TTS $SEL_{24\ hour}$ threshold ranges varied between 40 m and 350 m, and were highest for dolphins (100 – 350 m), followed by dugongs (70 – 210 m) and marine turtles (40 – 160m). As with the PTS thresholds ranges, it is unlikely that these EPBC Act listed marine fauna would remain within these ranges long enough (i.e. for 24 hours or greater) for TTS impacts to occur, and there are no known aggregation areas for these fauna within this range of trenching areas. However, the application of observation and exclusion zones, monitored from trenching vessels, together with the use of soft start operations, where practical, will be adopted to avoid TTS impacts (**Section 8.4**).

Modelling undertaken for hydraulic hammer use predicted that PTS and TTS threshold ranges would be significantly larger than for other trenching sound sources, that is, trenching using a TSHD, CSD or BHD and the use of an Xcentric Ripper rock breaking tool. In particular, the scale of hydraulic hammering TTS ranges (in the order of kms) suggests that TTS impacts would be possible to marine fauna remaining within these ranges for 24 hours or more, particularly given a behavioural response to this impulsive noise source noise may not occur until marine fauna are well within the TTS range. While an Xcentric Ripper tool is considered the base case for rock breaking from the BHD, a hydraulic hammer may be used as a contingency, therefore additional management controls were considered necessary (over and above those proposed for other trenching activities) and have been included in **Section 8.4**. This includes monitoring of significantly larger observation and exclusion zones and restricting hydraulic hammering to daylight hours only.

Based on the modelled behavioural effect ranges, in particular the continuous noise behavioural effect ranges, there is the potential for species of interest (dolphins, dugongs and turtles) to be affected by noise from dredging vessels on a scale of 100s to 1000s of metres. These ranges are expected to be similar to those associated with noise emissions from large non-Project commercial vessels that use

Santos

Darwin Harbour on a daily basis, as they have similar noise source levels and frequency bands and operate in the same areas (refer **Section 5.1.3**). Given the existing noise environment, it is expected that marine fauna will have developed some level of acclimatisation to vessel noise over a range similar to that modelled for the Project trenching vessels. It is also likely that some masking of Project vessel noise above the marine mammal behavioural threshold of 120 dB re 1µ Pa would occur from other commercial vessels that transit Darwin Harbour. In support of this, ambient noise measurements taken by noise loggers in East Arm by Salgado-Kent *et al.* (2015) recorded that noise from transiting commercial vessels was frequently in the range of 130 – 140 dB re 1 µPa. Masking of Project vessel noise by other anthropogenic noise sources would be expected to diminish the range of behavioural effect ranges around Project vessels in areas and times where other vessels are active. While there may be a more prolonged exposure of marine fauna to noise above behavioural threshold levels from slow moving trenching vessels working in an activity area (i.e. a trenching zone) when compared to transiting commercial vessels, trenching activity is expected to be completed relatively quickly, within a period of 2 to 3 months and therefore any behavioural effects are considered temporary.

Within and around Darwin Harbour there are known periods for biologically important behaviours for turtles and dolphins. There are known flatback turtle nesting sites on Cox Peninsula and Casuarina Beach and a known period of increased nesting activity from May to October. However, the densities of nesting turtles in these areas are very low and not significant on a regional scale (Chatto and Baker, 2008) and furthermore, these sites are on a scale of 1000s of meters away from the pipeline route and trenching areas (as they are from existing vessel traffic using navigation channels) therefore the relative risk of behavioural effects to turtles at this scale from vessel noise is considered low (Popper *et al.*, 2014).

For dolphins, there is evidence that there is a peak in calving within Darwin Harbour between October and April (Palmer, 2010). Important areas have not been defined however, given the high mobility of dolphin species within Darwin Harbour and the use of adjoining coastal areas (Griffiths *et al.*, 2019), it is unlikely that behavioural disturbance around DPD Project activities, relative to the total area of Darwin Harbour and surrounding coastal waters, would have a significant impact on dolphin calving behaviour.

Foraging activities by marine megafauna within and around Darwin Harbour are considered to occur year-round. While there is the potential for Project underwater noise to reach areas that can be used as foraging habitat (e.g. shallow areas that could support algae and seagrass), at a level above a behavioural response threshold, the Project activities will not restrict access to foraging habitats that wouldn't be available elsewhere within and around the harbour given the size of behavioural effect ranges relative to the size of Darwin Harbour and distribution of habitat.

On the basis that physiological impacts (PTS and TTS) to EPBC Act listed marine fauna from Project underwater noise emissions (in particular vessels undertaking trenching activities) will be avoided through the application of industry standard management controls and behavioural response to underwater trenching noise will be temporary and on the same scale as from existing commercial vessel using Darwin Harbour, impacts to marine fauna from underwater noise emissions are considered to be minor.

Table 6-5: PTS, TTS and Behavioural response threshold ranges for each fauna group for each modelled scenario/location at mean sea level

Hearing Group	SEL 24 hour (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural Response [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Location 1 – Backhoe Dredge digging (non-impulsive noise) (Talis Consultants, 2023)						
Dolphins	178	198	151	<50	120	454
Dugongs	186	206	100	<50	120	454
Turtle	200	220	80	<50	RISK[1]	High (N) Moderate (I) Low (F)
Location 1 – Backhoe Dredge rock breaking with Xcentric Ripper (non-impulsive noise) (Connell *et al.*, 2023)						
Dolphins	178	198	100	NR	120	14,000
Dugongs	186	206	70	NR	120	14,000
Turtle	200	220	40	NR	RISK[1]	High (N) Moderate (I) Low (F)
Location 1 – Backhoe Dredge rock breaking with hydraulic hammer (impulsive noise) (Connell *et al.*, 2023)						
Dolphins	170	185	1,830	130	160	220
Dugongs	175	190	2,500	160	160	220
Turtle	189	204	950	100	166	270
Location 2 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023)						
Dolphins	178	198	303	<50	120	1,667
Dugongs	186	206	170	<50	120	1,667
Turtle	200	220	131	<50	RISK[1]	High (N) Moderate (I) Low (F)
Location 3 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023)						
Dolphins	178	198	303	<50	120	2,273
Dugongs	186	206	200	<50	120	2,273
Turtle	200	220	120	<50	RISK[1]	High (N) Moderate (I) Low (F)

Hearing Group	SEL 24 hour (Weighted) Threshold [dB re 1µ Pa^2.s]		Distance [m]		SPL Behavioural Response [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Location 3 – Trailing Suction Hopper Dredge and Cutter Suction Dredge (non-impulsive noise) (Talis Consultants, 2023)						
Dolphins	178	198	350	<50	120	3,181
Dugongs	186	206	210	<50	120	3,181
Turtle	200	220	160	<50	RISK[1]	High (N) Moderate (I) Low (F)

Notes:

1. NR = threshold was not reached.
2. Risk rankings from Popper *et al*. (2014) for 'Shipping and Other Continuous Noise' have been applied to non-impulsive noise, for marine turtle behavioural response. Risk rankings are provided in context of distance from sound source; Near (N) (10s of metres), Intermediate (I) (100s of metres) and Far (F) (1000s of metres)

Table 6-6: Influence of BHD hydraulic hammering time on PTS and TTS ranges for each fauna group at mean sea level

Hearing Group	SEL 24 hour (Weighted) Threshold [dB re 1µ Pa^2.s]		Distance [m]	
	TTS	PTS	TTS	PTS
8 hours hammering/ per 24 hours				
Dolphins	170	198	1,830	130
Dugongs	175	206	2,500	160
Turtle	189	220	950	100
6 hours hammering/ per 24 hours				
Dolphins	170	198	1,510	90
Dugongs	175	206	1,790	110
Turtle	189	220	740	60
4 hours hammering/ per 24 hours				
Dolphins	170	185	1,200	60
Dugongs	175	190	1,410	80
Turtle	189	204	580	50
2 hours hammering/ per 24 hours				
Dolphins	170	198	670	30
Dugongs	175	206	840	50

Hearing Group	SEL $_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]	
	TTS	PTS	TTS	PTS
Turtle	189	220	380	30

Table 6-7: Quantitative behavioural disturbance threshold ranges for marine fauna across varying tidal states

Receptor Type	Sound Pressure Level (SPL) Behavioural Threshold (dB re 1µ Pa)	Threshold Range (metres) for tidal state		
		LAT	MSL	HAT
Location 1 – Backhoe Dredge digging (non-impulsive noise) (Talis Consultants, 2023)				
Dolphin	120	303	454	909
Dugong	120	303	454	909
Location 1 – Backhoe Dredge rock breaking with Xcentric Ripper (non-impulsive noise) (Connell *et al.*, 2023)				
Dolphin	120	14,700	14,000	13,100
Dugong	120	14,700	14,000	13,100
Location 1 – Backhoe Dredge rock breaking with hydraulic hammer (impulsive noise) (Connell *et al.*, 2023)				
Dolphin	160	270	220	170
Dugong	160	270	220	170
Turtle	166	90	60	60
Location 2 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023)				
Dolphin	120	1,450	1,667	20,000
Dugong	120	1,450	1,667	20,000
Location 3 – Trailing Suction Hopper Dredge (non-impulsive noise) (Talis Consultants, 2023)				
Dolphin	120	1,515	2,273	17,878
Dugong	120	1,515	2,273	17,878
Location 3 – Trailing Suction Hopper Dredge and Cutter Suction Dredge (non-impulsive noise) (Talis Consultants, 2023)				
Dolphin	120	3,000	3,181	20,000
Dugong	120	3,000	3,181	20,000

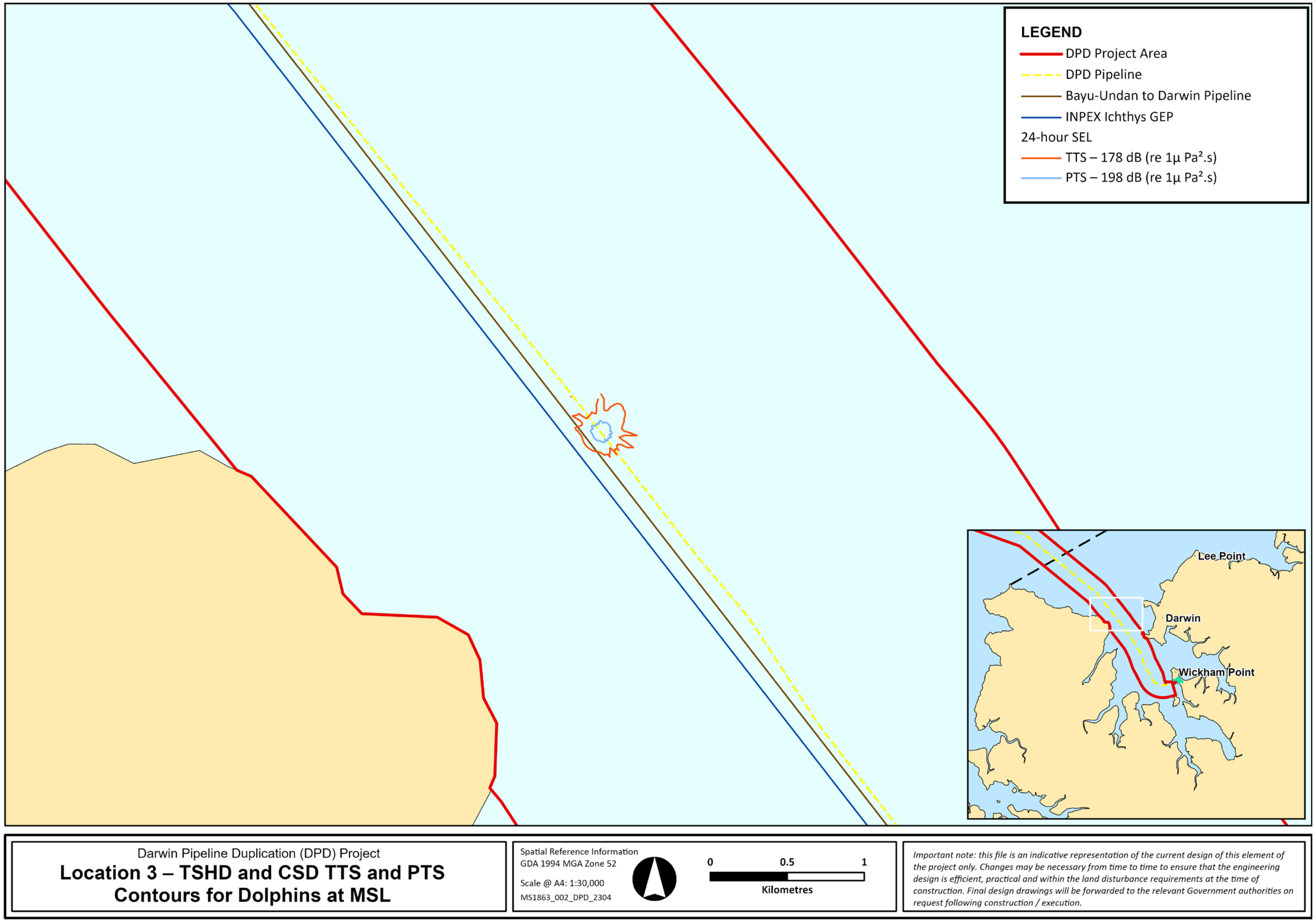


Figure 6-2: Modelling location 3 – TSHD and CSD TTS and PTS contours for dolphins (MSL)

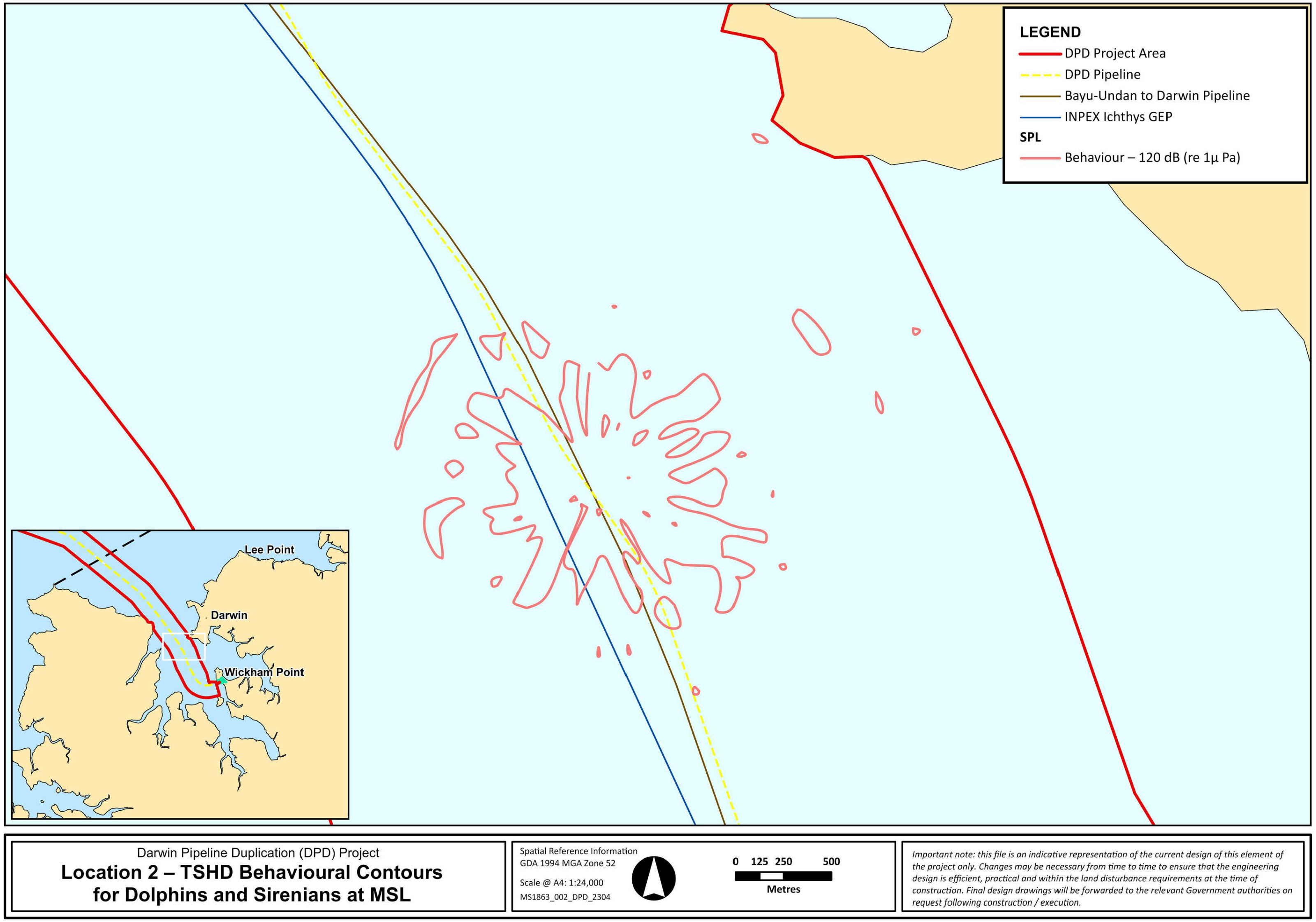


Figure 6-3: Modelling location 2 – TSHD behavioural contours for dolphins and sirenians (MSL)

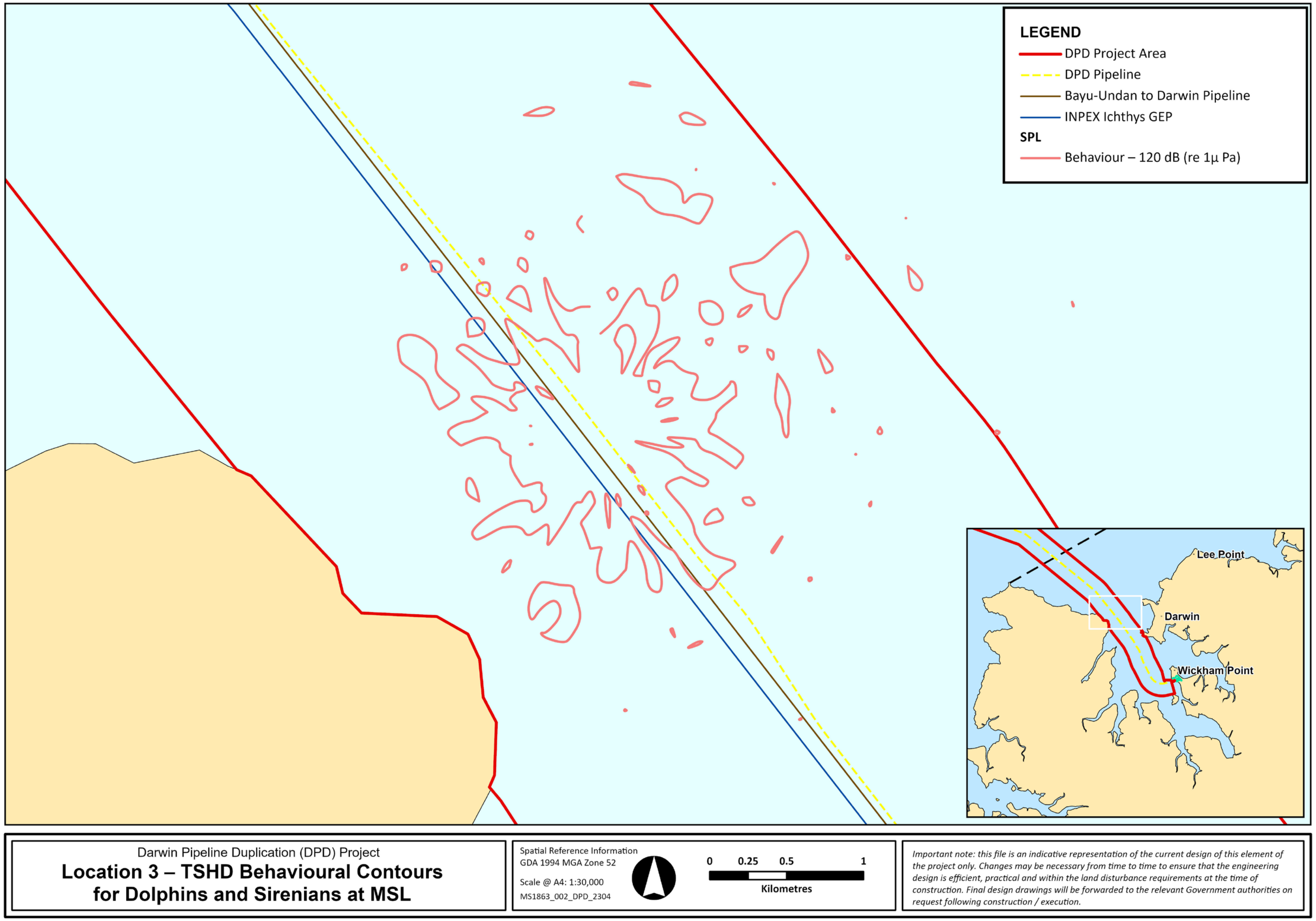


Figure 6-4: Modelling location 3 – TSHD and CSD behavioural contours for dolphins and sirenians (MSL)

7 Impact assessment

This MMNMP has employed a systematic impact assessment process to inform the management of underwater noise during construction activities for the DPD Project. As described below, the approach is consistent with the NT EPA Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015).

7.1 Conceptual site model

A conceptual site model, as required by the NT EPA, is a written or illustrated representation of the nature, fate and transport of discharges, wastes or contaminants that allows assessment of potential and/or actual exposure of the environment to contaminants (NT EPA, 2015). The conceptual site model for this MMNMP is embedded within the impact assessment, which, details receptors and impact pathways for noise emissions from construction activities, see **Section 7.3.**

7.2 Impact assessment methods

The MMNMP environmental impact assessment followed the Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02) with modified consequence descriptors to reflect the NT EPA key environmental factors and consequence descriptors (**Table 7-1**). Identification of management actions followed the Santos' Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02). An environmental aspect, for the purpose of this environmental management plan, is defined as characteristics of the construction activities that could potentially affect the environment.

7.2.1 Identification of environmental hazard

Environmental hazards related to noise for this MMNMP were identified using Santos' DPD Project NT EPA Referral (Santos, 2021), DPD Project Basis of Approval (BAS-210 0005; Santos, 2022) and discussion by DPD Project team and environmental specialists. Key DPD Project construction activities and associated hazards and results from the noise modelling study Talis Consultants (2023) noise modelling study were presented during ENVID workshops to inform the impact assessment process. Note the Connell *et al.* (2023) noise modelling study was completed after the ENVID workshops.

7.2.2 Standard controls

The standard controls identified in **Section 8** were drawn from:

+ Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021)
+ Santos' environmental plans and procedures for similar activities
+ Regulator approved management plans developed by other proponents.

Additional controls were provided by ENVID workshop attendees based on their relevant experience.

7.2.3 Impact assessment

All hazards identified were assigned a consequence level following the six levels and criteria outlined in Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02). The consequence criteria were then modified to incorporate the NT EPA Key Environmental Factors. The modified consequence descriptors shown in **Table 7-1.**

Santos

Table 7-1: Consequence descriptors

Consequence Level		**I**	**II**	**III**	**IV**	**V**	**VI**
Acceptability		**Acceptable**	**Acceptable**	**Unacceptable**	**Unacceptable**	**Unacceptable**	**Unacceptable**
Consequence Level Description		**Negligible** No impact of negligible impact	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors Localised effect	**Moderate** Significant impact to local population industry or ecosystem factors	**Major** Major long-term effect on local population industry or ecosystem factors	**Severe** Complete loss of local population industry or ecosystem factors AND/OR extensive regional impacts with slow recovery	**Critical** Irreversible impacts to regional population industry or ecosystem factors
Environmental Receptors	**Marine Ecosystems** Fauna, habitat, conservation significant areas and ecological function, processes and integrity	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of habitat critical / disruption to the breeding cycle/ vales of a protected area. No introduction of disease and no reduction in habitat area/function.	Detectable but insignificant decrease in local population size and threat to local population viability. Insignificant disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area. Detectable but insignificant loss of area/function of habitat with rapid recovery within 2 years.	Moderate. Significant decrease in local population size but no threat to overall population viability. Significant behavioural disruption or disruption to the breeding cycle of local population / Significant reduction in area of occupancy of species / loss of habitat critical to survival of a species. Modify, destroy, remove or decrease availability of quality habitat to the extent that a long-term decline in local population or function of habitat is likely with recovery over medium term (2-10 years) Introduction of disease likely to cause significant population decline	Long term decrease in local population size and threat to local population viability. Major disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area Fragmentation of existing population / Loss or change of habitat to the extent that a long-term decline in local population and function of habitat is likely with slow recovery over decades Introduction of disease likely to cause long term population decline	Complete loss of local population, habitat critical to survival of local population or protected area/conservation significant area Widespread (regional) decline in population size or habitat critical to regional population Extensive destruction of local habitat with no recovery or long term (decades) or widespread loss of area or function of primary producers on a regional scale	Complete loss of regional population Complete loss of habitat critical to survival of regional population
	Marine Environmental Quality Water quality, sediment quality, ecosystem health and parameters that support fishing, aquaculture, recreation, aesthetics and cultural/spiritual values	Negligible. No or negligible reduction in physical environment nor decrease in ecosystem function/health. No or negligible loss of value to socio-economic activities	Detectable but localised, short term and insignificant impact to physical environment or ecosystem function/health or value to socio-economic activities. Rapid recovery evident within ~ 2 years.	Significant wide-scale medium term impact to physical environment, decrease in ecosystem function/health or value to socio-economic activities. Recovery over medium term (2-10 years).	Wide-scale, long term impact to physical environment, long term decrease in ecosystem function/health or value to socio-economic activities. Slow recovery over decades.	Extensive impact to/destruction of physical environment with no recovery or shutdown of socio-economic activities Long term (decades) and widespread loss of ecosystem function/health on a regional scale that damages value to socio-economic activities.	Complete destruction of regional physical environment / habitat with no recovery Complete loss of area or function of primary producers on a regional scale

Consequence Level		I	II	III	IV	V	VI
	Coastal Processes Geophysical processes, primary productivity/ nutrient cycling, conservation significant areas/coastal landforms and cultural, aesthetic or recreation values	Short term changes to local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale	Detectable but insignificant loss or change to local geophysical/hydrological processes, area or function of primary producers/nutrient cycling or conservation significant areas with rapid recovery within 2 years.	Moderate. Significant modification, destruction, removal or change of local geophysical/hydrological processes, wide-scale loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with recovery over medium term (2-10 years).	Long term loss or change of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with slow recovery over decades	Extensive destruction of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with no recovery or long term (decades)	Complete loss or change of geophysical/hydrological processes. Complete loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale.
	Community and Economy Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping	No or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry. Significant medium-term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry. Permanent loss of key natural features or populations supporting the local industry.	Permanent shutdown of local or regional industry Permanent loss of key natural features or populations supporting the local or regional industry
	Culture and heritage Includes: Indigenous heritage and maritime heritage (i.e. shipwrecks)	No or negligible impact on the area's cultural or heritage values. No or negligible alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Detectable but insignificant impact on one or more of the area's cultural or heritage values. Detectable but insignificant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Significant impact on one or more of the area's cultural or heritage values. Significant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Major long-term effect on one or more of the area's cultural or heritage values. Major alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Complete loss of one or more of the area's cultural or heritage values.	Permanent loss of one or more of the area's cultural or heritage values with no recovery.

The consequence is defined as the resulting impact from an event occurring. Consequence level for this assessment was based on the credible worst-case scenario and assumed no management actions were in place. Categories of environmental consequence and severity level are outlined in **Table 7-2**. These consequence levels are not presented in this MMNMP but are contained in the ENVID documentation. Table 7-3 presents the residual consequence ranking which is the outcome after standard and additional (as low as reasonably practicable; ALARP) management actions are applied.

Consistent with the Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02), given the generation of noise is a planned event a residual risk ranking was not assigned. A comprehensive impact assessment for the planned event, and subsequent management actions proposed by Santos to reduce the impacts to ALARP are detailed in the following subsections. Within the ENVID developed by Santos some environmental aspects had multiple residual consequence ratings, in these cases the residual consequence of greater severity was chosen for this summary.

Table 7-2: Summary environmental consequence descriptors

Consequence Level	Consequence Level Description
I	**Negligible** – No impact or negligible impact
II	**Minor** – Detectable but insignificant change to local population, industry or ecosystem factors
III	**Moderate** – Significant impact to local population, industry or ecosystem factors
IV	**Major** – Major long-term effect on local population, industry or ecosystem factors
V	**Severe** – Complete loss of local population, industry or ecosystem factors AND/OR extensive regional impacts with slow recovery
VI	**Critical** – Irreversible impact to regional population, industry or ecosystem factors

7.3 Impact assessment summary

The outcomes of the planned event impact assessment are presented in **Table 7-3**, and where relevant includes reference to the relevant management strategy within this MMNMP proposed to manage individual environmental aspects.

Table 7-3: Summary of underwater noise impact assessment outcome

Aspect	Activity	Description of hazard	Spatial scale	Temporal scale	Potential impacts	Sensitive receptors	Residual consequence (planned impact)	Management strategy
Planned impacts								
Noise Emissions	Pre-lay works including: + Cutter suction dredge (CSD) + Trailer suction hopper dredge (TSHD) + Backhoe dredge (BHD) for excavating with potential used of hydraulic tools (Xcentric Ripper, hydraulic hammer) for fracturing rock + Mass flow excavation (MFE) + Construction of two temporary causeways either side of the trench at the shore crossing Pipelay by nearshore pipelay barge in shallower waters including Darwin Harbour. Pipelay by dynamic positioning (DP) vessel in deeper waters outside of Darwin Harbour. Operation of onshore plant and equipment within Project Area at DLNG facility Support operations including: + General vessel operations during all DPD Project activities + Vessel and subsea positioning equipment	Vessel noise is considered non-impulsive (continuous) and broadband and includes vessel thrusters, engines and propellers, as well as noise emitted onboard which is converted to underwater noise through the hull. The main source of vessel noise will be from propellers or dynamic positioning (DP) thrusters (deeper water pipelay only). Project vessels (excluding trenching vessels) may emit noise up to ~180 dB re 1 µPa at 1 m. Trenching will be completed using different trenching vessels, including a BHD, a TSHD and a CSD. Noise includes operation of vessel engines for propulsion (as applicable), onboard equipment, pumps and interaction of trenching equipment with the seabed. The following source levels are considered representative of trenching vessel non-impulsive noise: + TSHD: 184 dB re 1µPa @1m + CSD: 182 dB re 1µPa @1m + BHD: 175 dB re 1µPa @1m BHD rock breaking tools will be either non-impulsive from Xcentric Ripper tool or impulsive from hydraulic hammer (contingency only). Representative source levels are:	For TSHD, CSD and BHD trenching and Xcentric Ripper tool use, permanent threshold shift (PTS) SEL24 hour ranges for dolphins, dugongs and turtles modelled at <50 m. Equivalent threshold range for hydraulic hammer modelled at 100- 160 m. For TSHD, CSD and BHD trenching and Xcentric Ripper tool use, temporary threshold shift (TTS) SEL24 hour ranges for dolphins, dugongs and turtles modelled at 40-350 m. Equivalent threshold range for hydraulic hammer modelled at 950- 2,500 m. The PTS and TTS ranges were shown to decrease with reduced hammering time (per 24 hours) for the hydraulic hammer. For behavioural response thresholds, ranges for marine mammals (dolphins and dugongs) varied from 100s of metres to 10s of kilometres for scenarios modelled at MSL. Spatial scales for other activities are as follows: + Localised: A support vessel using main engines and bow thrusters to maintain position will become inaudible above background noise within thousands of metres.	Vessel noise for the duration of the construction activity (12-15 months), with intermittent survey equipment and helicopter noise. Trenching vessel noise expected over indicative period of 2-3 months. Noise will be infrequent during operations given scale of planned vessel pipeline inspection surveys indicatively every 1-3 years.	Project activities including trenching, pipelay, additional vessel operations and will add to the existing underwater noise profile inside and outside Darwin Harbour during construction. The use of sound in the underwater environment is important for marine animals, particularly cetaceans, to navigate, communicate and forage effectively, along with reptiles, sharks/rays and other fish, for a range of functions such as social interaction, foraging and orientation. Underwater noise could result in: + Acoustic masking: – Disruption to underwater acoustic cues – Masking of vocalisations and signals from predators and prey + Behavioural response: – Modification of fauna behaviour (avoidance, attraction and disruption of normal behaviour) – Disturbance, leading to behavioural changes or displacement from areas – Indirectly by inducing behavioural and physiological changes in predator or prey species. + Physiological impacts: – Increased stress levels – Physical injury to fauna from exposure to excessive noise	+ **Marine ecosystem** (marine mammals particularly cetaceans, marine reptiles, sharks, rays, pelagic and demersal fish) + **Marine environmental quality** (impact to parameters that support fishing, aquaculture, recreation, aesthetics and cultural/ spiritual values) +	II - Minor	**Section 8**

Aspect	Activity	Description of hazard	Spatial scale	Temporal scale	Potential impacts	Sensitive receptors	Residual consequence (planned impact)	Management strategy
	e.g. MBES, SSS, LBL) / USBL) + Helicopter operations	+ Xcentric Ripper: 184.8 dB re 1 µPa2 s m^2 + Hydraulic hammer: 192 dB 1 µPa2s m^2	+ Localised: A conservative estimate is that survey equipment (MBES/SSS) will be inaudible within thousands of metres, depending on the activity characteristics. + Localised: Helicopter noise will be highly localised and most of the noise will not transfer into the water.		(barotrauma, hearing loss including TTS and PTS Onshore construction activities are not expected to have an impact as they will not occur in water.			

7.4 Assessment of potential for cumulative impacts

The underwater noise emission from Project vessels and activities will add to the ambient noise environment within the Project Area which includes Darwin harbour and major shipping routes. The frequency and noise levels of DPD Project vessels are expected to be similar to that from existing shipping traffic. This is discussed in **Section 6.3.4.**

In terms of potential cumulative noise impacts between the DPD Project and other proposed projects within Darwin Harbour this is detailed within the DPD Project SER (BAS-210 0020), including an assessment of potential for overlap in time and space between projects.

Given the high level of uncertainty on the degree of overlap between specific noise generating activities of other projects with the DPD Project and the inherent difficulties in modelling multiple dynamic sound sources, underwater noise modelling has not attempted to integrate other project noise sources. However, modelling conducted for the DPD Project has conservatively assessed impacts from the operation of two DPD Project trenching vessels (TSHD and CSD) at the same location at the same time and results from this have informed the impact assessment.

Santos has and will continue to engage all relevant proponents and authorities, to minimise the potential for cumulative impacts. The consultation strategy is further detailed in SER (BAS-210 0020).

8 Environmental management strategy

This section outlines the environmental management strategy (EMS) that will be implemented for management of noise impacts associated with the DPD Project construction works, therefore minimising and/or mitigating the risks to sensitive receptors and protected marine megafauna.

The EMS outlines the commitments and objectives that are relevant and states specific measurable targets to achieve proposed objectives. Subsequently, these targets potentially trigger the use of certain management actions. Performance indicators and monitoring activities are used to quantify success in meeting requirements and identify the need for corrective actions. This ensures the continuous improvement of the effectiveness of the DPD Project's EMS. The EMS defines the reporting requirements, terms, and responsibilities.

The EMS is structured to align with the template presented in **Table 8-1**.

Table 8-1: Environmental management strategy template

Item	Content
Environmental Performance Objectives (EPO)	Environmental management goal(s) tailored to each aspect per NT EPA requirements.
Target	Aspect specific measurable performance necessary to successfully achieve objective. Part 1 of NT EPA required performance criteria.
Performance Indicator	Quantitative or qualitative measures representing the performance related to Target(s). Part 2 of NT EPA required performance criteria.
Management actions	Tasks to be undertaken to meet objective/s. For example, install turtle deflection chains on TSHD drag head, comply with Darwin Port vessel speed restrictions etc.

8.1 NT EPA hierarchy

In the development of the EMS outlined within this MMNMP Santos applied the Environmental Decision-Making Hierarchy outlined within the EP Act. This hierarchy being:

+ To ensure that actions are designed to avoid adverse impacts on the environment
+ To identify management options to mitigate adverse impacts on the environment to the greatest extent practicable
+ And if appropriate, provide for environmental offsets in accordance with the EP Act for residual adverse impacts on the environment that cannot be avoided or mitigated[1]

[1] No offsets were deemed necessary for this project.

8.2 Environmental performance objectives and performance criteria

To ensure environmental impacts will be of an acceptable level, an environmental performance objective (EPO) has been defined for noise impacts.

The EPO relevant to noise emissions, including performance criteria, are described in **Table 8-2**.

Table 8-2: Noise emissions EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Avoid hearing injury impacts to protected marine species from underwater noise generated by DPD Project trenching and spoil disposal activities	Zero incidents of injury or mortality to EPBC Act listed marine fauna from noise generated during DPD construction activities	+ Incident reports of injured or dead EPBC Act listed fauna + MFO records of EPBC Act listed fauna within vessel observation/exclusion zones
	Zero incidents of trenching or rock breaking while EPBC Act listed marine fauna observed in exclusion zone	+ MFO records of EPBC Act listed fauna within vessel exclusion zone

This EPO aligns with the following NT EPA Factor objectives:

- Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
- Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this planned impact are shown in **Section 8.4.6**.

8.3 Adaptive management mechanism

The proposed adaptive management actions are detailed in **Section 8.4.2**. Further adaptive management actions may be added based on approval conditions following assessment by NT EPA and DCCEEW.

Additionally, adaptive management can be triggered through Santos' incident response and assurance processes, with corrective actions and management adapted as required to address any incidents and non-conformances identified (detailed in Section 8.3 of the Offshore CEMP (BAS-210 0024)).

8.4 Noise impact management actions

Management actions will be implemented to meet the environmental objectives outlined above.

8.4.1 Vessel and Helicopter Approach Distances

Vessel and helicopter contractor procedures will comply with Part 8 of the Environment Protection and Biodiversity Conservation (EPBC) Regulations 2000, which includes controls for minimising interaction with marine megafauna. Whilst these measures are usually aimed at reducing the risk of collision, maintaining the correct approach distances will also help reduce the risk of disturbance and injury from noise emissions from vessels and helicopters.

The approach distances outlined in the EPBC Regulations include the ‘no approach zone’ which excludes vessels within 100 m to the side of and 300 m in front and to the rear of an adult whale and within 50 m to the side of and 150 m in front and to the rear of an adult dolphin. The EPBC Regulations also include a ‘caution zone’ in which vessel speed must be no more than six knots (~11 km/hr), no more than three vessels are allowed, and vessels cannot enter if animals are injured, stranded, entangled, distressed or where a calf is present. The ‘caution zone’ is between 300 and 100 m for an adult whale and 150 and 50 m for an adult dolphin.

8.4.2 Marine Megafauna Observation and Adaptive Management Protocol

Observation and exclusion zones can reduce the risk of physical and behavioural impacts to marine megafauna as construction activities can be paused until marine megafauna have moved outside of the exclusion zone and are no longer at risk of injury or disturbance.

8.4.2.1 Routine construction operations

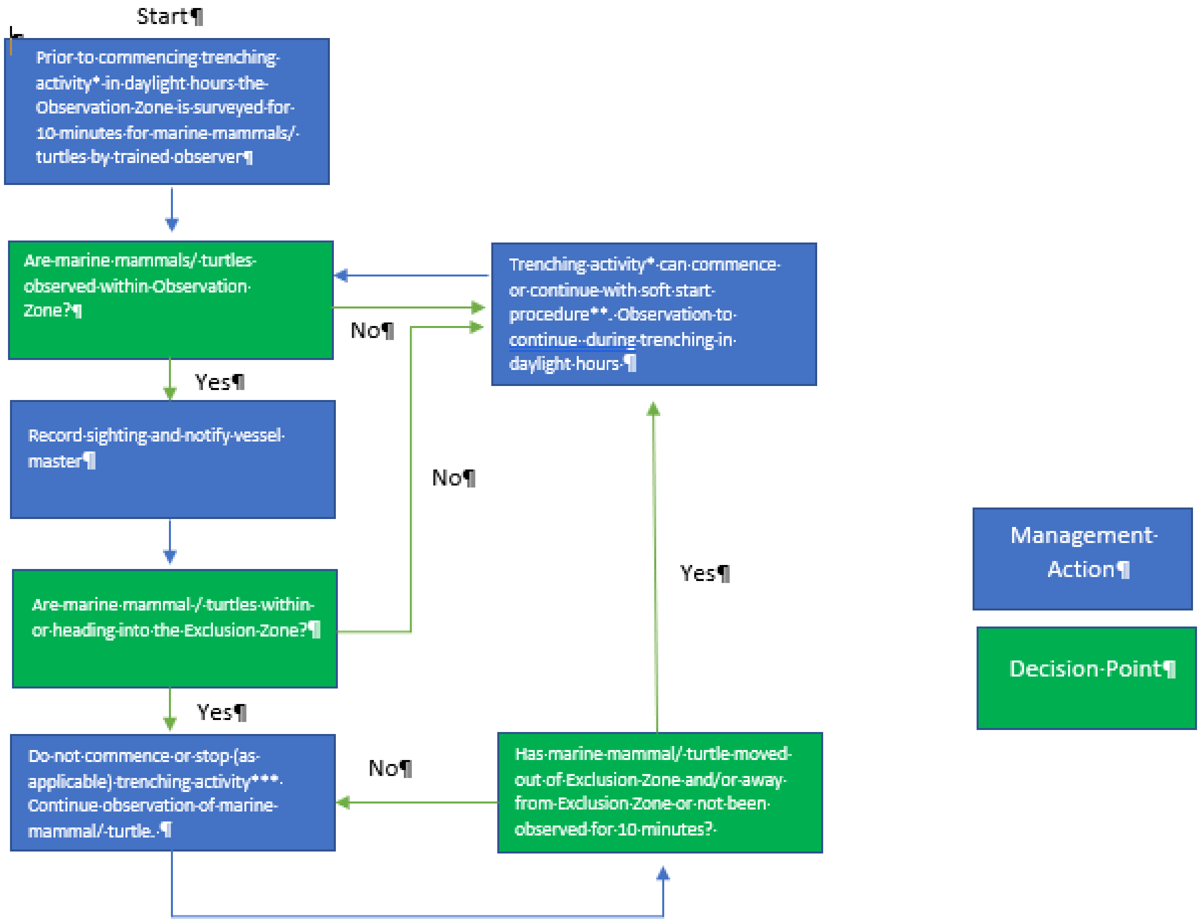
An Observation Zone of 150 m and an Exclusion Zone of 50 m has been proposed around vessels/plant engaged in routine construction activities including the use of an Xcentric Ripper rock breaking tool on the BHD where required. These zones align with Dolphin Caution Zones outlined in Part 8 of the EPBC Regulations. The 150 m observation zone also provides an appropriate range for observing marine mammals and turtles that could potentially receive temporary hearing injury over a 24-hour period. While the site-specific modelling results (**Section 6.3.3**) indicate TTS ranges could extend to 350 m for dolphins at MSL (based on concurrent operation of a TSHD and CSD in the same area), these are considered very conservative values given the known mobility and transient nature of dolphins within Darwin Harbour (Griffiths *et al.*, 2019) and the very low likelihood of dolphins remaining within this range for 24 hours. Therefore, a 150 m zone was considered sufficient on this basis and a more practical range for the observation of marine fauna by trained observers. For turtles, the proposed 150 m observation zone aligns with the TTS ranges at MSL.

The 50 m Exclusion Zone aligns with PTS ranges for marine mammals and turtles (and with dolphin No Approach Zones under Part 8 of the EPBC Regulations), although it is very unlikely these species would remain in close proximity to a trenching vessel over a full 24-hour period. Rather, the Exclusion Zone is considered to provide value in protecting marine fauna, in particular turtles, from direct interaction and injury from trenching equipment (refer to the Offshore CEMP and TSDMMP (BAS-210 0024; BAS-210 0023) for further information regarding this risk).

During daylight hours, prior to the commencement of any noise-intensive activity the Observation Zone will be monitored by a crew member trained in marine fauna observation. The Observation Zone will be monitored for a minimum of 10 minutes prior to a noise-intensive activity to ensure no key marine megafauna species (e.g., dolphins, dugongs or turtles) are present. If any such species are present within the zone, they will be recorded. If the marine megafauna is observed within or heading into the Exclusion Zone, noise-intensive activities will not commence until the animal is observed to leave and move away from the exclusion zone, or until 10 minutes of observations have passed since the last sighting and no further key marine megafauna have been sighted. Should noise-intensive activity be already underway when a key marine megafauna is observed within or heading into the Exclusion Zone, the activity will be stopped (as applicable) and observation of the marine megafauna will continue until animal is observed to leave or move away from the Exclusion Zone, or until 10 minutes of observations have passed since the last sighting.

All marine fauna interactions and observations during daylight hours will be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW.

The proposed marine megafauna observation and adaptive management protocol for routine operations (including use of Xcentric Ripper tool) is summarised in **Figure 8-1**.



KEY

*Trenching activity means: BHD excavating or rock breaking, activation of CSD cutter head, activation of TSHD suction pump

**Where practicable dependent on machine capability

***Not commencing or stopping trenching means the following:

- For BHD trenching—not commencing or stopping excavating or rock breaking activities
- For CSD trenching—not starting or stopping the cutter head
- For TSHD trenching—not starting or stopping the TSH suction pump

Observation Zone = 150m zone around vessel

Figure 8-1: Marine megafauna observation and adaptive management protocol for routine construction operations including the use of Xcentric Ripper tool.

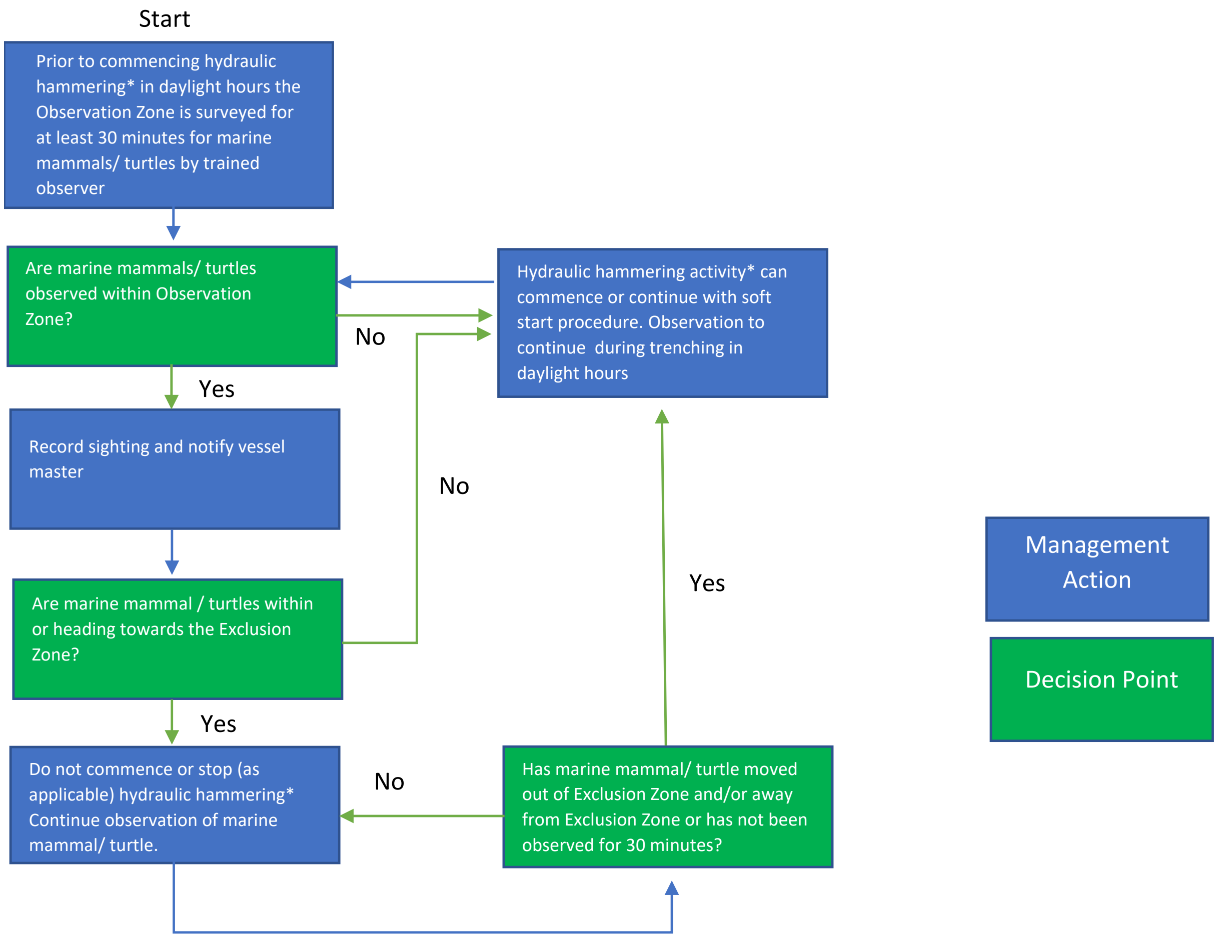
8.4.2.2 Hydraulic hammer operations

The underwater noise modelling for the hydraulic hammer has shown that hearing injury (PTS or TTS) could occur to marine turtles, dolphins and dugongs at ranges significantly greater (up to ~10x) those modelled for dredging vessel noise as well as over 10x the range determined for the Xcentric Ripper tool. The modelling indicates that hydraulic hammering could result in PTS for dolphins and dugongs if they remained (for 24 hours) within 130 and 160 m, respectively, of the rock breaking activity and result in TTS if they remained (for 24 hours) within 1.83 km and 2.5 km, respectively, of the activity. For marine turtles, the equivalent ranges were modelled as 100 m for PTS and 950 m for TTS. Given behavioural effect ranges for marine fauna applicable to hydraulic hammering are within the TTS ranges, natural avoidance of the noise source is not considered a mitigation for preventing TTS.

On the basis of the modelling results, the management actions for routine construction for preventing hearing injury to marine mammals or marine turtles are not considered adequate for rock breaking using a hydraulic hammer. They are, however, considered applicable and effective for preventing hearing injury to marine fauna during rock breaking using an Xcentric Ripper.

In the event that a hydraulic hammer is required for rock breaking (expected to occur only as a contingency), the following additional management actions will apply.

- Hydraulic hammering for no greater than 8 hrs over a 24 hr period.
- No hydraulic hammering at night
- A separate vessel with MFO onboard will be required to patrol the Observation Zone (Figure 8-2) prior to and during hydraulic hammering
- Increased Observation and Exclusion Zones for hydraulic hammering based on noise modelling results will be applied through a revised marine megafauna observation and adaptive management protocol for contingency hydraulic hammering as presented in **Figure 8-2**.



KEY

*Hydraulic hammering means use of an impulsive hydraulic hammer for rock breaking. It does not apply to the use of an Xcentric ripper.

Observation and Exclusion Zones for hydraulic hammering applied as follows:

- If up to 8 hours of rock breaking is required an Observation Zone of 2.5km (marine mammals) and 1km (turtle) will apply and an Exclusion Zone of 150m for marine mammals and turtles will apply
- If up to 6 hours of rock breaking is required an Observation Zone of 2 km (marine mammals) and 750 m (turtle) will apply and an Exclusion Zone of 100m for marine mammals and turtles will apply
- If up to 4 hours of rock breaking is required an Observation Zone of 1.5 km (marine mammals) and 750 m (turtle) will apply and an Exclusion Zone of 100 m for marine mammals and turtles will apply
- If up to 2 hours of rock breaking is required an Observation Zone of 1km (marine mammals) and 500 m (turtle) will apply and an Exclusion Zone of 50 m for marine mammals and turtles will apply

Figure 8-2: Marine megafauna observation and adaptive management protocol for contingency hydraulic hammering.

8.4.3 Marine fauna observer

Crew trained in marine fauna observation will ensure marine megafauna can be reliably identified to different species during observation periods. This will improve the ability to spot and identify marine megafauna at risk from injury or disturbance due to noise emissions from construction activities. At least one marine fauna observer (MFO) will be on duty per pipelay, trenching and rock installation vessel/barge during daylight hours. The MFO will sight and record marine megafauna interactions prior to, and during, trenching and rock breaking operations.

MFOs will also reduce the risk of direct interaction and injury from vessels and trenching activities (refer to the Offshore CEMP and TSDMMP (BAS-210 0024; BAS-210 0023) for further information regarding this risk).

Given the increased size of Observation Zone required for rock breaking with a hydraulic hammer, a separate vessel with MFO onboard will be required to patrol the Observation Zone prior to and during hydraulic hammering.

8.4.4 Soft start procedures

Where practicable, soft start procedures will be implemented which may reduce the impact to marine megafauna by allowing them to move away from the area of trenching or rock breaking activity prior to noise generation reaching maximum levels. Soft start procedures generally involve a slow ramp up of the activity so that energy and noise levels increase gradually before reaching maximum operating levels. This gradual ramp up will provide greater opportunities for animals to avoid exposure to the maximum noise levels by moving away from the activity during this gradual ramp up. The following controls will be applied:

+ Soft start (ramp-up) for rock breaking (Xcentric Ripper or hydraulic hammer) by BHD, where practicable
+ Soft start (ramp-up) for trenching equipment, where practicable, will apply to the CSD and TSHD

Soft start procedures will also reduce the risk of direct interaction and injury from vessels and trenching activities (refer to the Barossa CEMP and TSDMMP (BAS-210 0024; BAS-210 0023) for further information regarding this risk).

8.4.5 Reporting injured marine wildlife

Any injured marine megafauna must be reported to the NT EPA/DEPWS within 24 hours and reported to DCCEEW for EPBC Act listed species. If a marine mammal vessel strike incident has occurred it will be recorded in the National Marine Mammal Ship Strike database (AMMC, 2022).

8.4.6 Summary of management actions

A summary of management actions adopted for noise generating construction activities to reduce the risk of injury and disturbance to marine megafauna in the DPD Project Area is outlined in **Table 8-3** for routine construction operations, including the use of an Xcentric Ripper tool for rock breaking. As a contingency, a hydraulic hammer may be used if rock breaking cannot be completed successfully using an Xcentric Ripper. Additional contingency management actions for the use of a hydraulic hammer are outlined in **Table 8-4**. Environmental Performance Standards for these management actions will be developed in conjunction with Project contractors prior to finalisation of this MMNMP.

Table 8-3: Summary of management actions for noise emissions during routine construction including the use of an Xcentric Ripper tool

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA46	Observation and exclusion zones for marine fauna developed based on noise modelling results and standard protocols
Mitigation	
DPD-MA49	Vessel inductions for all crew to address marine fauna risks and the required management controls
DPD-MA50	Vessel and helicopter to complete Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA51	Personnel trained in MFO to be present on pipelay, dredge and rock installation vessels/barges during daylight hours, including one crew member with MFO training on the bridge at all times
DPD-MA52	All marine fauna interactions and observations to be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW as required
DPD-MA55	Maintenance of vessel, vehicle and equipment combustions engines and vessel incinerators as per planned maintenance system
Additional (ALARP) management actions	
Avoidance	
DPD-MA56	Observation and shut-down zones for marine fauna have been developed based on noise modelling results for trenching and standard protocols and include: + Observation (150 m) and exclusion (50 m) zones for marine mammals and turtles. + Observation zone monitored for 10 minutes prior to commencing trenching during daylight only. A Marine Megafauna Observation and Adaptive Management Protocol for routine construction operations, including the use of Xcentric Ripper tool, is to be followed as per **Figure 8-1**
Mitigation	

MA reference	Management actions
DPD MA62	+ Soft start (ramp-up) of hydraulic tools (rock breaking) by BHD, where practicable + Soft start (ramp-up) of trenching equipment, where practicable, will apply to the CSD and TSHD
Additional (ALARP) management actions not adopted	
1	Schedule trenching activities outside of peak flatback turtle nesting period (May to October) or outside of peak Darwin Harbour dolphin calving period (October to April). Reason for rejection: + It would not be possible to avoid both peak periods. + The potential benefit of avoiding locations of higher marine megafauna sensitivity at certain times of the year, such as nesting periods for turtles and dolphin calving periods, is considered disproportionately low compared to the implications to Project scheduling and costs – While there are known flatback turtle nesting sites (Cox Peninsula and Casuarina Beach), and a known period of increased nesting activity (May to October), the densities of nesting turtles in these areas are very low and not significant on a regional scale (Chatto and Baker, 2008). Furthermore, these sites are on a scale of 1000s of meters away from the pipeline route and trenching areas (as they are from existing vessel traffic using navigation channels) and the relative risk of behavioural effects to turtles at this scale from vessel noise is considered low (Popper et al., 2014). For dolphins, there is evidence that there is a peak in calving within Darwin Harbour between October and April (Palmer, 2010). Important areas have not been defined however and given the high mobility of dolphin species within Darwin Harbour and the use of adjoining coastal areas (Griffiths et al., 2019) it is unlikely that behavioural disturbance around DPD Project activities, relative to the total area of Darwin Harbour and surrounding coastal waters, would have a significant impact on calving behaviour.

MA reference	Management actions
2	The observation period for marine megafauna prior to commencing dredging and pile driving is 20 minutes and the MFO is solely dedicated to the task of sighting and recording marine megafauna interactions prior to, and during, dredging and pile driving operations. Reason for rejection: + A 20-minute observation period was considered excessive for the size of the Observation Zone (150 m) and a 10-minute observation period was considered sufficient to monitor this zone for marine fauna. An additional 10 minutes would prolong dredging operations without any appreciable benefit. + A MFO for the pre-start up observation period was considered warranted however a MFO solely to the task of sighting and recording marine megafauna for the entirety of dredging operations was not considered warranted given that the dredging vessel to have multiple crew with marine fauna observation training onboard during daylight hours and the vessel bridge to be constantly manned with at least one crew with MFO training on the bridge at all times.
3	No use of DP vessels. Reason for rejection: + Not using DP vessels will cause additional seabed and benthic habitat impacts through the need to use anchoring to hold position during pipelay. The use of DP also decreases pipelay duration and reduces impact to other users through shorter timeframe.
4	Cease noise generating activities (e.g. DP) when near marine fauna. Reason for rejection: + Ceasing DP activities when near sensitive fauna may reduce the potential for impacts, however, the potential for impacts beyond behavioural disturbance are very low. Engine/DP thruster noise cannot reliably be ceased due to the safety critical role of vessel propulsion. It is also not practical to cease pipelay or other critical construction activities in a short timeframe as safely abandoning such operations can often take a number of hours (namely laying down the pipeline or disconnecting from a structure), during which time the impacted fauna will have left the area. Therefore, this control is not deemed feasible.
5	Soft start/power-up procedures for use of sonar equipment and use of fauna observation and shutdown zones. Reason for rejection: + The systems being used are at a low power or are an intermittent type such that the reduced cumulative exposure would reduce TTS or PTS impacts for marine fauna and behavioural impacts were not considered credible

MA reference	Management actions
6	No use of helicopters. Reason for rejection: + Use of helicopters required (e.g. vessel/crew transfers) and restriction will result in an overall longer duration construction activity and therefore noise impacts
7	Avoidance of night work for routine construction and Xcentric Hammer use. Reason for rejection: + Avoidance will result in an overall longer duration construction activity and therefore noise impacts and also increase the safety risk profile. The cost of implementing this far exceeds the benefit gained

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Table 8-4: Summary of additional environmental management actions for contingency rock breaking using hydraulic hammer

MA reference	Management actions
Contingency management actions	
1	Increased Observation and Exclusion Zones for hydraulic hammering based on noise modelling results will be applied as follows: + If up to 8 hours of rock breaking is required, an increased Observation Zone of 2.5km (marine mammals) and 1km (turtle) will apply and an increased Exclusion Zone of 150m for marine mammals and turtles will apply + If up to 6 hours of rock breaking is required, an increased Observation Zone of 2 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100m for marine mammals and turtles will apply + If up to 4 hours of rock breaking is required, an increased Observation Zone of 1.5 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100 m for marine mammals and turtles will apply + If up to 2 hours of rock breaking is required, an increased Observation Zone of 1 km (marine mammals) and 500 m (turtle) will apply and an increased Exclusion Zone of 50 m for marine mammals and turtles will apply
2	Contingency hydraulic hammering protocols for managing noise impacts will be followed as per **Figure 8-2**
3	Hydraulic hammering for no greater than 8 hrs over a 24 hr period.
4	No hydraulic hammering at night
5	A separate vessel with MFO onboard will be required to patrol the Observation Zone prior to and during hydraulic hammering

8.4.7 Demonstration of ALARP

Use of vessels and subsea equipment will be required to complete construction activities, therefore underwater noise emissions are unavoidable if the planned activity is to proceed. Trenching and rock breaking activities will follow industry standard measures to prevent physiological impact to marine megafauna from noise, including implementation of Observation and Exclusion Zones and associated adaptive management measures, use of marine fauna observers to monitor zones and use of soft-starts where practicable. These zones have been informed by underwater noise modelling and appropriate thresholds to ensure the scale of these zones are sufficient to meet environmental objectives. In addition to the implementation of monitored zones, marine megafauna are expected to display avoidance behaviour of sound source at close ranges, thereby reducing the potential for physiological impact. For contingency hydraulic hammering, while not expected to be required, the zones have been increased significantly and additional measures put in place to ensure physiological impacts do not occur to marine megafauna.

While there is the potential for behavioural response on larger scales of 100s of metres to 1000s of metres from continuous noise from trenching activities, depending upon fauna type, the activities are not expected to produce emissions significantly louder than other marine vessels that frequent or transit through the vicinity of the Project Area (e.g. cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels). Given construction activity is temporary and trenching is expected to last for ~2-3 months, the addition of Project noise sources to the existing ambient noise environment is not expected to result in any significant additional behavioural effects within Darwin Harbour. The activity is unlikely to affect the health of and/or displace marine megafauna, as biologically important behaviours can continue given the widespread availability of suitable habitat within Darwin Harbour relative to the size of behavioural effect ranges.

Santos has considered the actions prescribed in various recovery plans and conservation advice, such as the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017), when developing the controls relevant to potential construction activities to minimise noise impacts on marine fauna. Management controls are in place to reduce operating noise, including vessel operational protocols, and to adhere to the fauna interaction management stated in EPBC Regulations (Part 8). As such, noise emitted during the activities is not expected to significantly impact on marine fauna within the Project Area.

The potential benefit of avoiding locations of higher marine megafauna sensitivity at certain times of the year, such as nesting periods for turtles and dolphin calving periods, is considered disproportionately low compared to the implications to Project scheduling and costs. There are also mutually exclusive sensitivity periods for dolphins and turtles. While there are known flatback turtle nesting sites (Cox Peninsula and Casuarina Beach), and a known period of increased nesting activity (May to October), the densities of nesting turtles in these areas are very low and not significant on a regional scale (Chatto and Baker, 2008). Furthermore, these sites are on a scale of 1000s of meters away from the pipeline route and trenching areas (as they are from existing vessel traffic using navigation channels) and the relative risk of behavioural effects to turtles at this scale from vessel noise is considered low (Popper et al., 2014).

For dolphins, there is evidence that there is a peak in calving within Darwin Harbour between October and April (Palmer, 2010). Important areas have not been defined however and given the high mobility of dolphin species within Darwin Harbour and the use of adjoining coastal areas (Griffiths et al., 2019) it is unlikely that behavioural disturbance around DPD Project activities, relative to the total area of Darwin Harbour and surrounding coastal waters, would have a significant impact on calving behaviour.

Other additional management actions were considered but rejected due to lack of feasibility, the associated cost or because the effort was disproportionate to any benefit (**Table 8-3**). Therefore, the risks to marine fauna from noise associated with the DPD Project activities are considered to be ALARP.

The potential consequence of noise emissions on receptors is assessed as II - Minor following the implementation of standard and additional (ALARP) management actions and will not have a significant impact on any habitat identified as critical to the survival of marine megafauna. With the management actions in place, no significant impacts are expected. Therefore, the impacts of noise emissions to the receiving environment are ALARP and considered environmentally acceptable.

9 Environmental management implementation strategy

Section 8 of the Offshore CEMP (BAS-210 0024) outlines the processes and procedures that will be implemented more broadly to all aspects of the DPD Project to ensure the environmental requirements within this MMNMP will be met, including:

+ Specific systems, practices and procedures that ensure both environmental impacts and risks are reduced to ALARP and EPOs, performance criteria and management actions are being met;
+ A clear chain of command, outlining roles and responsibilities of personnel involved in the implementation, management and review of the MMNMP;
+ Measures to ensure that employees and/or contractors working in relation to this activity are aware of their responsibilities regarding the environment and have the appropriate skill and training;
+ Auditing, review and revision processes;
+ Incident recording and reporting in line with Santos and regulatory requirements;
+ Maintenance of quantitative records of discharges and emissions; and
+ Details of emergency response and oil spill arrangements.

This implementation strategy is consistent with the Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

Stakeholder engagement is assessed separately for the requirements of the activity. Ongoing stakeholder management strategies are discussed in **Section 10.**

10 Stakeholder engagement and communications

The stakeholder engagement approach used for the Project is in accordance with Santos's corporate approach to stakeholder engagement and industry leading standards and practice. The approach recognises and is aligned with the NT EPA's Guidance for Proponents – Stakeholder Engagement (NT EPA 2021a), the NT EPA's guidance for Preparing a Supplementary Environmental Report (NT EPA 2021b) and the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement (IAP2 2015).

Due to the iterative nature of the stakeholder process all relevant details have been contained in one document, the SER (BAS-210 0020), to contain updates to one location. The SER provides an outline of the objectives, process and key stakeholders consulted for the DPD Project. Additionally, the Stakeholder Engagement Plan (SEP) is attached to the SER. It details all consultation undertaken to date and information on future engagement activities.

In preparing the SER, and project management plans, Santos has considered and assessed each submission individually, and taken into consideration the issues raised when engaging with stakeholders to assess potential impacts and proposed management measures.

The SER provides a summary of the issues raised relevant to the Project and Santos' assessment and response to these issues. A full register, with all submissions and responses, is provided as an attachment to the SER.

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Appendix 1: Santos Environment, Health and Safety Policies

Environment, Health & Safety

Santos

Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Jodie Hatherly, General Counsel and VP Legal, Risk and Governance		
Approved by:	The Board	Version:	3

20 August 2019 Page 1 of 1

Santos

Appendix 8: Underwater Noise Modelling Report (Talis)

talis consultants

Darwin Underwater Noise Modelling Assessment

Santos Darwin Pipeline Duplication Project

rps

Prepared for Santos

25 January 2023

Project Number: TN21068-1

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Table of Contents

1 Introduction 1
1.1 Aim 1
1.2 Scope 1
1.3 Applicable Documents 1
2 Project Background and Noise Sources 2
2.1 Overview 2
2.2 Construction Overview 2
3 Underwater Noise 1
4 Marine Fauna 3
4.1 Species of Interest 3
4.2 Assessment Criteria 3
5 Methodology 5
5.1 Overview 5
5.2 Noise Sources 5
5.2.1 Sheet Piling Noise Source Level 5
5.2.2 Dredging Noise Source Level 8
5.2.3 BHD with Hydraulic Hammer 10
5.3 Noise Source Locations 12
5.4 Modelled Scenarios 12
5.5 Bathymetry 14
5.6 Seabed Types 14
5.7 Sound Speed Profile 15
5.8 Hearing Threshold Weighting Curves 15
5.9 Model Limitations 15
6 Noise Model Results and Discussion 17
6.1 Location 1 – BHD 17
6.1.1 Location 1 – BHD Digging 17
6.1.2 Location 1 – BHD with Hydraulic Hammer 17
6.2 Location 2 – TSHD 19
6.3 Location 3 – TSHD 20
6.4 Location 3 – TSHD and CSD 21
6.5 Location 4 – Sheet Piling 22
6.6 Behavioural Ranges for LAT, MSL and HAT 23

7 Conclusion..25

Tables

Table 4-1 : Marine Fauna – Species of Interest for this study 3

Table 4-2 : Behavioural Disturbance, TTS and PTS Onset Thresholds (24-hour) 4

Table 5-1 : Vibratory hammer specifications (based on 416L ICE) and modelled source level (SEL)[6].... 6

Table 5-2 : Sheet piling noise source level 7

Table 5-3 : Dredging noise source.. 9

Table 5-4 : Hydraulic Hammer noise source 11

Table 5-5 : Noise Source model locations (MGA zone 52).. 12

Table 5-6 : Noise Model Scenarios.. 12

Table 5-7 : Seabed geo-acoustic properties used in the model[34] 14

Table 6-1 : Behavioural disturbance, TTS and PTS Onset threshold ranges for BHD Digging (non-impulsive) at Location 1 (MSL).. 17

Table 6-2 : Behavioural disturbance, TTS and PTS Onset threshold ranges for BHD with Hydraulic Hammer at Location 1 (MSL) 18

Table 6-3 : Behavioural disturbance, TTS and PTS Onset Threshold Ranges for TSHD at Location 2 (MSL) 19

Table 6-4 : Behavioural disturbance, TTS and PTS Onset Threshold Ranges for TSHD at Location 3 (MSL) 20

Table 6-5 : Behavioural disturbance, TTS and PTS Onset Threshold Ranges for TSHD and CSD at Location 3 (MSL).. 21

Table 6-6: Behavioural disturbance, TTS and PTS Onset Threshold Ranges for Sheet Piling at Location 4 22

Table 6-7: Behavioural disturbance Threshold Ranges for all locations for LAT, MSL and HAT........ 23

Figures

Figure 2-1 : Project Area and Trench and Noise Modelling Locations (source: RPS)............................ 1

Figure 3-1 : Ambient Sea Noise in Australian Waters [6].. 1

Figure 5-1 : Sheet piling using a vibratory hammer 6

Figure 5-2 : Vibratory Hammer Sheet Piling source characteristics. 7

Figure 5-3 : TSHD noise source characteristics (at frequencies higher than reported a 20 dB/decade decay rate is assumed).. 9

Figure 5-4 : CSD noise source characteristics 10

Figure 5-5 : BHD noise source characteristics (at frequencies higher than reported a 20 dB/decade decay rate is assumed).. 10

Figure 5-6 : Bathymetry (Mean Australian Sea Level) 14

Figure 7-1 :Location 1 – BHD (Digging) TTS and PTS Contours for Turtles (MSL) 32

Figure 7-2 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Turtles (MSL).................................... 33

Figure 7-3 : Location 1 – BHD (Digging) TTS and PTS Contours for Dolphins (MSL) 34

Figure 7-4 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Dolphins (MSL) 35
Figure 7-5 : Location 1 – BHD (Digging) TTS and PTS Contours for Sirenians (MSL) 36
Figure 7-6 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Sirenians (MSL) 37
Figure 7-7 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Fish (MSL) 38
Figure 7-8 :Location 1 - BHD (Hammer) TTS and PTS Contours for Turtles (MSL) 39
Figure 7-9 : Location 1 – BHD (Hammer) $SEL_{24\ hours}$ Contours for Turtles (MSL) 40
Figure 7-10 : Location 1 – BHD (Hammer) TTS and PTS Contours for Dolphins (MSL) 41
Figure 7-11 : Location 1 – BHD (Hammer) $SEL_{24\ hours}$ Contours for Dolphins (MSL) 42
Figure 7-12 : Location 1 – BHD (Hammer) TTS and PTS Contours for Sirenians (MSL) 43
Figure 7-13 : Location 1 – BHD (Hammer) $SEL_{24\ hours}$ Contours for Sirenians (MSL) 44
Figure 7-14 : Location 1 – BHD (Hammer) TTS and PTS Contours for Fish (MSL) 45
Figure 7-15 : Location 1 – BHD (Hammer) $SEL_{24\ hours}$ Contours for Fish (MSL) 46
Figure 7-16 :Location 2 – TSHD TTS and PTS Contours for Turtles (MSL) 47
Figure 7-17 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Turtles (MSL) 48
Figure 7-18 : Location 2 – TSHD TTS and PTS Contours for Dolphins (MSL) 49
Figure 7-19 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Dolphins (MSL) 50
Figure 7-20 : Location 2 – TSHD TTS and PTS Contours for Sirenians (MSL) 51
Figure 7-21 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Sirenians (MSL) 52
Figure 7-22 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Fish (MSL) 53
Figure 7-23 :Location 3 – TSHD TTS and PTS Contours for Turtles (MSL) 54
Figure 7-24 : Location 3 – TSHD $SEL_{24\ hours}$ Contours for Turtles (MSL) 55
Figure 7-25 : Location 3 – TSHD TTS and PTS Contours for Dolphins (MSL) 56
Figure 7-26 : Location 3 – TSHD $SEL_{24\ hours}$ Contours for Dolphins (MSL) 57
Figure 7-27 : Location 3 – TSHD TTS and PTS Contours for Sirenians (MSL) 58
Figure 7-28 : Location 3 – TSHD $SEL_{24\ hours}$ Contours for Sirenians (MSL) 59
Figure 7-29 : Location 3 – TSHD $SEL_{24\ hours}$ Contours for Fish (MSL) 60
Figure 7-30 :Location 3 – TSHD and CSD TTS and PTS Contours for Turtles (MSL) 61
Figure 7-31 : Location 3 – TSHD and CSD $SEL_{24\ hours}$ Contours for Turtles (MSL) 62
Figure 7-32 : Location 3 – TSHD and CSD TTS and PTS Contours for Dolphins (MSL) 63
Figure 7-33 : Location 3 – TSHD and CSD $SEL_{24\ hours}$ Contours for Dolphins (MSL) 64
Figure 7-34 : Location 3 – TSHD and CSD TTS and PTS Contours for Sirenians (MSL) 65
Figure 7-35 : Location 3 – TSHD and CSD $SEL_{24\ hours}$ Contours for Sirenians (MSL) 66
Figure 7-36 : Location 3 – TSHD and CSD $SEL_{24\ hours}$ Contours for Fish (MSL) 67
Figure 7-37 :Location 4 – Sheet Piling TTS and PTS Contours for Turtles (MSL) 68
Figure 7-38 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Turtles (MSL) 69
Figure 7-39 : Location 4 – Sheet Piling TTS and PTS Contours for Dolphins (MSL) 70

Figure 7-40 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Dolphins (MSL) 71
Figure 7-41 : Location 4 – Sheet Piling TTS and PTS Contours for Sirenians (MSL) 72
Figure 7-42 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Sirenians (MSL).................................. 73
Figure 7-47 : Location 4 – Sheet Piling TTS and PTS Contours for Fish (MSL).................................... 74
Figure 7-48 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Fish (MSL) 75
Figure 7-49 : Location 1 – BHD Behavioural Contours for Dolphins (MSL).. 77
Figure 7-50 : Location 1 – BHD SPL Contours for Dolphins (MSL).. 78
Figure 7-51 : Location 1 – BHD Behavioural Contours for Sirenians (MSL) 79
Figure 7-52 : Location 1 – BHD SPL Contours for Sirenians (MSL) 80
Figure 7-53 :Location 1 – BHD (Hammer) Behavioural Contours for Turtles (MSL) 81
Figure 7-54 : Location 1 – BHD (Hammer) SPL Contours for Turtles (MSL) 82
Figure 7-55 : Location 1 – BHD (Hammer) Behavioural Contours for Dolphins (MSL) 83
Figure 7-56 : Location 1 – BHD (Hammer) SPL Contours for Dolphins (MSL) 84
Figure 7-57 : Location 1 – BHD (Hammer) Behavioural Contours for Sirenians (MSL)........................ 85
Figure 7-58 : Location 1 – BHD (Hammer) SPL Contours for Sirenians (MSL).................................... 86
Figure 7-59 : Location 2 – TSHD Behavioural Contours for Dolphins (MSL) 87
Figure 7-60 : Location 2 – TSHD SPL Contours for Dolphins (MSL) 88
Figure 7-61 : Location 2 – TSHD Behavioural Contours for Sirenians (MSL)....................................... 89
Figure 7-62 : Location 2 – TSHD SPL Contours for Sirenians (MSL) 90
Figure 7-63 : Location 3 – TSHD Behavioural Contours for Dolphins (MSL) 91
Figure 7-64 : Location 3 – TSHD SPL Contours for Dolphins (MSL) 92
Figure 7-65 : Location 3 – TSHD Behavioural Contours for Sirenians (MSL)....................................... 93
Figure 7-66 : Location 3 – TSHD SPL Contours for Sirenians (MSL) 94
Figure 7-67 : Location 3 – TSHD and CSD Behavioural Contours for Dolphins (MSL) 95
Figure 7-68 : Location 3 – TSHD and CSD SPL Contours for Dolphins (MSL)...................................... 96
Figure 7-69 : Location 3 – TSHD and CSD Behavioural Contours for Sirenians (MSL) 97
Figure 7-70 : Location 3 – TSHD and CSD SPL Contours for Sirenians (MSL) 98
Figure 7-71 :Location 3 – Sheet Piling Behavioural Contours for Turtles (MSL) 99
Figure 7-72 : Location 3 – Sheet Piling SPL Contours for Turtles (MSL).. 100
Figure 7-73 : Location 3 – Sheet Piling Behavioural Contours for Dolphins (MSL) 101
Figure 7-74 : Location 3 – Sheet Piling SPL Contours for Dolphins (MSL).. 102
Figure 7-75 : Location 3 – Sheet Piling Behavioural Contours for Sirenians (MSL)........................... 103
Figure 7-76 : Location 3 – Sheet Piling SPL Contours for Sirenians (MSL) 104
Figure 7-77 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Dolphin 106
Figure 7-78 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Dugongs 106
Figure 7-79 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Turtles.. 107

Figure 7-80 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Fish 107

Figure 7-81 : MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Dolphin 108

Figure 7-82 : MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Dugongs 108

Figure 7-83 : MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Turtles 109

Figure 7-84 MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Fish 109

Figure 7-85 : MSL TSHD Location 2 maximum cumulative SEL with distance for Dolphin 110

Figure 7-86 : MSL TSHD Location 2 maximum cumulative SEL with distance for Dugongs 110

Figure 7-87 : MSL TSHD Location 2 maximum cumulative SEL with distance for Turtles 111

Figure 7-88 : MSL TSHD Location 2 maximum cumulative SEL with distance for Fish 111

Figure 7-89 : MSL TSHD Location 3 maximum cumulative SEL with distance for Dolphin 112

Figure 7-90 : MSL TSHD Location 3 maximum cumulative SEL with distance for Dugongs 112

Figure 7-91 : MSL TSHD Location 3 maximum cumulative SEL with distance for Turtles 113

Figure 7-92 : MSL TSHD Location 3 maximum cumulative SEL with distance for Fish 113

Figure 7-93 : MSL TSHD and CSD Location 3 maximum cumulative SEL with distance for Dolphin 114

Figure 7-94 : MSL TSHD and CSD Location 3 maximum cumulative SEL with distance for Dugongs 114

Figure 7-95 : MSL TSHD and CSD Location 3 cumulative SEL with distance for Turtles 115

Figure 7-96 : MSL TSHD and CSD Location 3 maximum cumulative SEL with distance for Fish 115

Figure 7-97 : Sheet Pile Driving maximum SEL with distance for Dolphins 116

Figure 7-98 : Sheet Pile Driving maximum SEL with distance for Dugongs 116

Figure 7-99 : Sheet Pile Driving maximum SEL with distance for Turtles 117

Figure 7-100 : Sheet Pile Driving maximum SEL with distance for Fish 117

Figure 7-101 : MSL BHD (Digging) Location 1 maximum behavioural distance for Dolphin 119

Figure 7-102 : MSL BHD (Digging) Location 1 maximum behavioural distance for Dugongs 119

Figure 7-103 : MSL BHD (Hydraulic Hammer) Location 1 maximum behavioural distance for Dolphin 120

Figure 7-104 : MSL BHD (Hydraulic Hammer) Location 1 maximum behavioural distance for Dugongs 120

Figure 7-105 : MSL BHD (Hydraulic Hammer) Location 1 maximum behavioural distance Turtles 121

Figure 7-106 : MSL TSHD Location 2 maximum behavioural distance for Dolphin 121

Figure 7-107 : MSL TSHD Location 2 maximum behavioural distance for Dugongs 122

Figure 7-108 : MSL TSHD Location 3 maximum behavioural distance for Dolphin 122

Figure 7-109 : MSL TSHD Location 3 maximum behavioural distance for Dugongs 123

Figure 7-110 : MSL TSHD and CSD Location 3 maximum behavioural distance for Dolphin 123

Figure 7-111 : MSL TSHD and CSD Location 3 maximum behavioural distance for Dugongs 124
Figure 7-112 : Sheet Pile Driving behavioural distance for Dolphins 124
Figure 7-113 : Sheet Pile Driving behavioural distance for Dugongs 125
Figure 7-114 : Sheet Pile Driving behavioural distance for Turtles 125

Appendices

APPENDIX A Reference Documents
APPENDIX B PTS and TTS Contours
APPENDIX C Behavioural Contours
APPENDIX D TTS and PTS Ranges
APPENDIX E Behavioural Ranges
APPENDIX F
Summary of Auditory Weighting and Exposure Function Parameters

1 Introduction

This report summarises the outcomes of an underwater noise modelling study undertaken for Santos' proposed Darwin Pipeline Duplication Project (the Project).

1.1 Aim

The aim of this study is to model predicted underwater noise levels from construction activities (i.e. sheet piling and dredging) associated with the Project.

1.2 Scope

The report includes a summary of the methods and results of underwater noise modelling undertaken for the Project. It focuses on sheet piling and dredging as these are the most significant sources of underwater noise identified for the Project.

1.3 Applicable Documents

The following project document was used in support of the underwater noise study:

- EEN20291.007 – Santos Barossa PTS Underwater Noise Technical Note_0_220404.

References used for the underwater noise study are given in Appendix A and abbreviations and acronyms are given in Appendix B.

2 Project Background and Noise Sources

2.1 Overview

The Darwin Pipeline Duplication (DPD) Project is associated with the Barossa gas field development in northern Australia. The DPD Project involves the construction of a new pipeline running parallel to and approximately 50-100m from the existing Bayu-Undan to Darwin pipeline through Darwin Harbour and to the Darwin LNG facility (beach valve location). Some sections of the pipeline route through Darwin Harbour will be trenched using dredging vessels prior to pipelay (as shown in Figure 2-1). The pipeline will come ashore through a trenched shore crossing at the DLNG facility which may require the installation of a cofferdam.

2.2 Construction Overview

The following construction activities will be undertaken for the Project:

- Sheet piling may occur in the supratidal zone at the shore crossing site.
- Trenching activities using a dredger will occur in some sections along the pipeline route through the harbour.
- Rock breaking (hydraulic hammering) in areas of surficial rock.
- Laying of pipe on the seabed and within trenched area.

The most significant underwater noise sources are as follows:

- **Sheet Piling:** Steel sheets may be piled to create a cofferdam wall on the mudflats using a vibratory hammer. Sheet piling is not planned to take place at high tide or at night-time. As a result, the cumulative impacts from sheet piling have been determined using the hammer energy source level multiplied by the frequency over a maximum duration of eight hours (thus by adding it cumulatively over 480 minutes) over a 24-hour period.
- **Dredge Vessel:** Trenching will be undertaken in trenching zones by utilising a Trailing Suction Hopper Dredge (TSHD), a Cutter Suction Dredge (CSD) and a Backhoe Dredge (BHD) depending on the area. The following indicative 24-hour cycle times have been used to inform modelling:
  - **TSHD**: Cycle times are dependent on distance from spoil ground. On average it is expected that 3 hours will be spent dredging, 2 hours will be spent in transit/spoil dump repeated over period of 24 hours.
  - **CSD**: The CSD will have two cycles over a 24-hour period, with each cycle consisting of 10 hours of cutting and 2 hours of downtime.
  - **BHD – Hydraulic Hammering and Digging:** Rock breaking (hydraulic hammering) using a BHD. Indicative 24-hour cycle consisting of two cycles of 4 hours hammering, 4 hours of downtime followed by 4 hours of digging have been used to inform modelling.

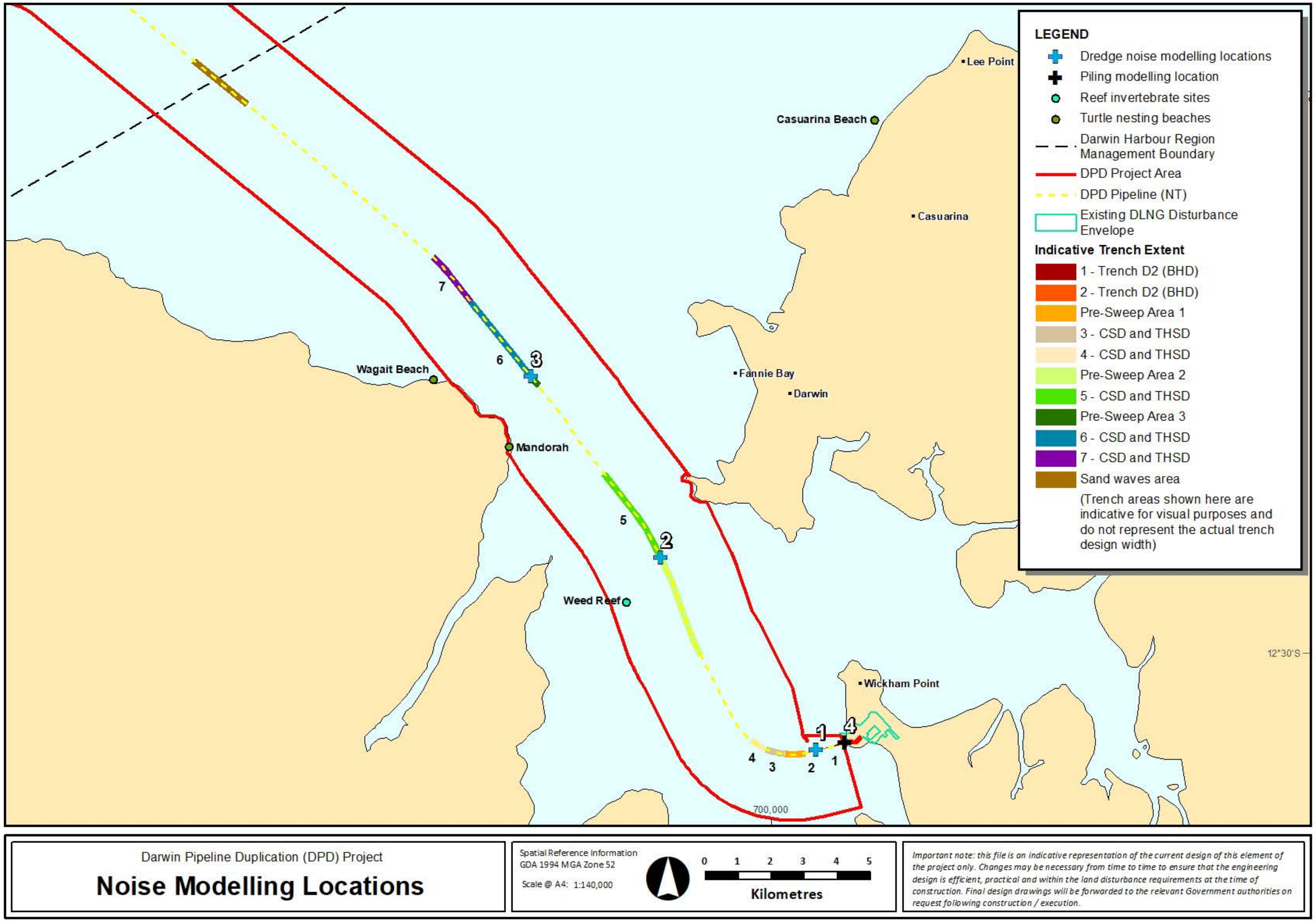

Figure 2-1 : Project Area and Trench and Noise Modelling Locations (source: RPS)

3 Underwater Noise

The ocean soundscape consists of naturally produced sounds and anthropogenically generated noise. Natural underwater sound occurs from marine life and events such as waves, storms, and underwater earthquakes. Anthropogenic noise results from activities such as piling, vessel traffic, seismic exploration, marine construction, and military activities.

The ambient underwater soundscape tends to be consistent and widespread across large areas of ocean, however, noise generated by anthropogenic activities can often be localised. If sufficiently loud, noise may be detrimental to certain marine species under some circumstances. The degree of impact is influenced by many factors, including the sound's duration, amplitude, and frequency; the distance between the sound source and marine life; the total time that the marine life is exposed to the sound and the sensitivity of marine life to the site-specific combination of these factors.

A two-year underwater noise measurement program [31] was undertaken by the Centre of Marine Science and Technology (CMST) between 2012 – 2015. The mean and minimum noise spectrum levels provided in the report are between 90 and 60 dB re 1µPa^2/Hz they are similar to the ambient sea noise in Australian waters given in Figure 3-1.

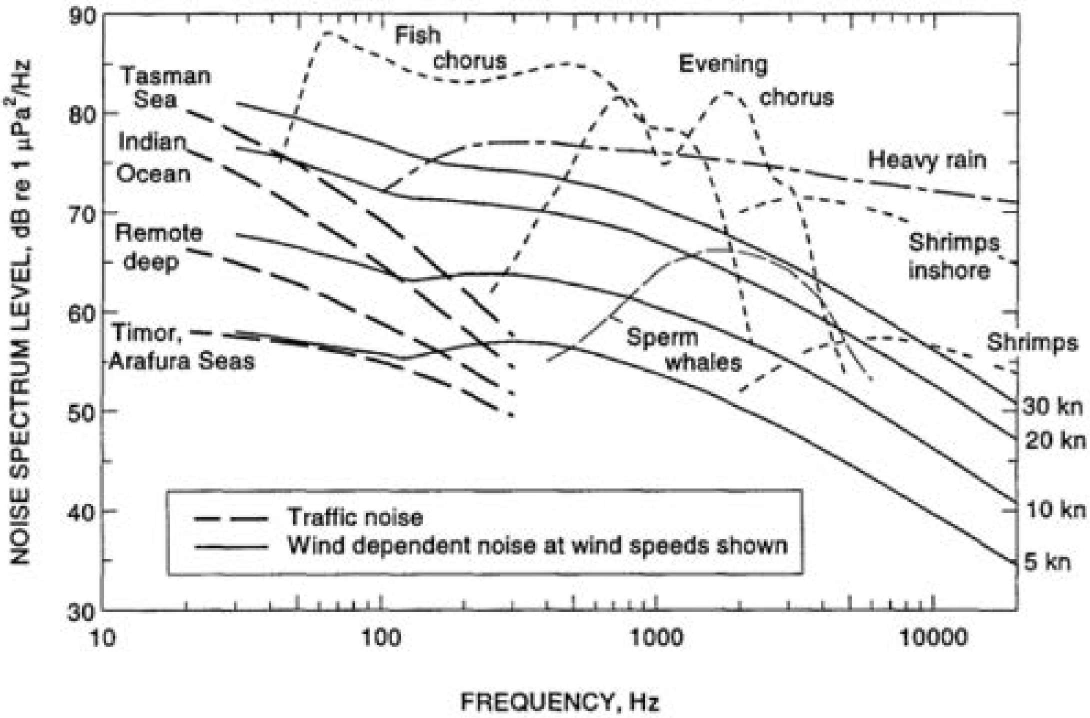

Figure 3-1 : Ambient Sea Noise in Australian Waters [6]

Sound travels further in the ocean than in air due to the natural duct created between the sea surface and the seabed, and the refractive properties of the water column. Additionally, the higher sound speeds in water result in longer wavelengths than in air, which result in low frequencies travelling further before they are absorbed to levels below ambient noise levels.

In shallow continental shelf water (< 200 m deep)[1], sound attenuates a lot faster than in the deeper, open ocean as the natural duct created between the sea surface and the seabed is very narrow,

[1] In the field of ocean acoustics, "shallow water" commonly refers to coastal waters extending from the shoreline out to the edge of the continental shelf to a depth of about 200 m, where the seafloor slope increases.

resulting in the acoustic pressure wave reflecting multiple times off the seabed and surface, with every reflection resulting in the pressure wave losing energy. Additionally, in very shallow water, low frequencies below a (depth dependant) cut off frequency attenuate very quickly, thus not having any impact at distance from the source.

4 Marine Fauna

4.1 Species of Interest

The conservation significant species with the highest likelihood of occurrence in the Project area are listed in Table 4-1. Fish are also included due to their potential commercial and recreational value.

Table 4-1 : Marine Fauna – Species of Interest for this study

Marine Fauna Type	Species
Cetaceans (high frequency dolphins)	• Indo-Pacific Humpback • Australian Snubfin • Spotted Bottlenose
Turtles	• Flatback • Olive Ridley • Hawksbill • Leatherback • Green • Loggerheads
Sirenians (SI)	• Dugong
Fish	• Various fish, sharks, and rays (including sawfish)

4.2 Assessment Criteria

Research has found that the noise levels at which Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) occur is dependent on whether the noise being generated is classed as impulsive or non-impulsive.

The definition of these two categories is as follows:

- **Impulsive** – sounds produced are typically transient, brief (less than one second), broadband and consist of high peak pressure with rapid rise time and rapid decay [2]. This noise source is associated with activities such as pile driving, seismic activities and underwater blasting and results in some of the most powerful sounds produced underwater [26], [27].
- **Non-impulsive** – sounds produced can be broadband, narrowband, or tonal, brief or prolonged, continuous or intermittent and typically do not have the high peak sound pressure with rapid rise / decay times that impulsive sounds do [2]. This type of noise source is associated with activities such as dredging, vessel noise, drilling and some construction activities.

See section 5.2 for a classification of the noise sources used in the study.

The assessment criteria for each fauna type are divided into noise levels that may result in TTS, PTS and behavioural disturbance (see Table 4-2). To determine the levels at which TTS and PTS occurs the study has relied on the following:

- **Dolphins**. For dolphins, the threshold levels for TTS and PTS for high frequency cetaceans as defined in Southall et al [1] and NOAA's 'Technical Guidance for Assessing the Effects of

Anthropogenic Sound on Marine Mammal Hearing' [2] respectively, are appropriate for this study. Behavioural threshold levels from NOAA's ESA Section 7 [2] have been used. Peak SPL levels at which PTS and TTS are provided for dolphins (see [1] and [2]) where peak levels of 230 and 224 dB re 1µPa are given for the onset of PTS and TTS respectively.

- **Sirenians**. For sirenians, the threshold levels for TTS and PTS for Sirenians as defined in Southall et al [1] and NOAA's 'Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing' [2] respectively, are appropriate for this study. Behavioural threshold levels from NOAA's ESA Section 7 [2] have been used.
- **Turtles.** The TTS and PTS criteria for turtles were taken from Criteria and Thresholds for U.S Navy Acoustics and Explosive Effect Analysis [22]. As there is a paucity of data regarding behavioural responses of turtles to non-impulsive sources a risk-based approach proposed by Popper et al [5] has been adopted. Using this approach, the risk is evaluated at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).
- **Fish.** The fish threshold criteria were taken from Popper et al [5] . Due to the paucity of data for behavioural responses a relative risk (high, moderate, low) as proposed by Popper et al [5] has been adopted. Using this approach, the risk is evaluated at three distances from the source defined in relative terms as Near (N) (scale of 10's of metres), Intermediate (I) (scale of 100's of metres), and far (F) (scale of 1000's of metres).

Note: Behavioural disturbance levels are not based on cumulative exposure or SEL[2], but rather on a Root Mean Square (RMS) Sound Pressure Level (SPL[3]).

Table 4-2 : Behavioural Disturbance, TTS and PTS Onset Thresholds (24-hour)

Marine Fauna Type	Marine Hearing Groups	Hearing Bandwidth	Noise Type	SEL_{24hour} (Weighted) dB re 1µ Pa^2.s		SPL Possible Behavioural Disturbance dB re 1µ Pa
				TTS	PTS	
Dolphins	High Frequency (HF)	150 Hz to 160 kHz	Non-Impulsive	178	198	120
			Impulsive	170	185	160
Sirenians	SI	100 Hz to 50 kHz	Non-Impulsive	186	206	120
			Impulsive	175	190	160
Turtles	N/A	100 Hz to 2 kHz	Non-Impulsive	200	220	Relative risk*
			Impulsive	189	204	166
Fish	N/A	100 Hz to 1 kHz	Non-Impulsive	Relative risk*		Relative risk*
			Impulsive	186	203	

* High, Moderate, Low.

[2] Sound exposure levels (SEL) is the cumulative level of energy contained within underwater noise and is typically used to assess health and welfare impacts. This is also referred to as the "noise dose".

[3] Sound Pressure Level (SPL) is the measure of the amplitude of acoustic pressure compared to 1 µPa.

5 Methodology

5.1 Overview

The desktop study has been undertaken using a computer noise model to simulate underwater noise emissions. The underwater software calculation kernel[4] utilises the Monterey Miami Parabolic Equation (MMPE [36]) which was developed by the University of Miami and Naval Postgraduate School Monterey in the USA. The model can predict transmission loss from multiple noise emission sources simultaneously in both broadband and narrowband frequency ranges.

Underwater propagation models require inputs including bathymetric data, geo-acoustic information, and oceanographic parameters to produce three-dimensional (3D) estimates of the acoustic field at any depth and distance from the source. As with any model, the quality of the prediction is directly related to the quality of the environmental information used in the model.

5.2 Noise Sources

The selection of noise sources has been based on the best information available from the project. The noise sources were selected in collaboration and with the project team. The sources selected were based on the best possible match to the activities and equipment provided at the time. The noise source levels used for modelling have therefore been calculated based on a combination of project data and source levels from an in-house database of underwater noise sources which have been developed from publicly available data. All source levels include overall and spectral levels.

5.2.1 Sheet Piling Noise Source Level

The action of driving a sheet pile into the seabed excites bendy[5] waves in the sheet pile that propagate along the length of the pile and transfer into the sea and seabed (see Figure 5-1). The compression component of the wave propagates into the ocean, while both compression and transverse components propagate into the seabed. Once in the seabed, the energy will then propagate outwards as compression and shear waves. Vibratory piling generates pulses that have rapid rise time and rapid decay and can therefore be considered as impulsive. They can also be considered as non-impulsive as the acoustic signal has sufficient duration to overcome starting transients and reach a steady-state condition [2]. Field data from 57 projects [33] show that levels from vibrational piling are highly variable and cannot be summarized into one level for a certain type of pile. This is due to several factors such as hammer size and pile type water depth, geotechnical conditions, and topography. As a result, a conservative approach has been taken and the vibratory hammer has been classed as an impulsive source as the threshold criteria for impulsive sources are stricter than non-impulsive sources.

The Project may use a vibratory hammer to drive the sheet piles if a cofferdam is required to be built. The frequency of a vibratory hammer is a lot higher than that of a hydraulic hammer with hammering frequencies ranging from 1,600 to 2,500 Hz.

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[4] The MMPE kernel used in this study has been rigorously tested at SWAM [32] and has undergone infield verification for both deep and shallow water.

[5] Bendy wave is a wave that comprises of a compression wave and a transverse wave.

The vibratory hammer specifications that have been used to calculate the source levels for modelling are given in Table 5-1.

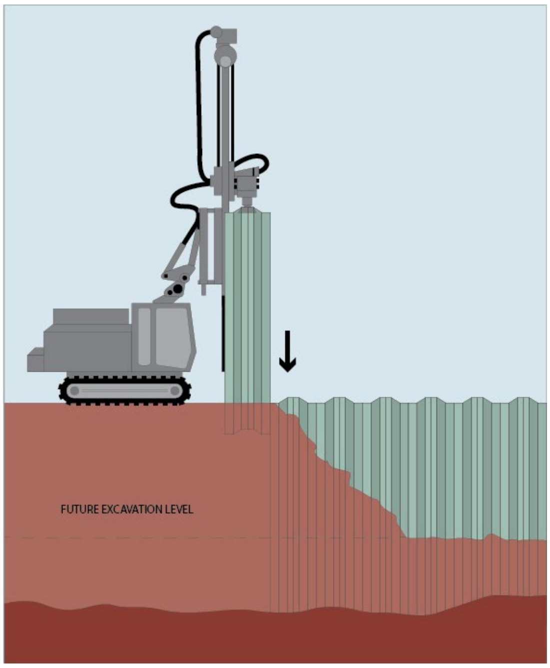

Figure 5-1 : Sheet piling using a vibratory hammer

Table 5-1 : Vibratory hammer specifications (based on 416L ICE) and modelled source level (SEL)[6]

Parameter	Value	SEL dB re 1µPa^2.s @ 1m	SPL Peak dB re 1µPa @ 10m
Eccentric moment kgm	23	165[6]	189[7]
Max. centrifugal force kN	645		
Max. frequency rpm	1600		
Max. amplitude mm	19.6		
Max. static line pull kN	400		
Max. oil flow L/min	359		
Dynamic weight kg	2350		
Total weight kg	3900		
L x W x H *) mm	2546 x 490 x 1566		

[6] Steel Sheet Pile [33] SWL calculated using 10*log10(2*pi*r) for approximated attenuation.

[7] Based on measured sheet pile levels at 10 m [33].

Parameter	Value	SEL dB re 1µPa^2.s @ 1m	SPL Peak dB re 1µPa @ 10m
Recommend. Power pack	400 series		
Recommended clamp	100TU		

Table 5-1 gives the sheet piling source level (SEL) for the vibratory hammer energy. Sheet piling is not planned to take place at high tide or at night-time. The cumulative impacts from sheet piling have been determined using the hammer energy source level multiplied by the frequency over a maximum duration of eight hours (thus by adding it cumulatively over 480 minutes) to give an overall cumulative SEL[8], as shown in Table 5-2.

Table 5-2 : Sheet piling noise source level

Parameter	Cumulative SEL $_{24\ hour}$
Source Level (SL)	227 dB re 1µPa^2.s @ 1m[8]

Note: If vibratory hammering only occurs during the low tide period, it has been assumed maximum of eight hours of driving will be undertaken.

The measured peak levels at 10m, as given in Table 5-1, are significantly less than the peak levels for the onset of PTS and TTS peak levels given in section 4.2. As a result, peak levels are not considered further in the assessment as sheet piling peak levels will be less than the threshold levels at ranges very close to the pile.

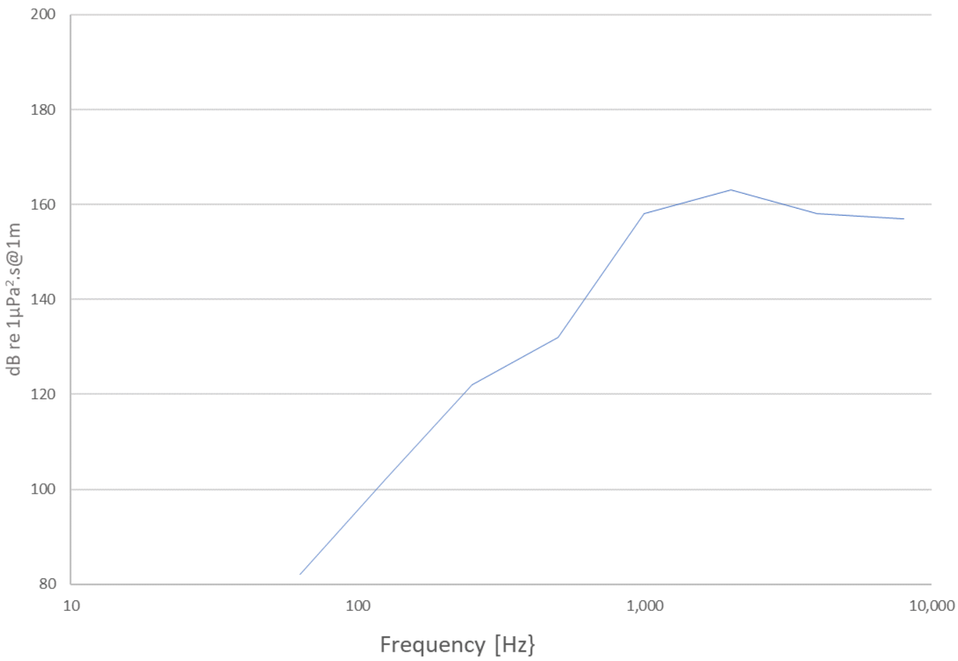

Figure 5-2 : Vibratory Hammer Sheet Piling source characteristics.

[8] 10*log10(N) where N is the number of minutes.

5.2.2 Dredging Noise Source Level[9]

Dredging is an underwater excavation activity used to increase the water depth, carried out by gathering up bottom sediment and disposing of the material at an approved spoil ground. Dredgers are non-impulsive noise sources.

The Project will use a TSHD, CSD and a BHD for trenching purposes. Dredging noise levels can vary significantly and are dependent on several factors including dredger design, equipment used, type of material being dredged and bathymetry. As RPS's 2022 pipeline route benthic habitat survey report [35] indicates that the pipeline route sediment consists of mud, gravel and sand, with sand being the predominate sediment, the dredging noise sources have been selected based on measurements undertaken of dredgers removing unconsolidated aggregate and sand [37].

Underwater noise measurements have been recorded from the CSD *Athena* conducting dredging operations at Walker Shoal in the East Arm of Darwin Harbour for the INPEX Ichthys project, as presented in Salgado-Kent et al [31]. These results have been reviewed but considered unlikely to be representative of CSD trenching operations for the DPD Project for the following reasons:

- Walker Shoal comprised areas of extremely high-strength conglomerate material (rock) which required special techniques to remove [39]. Some areas of rock were found to have had unconfined compressive strength (UCS) of 50 MPa to ~80 MPa; INPEX therefore determined that traditional dredging techniques, suitable for material strengths up to 30-50 MPa, could not be used [39].
- The CSD Athena was fitted with a specially modified cutting head (heavier with more teeth than a standard cutting head) to allow this high-strength rock to be removed [39]. The Athena was chosen on the basis that it was one of the few CSDs powerful enough to drive this cutting head [39].
- The DPD Project trenching areas does not comprise rock greater than 50 MPa and a conventional cutting head is considered sufficient to break up the rock encountered.

The equipment used and geology encountered during Ichthys project Walker Shoal dredging is therefore not considered representative for the DPD Project and CSD noise measurements in [31] have been used to inform the CSD source level used in this report.

A description of the dredging activities for the project are as follows:

- A TSHD uses a head suction pipe with nozzles connected to a high-pressure water installation to loosen the material on the seabed. The resulting lower pressure in the pipe lifts the material discharging it into a hopper. The SEL for the TSHD is based on a cycle time of dredging for 3 hours followed by 2 hours spent in transit/spoil dump repeated over period of 24 hours.
- A CSD is a vessel that includes a cutter head used to loosen the material and a suction mouth, inlet and pump used to mobilise the material from the seabed through piping into a hopper. The SEL for the CSD have been based on the cycle time of 10-hours of cutting and 2 hours of downtime repeated over 24 hours.
- A BHD will be used for digging and rock breaking. BHD noise was modelled in a rock-breaking phase (considered to be the noisiest activity undertaken by the BHD), whereby rock-breaking alternates with removal of broken rock via digging separate to the digging activities. The SEL

[9] Note: proposed equipment might not necessarily be the actual project equipment but are used as proxy sources reflective of actual equipment used by project.

for the BHD have been based on the cycle time of two cycles of 4 hours hammering, 4 hours of downtime followed by 4 hours of digging. As hydraulic hammering is impulsive, the exposure due to rock breaking has been calculated separately from the digging activity which has been modelled as non-impulsive noise.

The project dredge locations are shown in Figure 2-1 and the source levels used for modelling of dredging activities is given in Table 5-3.

Table 5-3 : Dredging noise source

Dredger Type	SPL[10] [dB re 1µPa @ 1m]	Reference Figure
TSHD [37]	184	**Figure 5-3**
CSD [37]	182	**Figure 5-4**
BHD (Digging) [26]	175	**Figure 5-5**

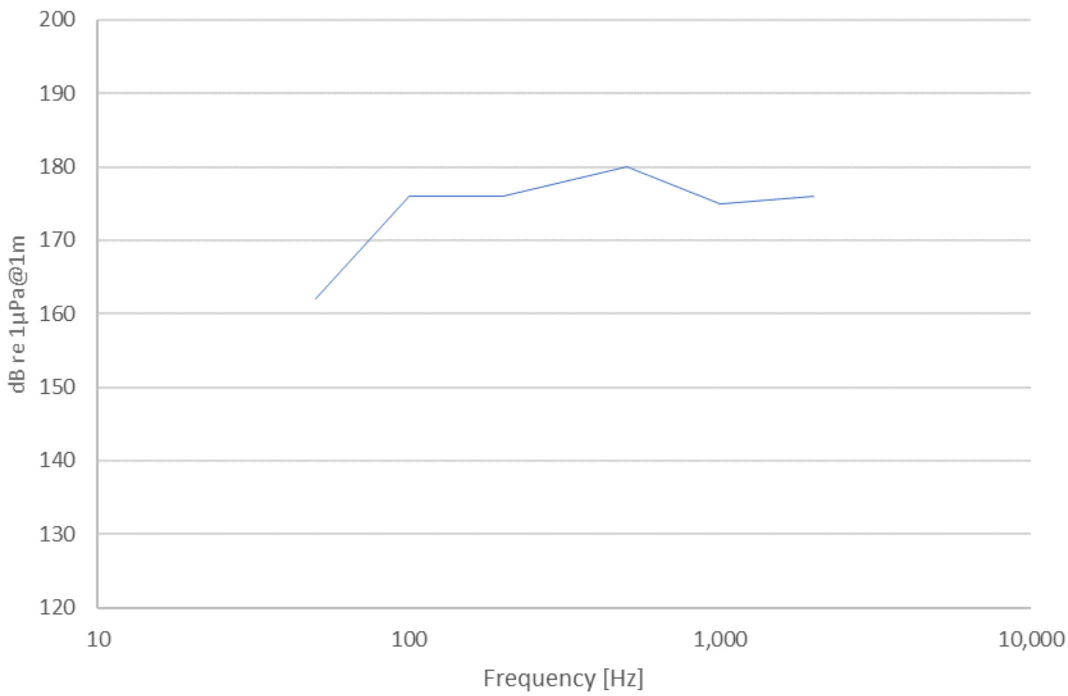

Figure 5-3 : TSHD noise source characteristics (at frequencies higher than reported a 20 dB/decade decay rate is assumed)

[10] Sound Pressure Level Root Mean Square.

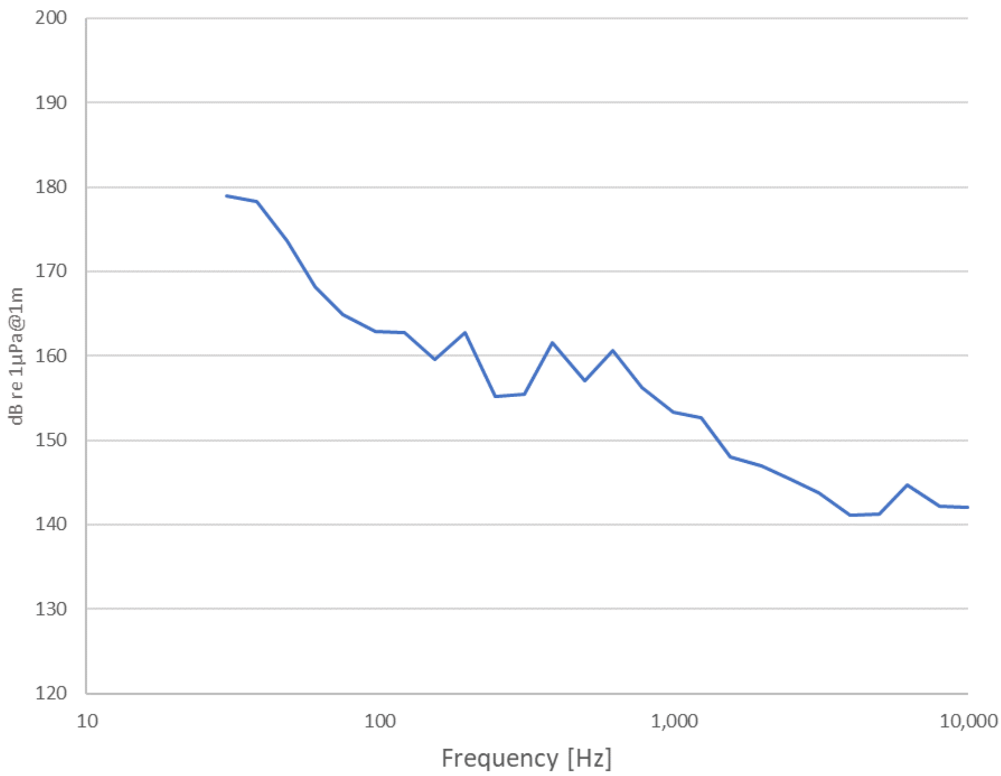

Figure 5-4 : CSD noise source characteristics

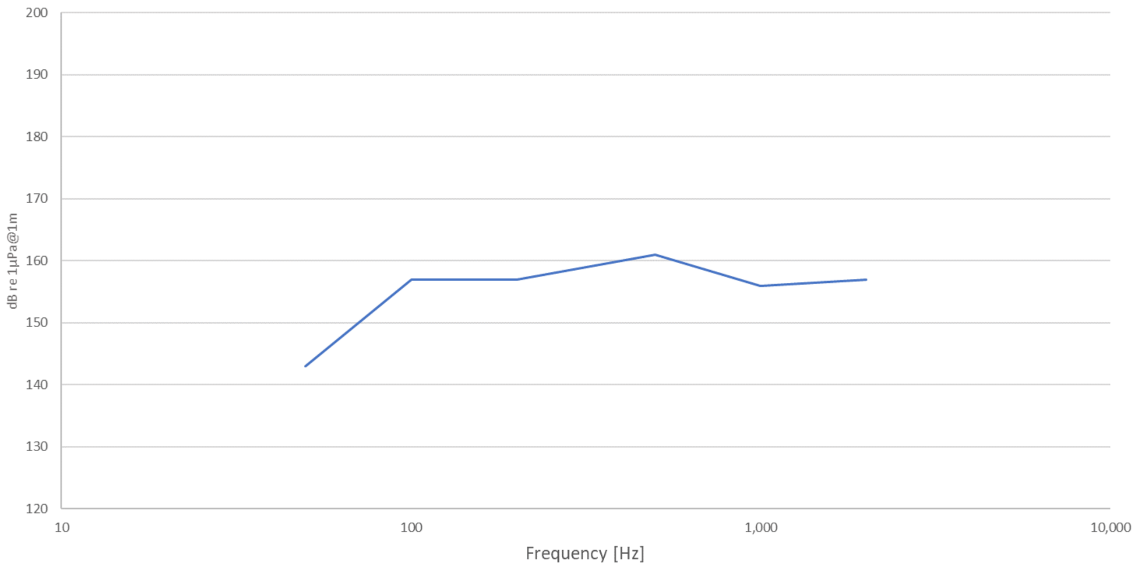

Figure 5-5 : BHD noise source characteristics (at frequencies higher than reported a 20 dB/decade decay rate is assumed)

5.2.3 BHD with Hydraulic Hammer

No publicly available underwater noise information could be found for hydraulic hammers. As a result, it has been assumed that the hydraulic hammer will have very similar levels to that of the vibratory hammer and the source levels in section 5.2.1 adopted as shown in Table 5-4.

Table 5-4 : Hydraulic Hammer noise source

Dredger Type	Cumulative SEL $_{24\ hour}$	Reference Figure
BHD Hydraulic Hammer	227 dB re 1µPa^2.s @ 1m	**Figure 5-2**

5.3 Noise Source Locations

Table 5-5 and Figure 2-1 gives the modelled noise source locations. For locations 1, 2 and 3, the source was positioned approximately halfway in the water column between surface and seabed.

Hydraulic sheet piling, if required, will be undertaken on the mud flats where there is no or very little water. As noise from the sheet piling can travel through the mud and reradiate into the water a noise source at Location 4 was placed 1m below the mud layer simulated in the model.

Table 5-5 : Noise Source model locations (MGA zone 52)

	Location Name	Easting	Northing
Location 1	Dredge Location 1	701366	8614382
Location 2	Dredge Location 2	696636	8620225
Location 3	Dredge Location 3	692710	8625712
Location 4	Sheet Pile Location	702240	8614600

5.4 Modelled Scenarios

Table 5-5 provides a summary of the modelled scenarios for each location and the 24 hour cycle time that was used to calculate exposure levels.

Notes:

- Noise sources are all static in the model.
- All model scenarios to SEL 24hour are at MSL. MSL was selected by the Project as Darwin harbour experiences extreme tidal ranges and high and low tide water levels occur for only a short period of time across a 24 hour period (or across spring-neap tidal cycle). A MSL therefore provides a more realistic representation of cumulative $SEL_{24\ hour}$ exposures as the water levels fluctuate around MSL over a 24 hour period.

Table 5-6 : Noise Model Scenarios

	Scenario	Water Depth [m]	Cycle Times within a 24 Hour periods
Location 1	BHD (Digging)	6	Two x 4 hours of digging over 24 hours during rock-breaking phase.
	BHD (Hydraulic Hammer)		Two x 4 hours hammering over 24 hours during rock-breaking phase.

	Scenario	Water Depth [m]	Cycle Times within a 24 Hour periods
Location 2	TSHD	17	3 hours dredging and 2 hours transit/spoil dump.
Location 3	TSHD	18	3 hours dredging and 2 hours transit/spoil dump
	Concurrent operations - TSHD and CSD		TSHD (3 hours dredging and 2 hours transit/spoil dump). CSD (10 hours of cutting and 2 hours downtime).
Location 4	Sheet Piling	0	8 hours over 24 hours.

5.5 Bathymetry

The bathymetry applied to the model was sourced from Geoscience Australia [38]. The bathymetry extended up to 20km from Darwin Harbour and 31km from the Project location. As shown in Figure 5-6, the water depth within the bathymetry which has been applied to the model is shallow (between 0m and ~25m).

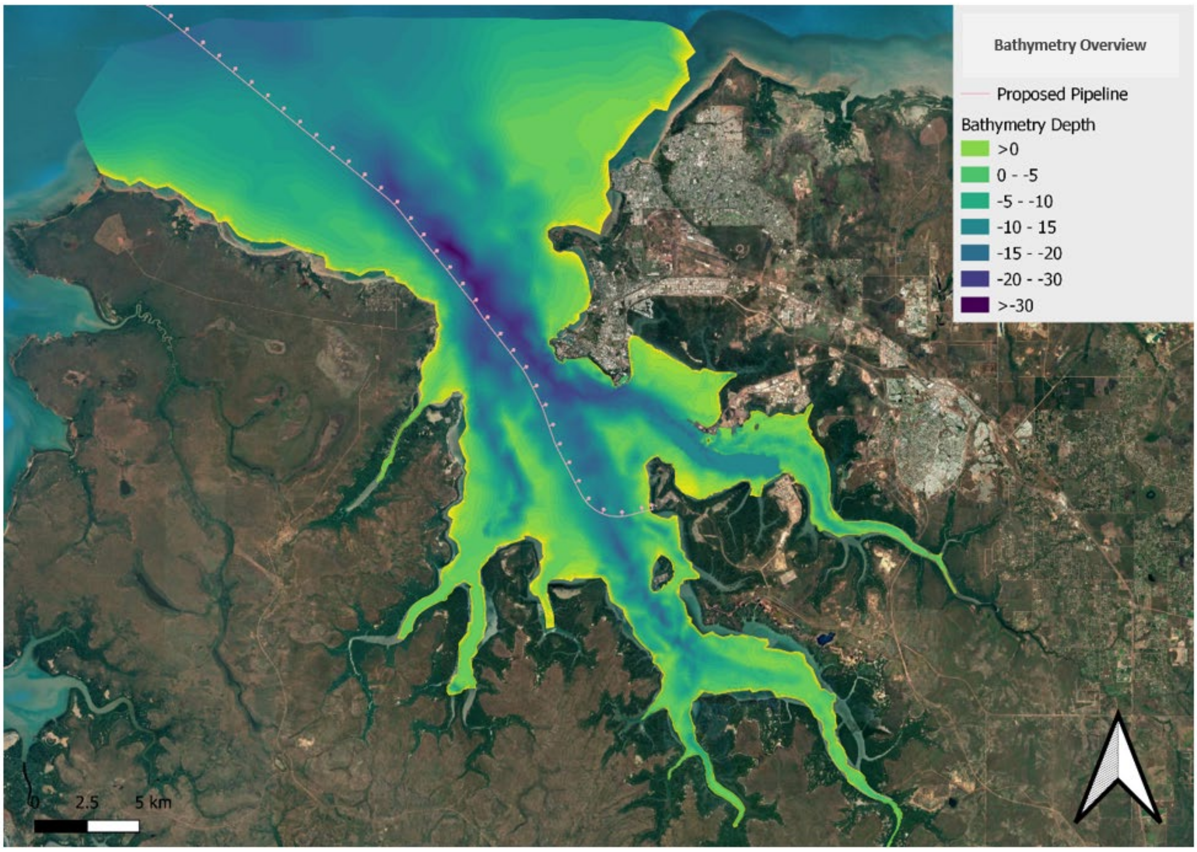

Figure 5-6 : Bathymetry (Mean Australian Sea Level)

5.6 Seabed Types

RPS's 2022 pipeline route benthic habitat survey report [35] shows that the pipeline route sediment consists of mud, gravel and sand, with sand being the predominant sediment. As a result, sand has been selected to represent the seabed for the study area with geo-acoustic properties as shown in Table 5-7. This is also a conservative approach as sand is more reflective in shallow water environments (i.e. shallow grazing angles) than limestone and other hard materials which absorb more of the energy of the pressure wave with each reflection [34]. This phenomenon is due to the properties of harder materials (such as limestone and calcarenite) where on reflection, the pressure wave at low grazing angles, excites both a compression and shear waves thus removing more energy from the wave. Sand on the other hand, excites only a compressional wave on reflection and therefore absorbs less energy.

Table 5-7 : Seabed geo-acoustic properties used in the model [34]

Type	Sound Speed (m/s)	Density (g/cm³)	Sound attenuation (dB/m/kHz)		Shear Speed (m/s)
			Compression	Shear	
Fine to medium sand	1774	2.05	0.374	0	0

5.7 Sound Speed Profile

The noise sources and a large proportion of the study area is in shallow water (<20m). The temperature profile through the water column has therefore been assumed to be isothermal (as sound speed profiles are not readily available). The sound speed profile used for modelling is for a constant water temperature of 28°C and a constant salinity of 27 parts per thousand (ppt), which are the mean values for water temperature and salinity in Darwin Harbour [11].

5.8 Hearing Threshold Weighting Curves

Hearing weighting curves used in the study are based on NOAA's technical guidance [2] for marine mammal species and the 2017 US Navy Acoustics and Explosive Effects report [22] for sirenians, fish and turtles. See Appendix F for a more detailed overview of the hearing curves.

5.9 Model Limitations

The following limitations apply to the noise modelling:

- **Reflection** – Specular reflection due to rough seabed surface and wave action is not accounted for in the model.
- **Airborne noise** – A small component of the airborne noise generated above the sea surface will be transferred into the water column. The levels from airborne noise will be a lot lower than for noise generated underwater. They will therefore not make a material difference to the outcomes of the underwater noise study.
- **Temperature, Salinity and Sound Speed Profiles** – The model has assumed negligible variation in sea temperature or salinity. It is assumed that the water column is isothermal (i.e. constant temperature) because the water depth in the modelling area is relatively shallow. Variation in the sound speed profile has been limited to the effects of water column pressure.

Technical Note on the impact of salinity, temperature and change of sound speed profile in shallow water:

- The Project area is in an acoustically shallow water environment (i.e. Depth <200 m [28]). In these environments sound is propagated to a distance by repeated reflections from both the surface and the bottom. In water that is acoustically shallow the acoustic characteristics of the surface and seabed are the most significant transmission paths. As a result, the interaction of the acoustic wave with the surface and the bottom becomes important for predicting received levels. As the project is in a very shallow environment and in an area where there is no major influx of cooler water or any other cooling effect the stratification of the water column won't be significant, and refraction will minimal.
- **Temperature**: In shallow water environments temperature affects the acoustic impedance between the water and seabed interface [29]. Water temperature has a cubic effect on sound speed and an increase or decrease in sound speed affects the efficiency of sound reflections. Due to uncertainty of the Projects schedule a mid-range temperature was appropriate.

[11] Darwin harbour water temperature ranges between 23°C in June-July and 33°C in October-November. Salinity ranges between 25 parts per thousand (ppt) and 29 ppt. See reference [25].

- **Salinity**: Salinity, when compared to temperature, has a far smaller effect on sound speed. Additionally, salinity does not have an impact on absorption [30]. Salinity therefore does not affect the absorption of the acoustic wave or the sound speed profile (note it will only make a marginal difference to the sound speed profile in deep water). As a result, a change in salinity will not affect the predicted outcomes.

6 Noise Model Results and Discussion

6.1 Location 1 – BHD

Section 6.1.1 presents the ranges of predicted disturbance to each hearing group from the BHD (i.e. non-impulsive source) at Location 1, and section 6.1.2 gives the predicted disturbance to each hearing group from the BHD using a hydraulic hammer (i.e. rock breaking) at Location 1.

6.1.1 Location 1 – BHD Digging

Table 6-1 provides the ranges at which TTS and PTS is expected to exceed the threshold for each hearing group for BHD digging activity at Location 1 (as defined in section 5.4), and the estimated disturbance ranges. These ranges are as follows:

- TTS exceedances are between <50m and 151m.
- PTS exceedances are predicted to be <50m.
- Behavioural disturbance risks for turtles and fish have been assessed as Low in the nearfield (i.e. scales of 10s of metres) as defined in [5].
- Behavioural disturbance for dolphins and dugongs is predicted to occur within 454m from the BHD.

Appendix B, section B.1 provides the TTS and PTS noise maps and Appendix C, section C.1 contains the behavioural noise maps for all the hearing groups. Appendix D, section D.1 and Appendix E, section E.1 provides the maximum received levels with distance graphs.

Table 6-1 : Behavioural disturbance, TTS and PTS Onset threshold ranges for BHD Digging (non-impulsive) at Location 1 (MSL)

Hearing Group	$SEL_{24\,hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Turtle	200	220	<50	<50	RISK	10's of metres
Dugongs	186	206	200	<50	120	454
Dolphins	178	198	145	<50	120	454
Fish	RISK		10's of metres	10's of metres	RISK	10's of metres

6.1.2 Location 1 – BHD with Hydraulic Hammer

Table 6-2 provides the ranges at which TTS and PTS is expected to exceed the threshold for each hearing group for BHD using a hydraulic hammer during rock-breaking phase at Location 1 (as defined in Section 5.4), and the estimated disturbance ranges. These ranges are as follows:

- TTS exceedances are between <50m and 200m.
- PTS exceedances are predicted to be <50m.

- Behavioural disturbance risks for fish have been assessed as Moderate in the nearfield (10's of metres) as defined in [5].
- Behavioural disturbance for turtles is predicted to occur at 151m from the BHD with Hydraulic Hammer activity.
- Behavioural disturbance for dolphins and dugongs is predicted to occur at 100m from the BHD with Hydraulic Hammer activity.

Appendix B, section B.1 provides the TTS and PTS noise maps and Appendix C, section C.1 contains the behavioural noise maps for all the hearing groups. Appendix D, section D.1 and Appendix E, section E.1 provides the maximum received levels with distance graphs.

Table 6-2 : Behavioural disturbance, TTS and PTS Onset threshold ranges for BHD with Hydraulic Hammer at Location 1 (MSL)

Hearing Group	$SEL_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Turtle	189	204	<50	<50	166	151
Dugongs	175	190	200	<50	160	100
Dolphins	170	185	151	70	160	100
Fish	186	201	100	<50	RISK	100's of metres

6.2 Location 2 – TSHD

Table 6-3 provides the ranges at which TTS and PTS is expected to exceed the threshold for each hearing group for the TSHD activity at Location 2, and the estimated disturbance ranges. These ranges are as follows:

- TTS exceedances are between 131m and 303m.
- PTS exceedances are predicted to be <50m.
- Behavioural disturbance risks for turtles and fish have been assessed as Low in the nearfield (10's of metres) as defined in [5].
- Behavioural disturbance for dolphins and dugongs is predicted to occur at 1,667m from the TSHD.

Appendix B, section B.3 provides the TTS and PTS noise maps and Appendix C, section C.3 contains the behavioural noise maps for all the hearing groups. Appendix D, section D.3 and Appendix E, section E.3 provides the maximum received levels with distance graphs.

Table 6-3 : Behavioural disturbance, TTS and PTS Onset Threshold Ranges for TSHD at Location 2 (MSL)

Hearing Group	$SEL_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Turtle	200	220	131	<50	RISK	10's of metres
Dugongs	186	206	170	<50	120	1,667
Dolphins	178	198	303	<50	120	1,667
Fish	RISK		10's of metres	10's of metres	RISK	10's of metres

6.3 Location 3 – TSHD

Table 6-4 provides the ranges at which TTS and PTS is expected to exceed for each hearing group for TSHD at Location 3, and the estimated disturbance ranges. These ranges are as follows:

- TTS exceedances are between 120m and 303m.
- PTS exceedances are predicted to be <50m.
- Behavioural disturbance risks for turtles and fish have been assessed as Low in the nearfield (10's of metres) as defined in [5].
- Behavioural disturbance for dolphins and dugongs is predicted to occur at 2,273m from the TSHD.

Appendix B, section B.4 provides the TTS and PTS noise maps and Appendix C, section C.4 contains the behavioural noise maps for all the hearing groups. Appendix D, section D.4 and Appendix E, section E.4 provides the maximum received levels with distance graphs.

Table 6-4 : Behavioural disturbance, TTS and PTS Onset Threshold Ranges for TSHD at Location 3 (MSL)

Hearing Group	$SEL_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Turtle	200	220	120	<50	RISK	10's of metres
Dugongs	186	206	200	<50	120	2,273
Dolphins	178	198	303	<50	120	2,273
Fish	RISK		10's of metres	10's of metres	RISK	10's of metres

6.4 Location 3 – TSHD and CSD

Table 6-5 provides the ranges at which TTS and PTS is expected to exceed for each hearing group for concurrent TSHD and CSD at Location 3, and the estimated disturbance ranges. These ranges are as follows:

- TTS exceedances are between 160m and 350m.
- PTS exceedances are predicted to be <50m.
- Behavioural disturbance risks for turtles and fish have been assessed as Low in the nearfield (10's of metres) as defined in [5].
- Behavioural disturbance for dolphins and dugongs is predicted to occur at 3,181m from the TSHD and CSD activities.

Appendix B, section B.5 provides the TTS and PTS noise maps and Appendix C, section C.5 contains the behavioural noise maps for all the hearing groups. Appendix D, section D.5 and Appendix E, section E.5 provides the maximum received levels with distance graphs.

Table 6-5 : Behavioural disturbance, TTS and PTS Onset Threshold Ranges for TSHD and CSD at Location 3 (MSL)

Hearing Group	$SEL_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Turtle	200	220	160	<50	RISK	10's of metres
Dugongs	186	206	210	<50	120	3,181
Dolphins	178	198	350	<50	120	3,181
Fish	RISK		10's of metres	10's of metres	RISK	10's of metres

6.5 Location 4 – Sheet Piling

Table 6-6 provides the ranges at which TTS and PTS is expected to exceed for each hearing group for Sheet Piling at Location 3, and the estimated disturbance ranges. These ranges are as follows:

- TTS exceedances are between <50m and 85m.
- PTS exceedances are predicted to be <50m.
- Behavioural disturbance risks for fish have been assessed as low in the nearfield (10's of metres) as defined in [5].
- Behavioural disturbance for turtles, dolphins and dugongs is predicted to occur at <50m from the Sheet Piling.

Appendix B, section B.6 provides the TTS and PTS noise maps and Appendix C, section C.6 contains the behavioural noise maps for all the hearing groups. Appendix D, section D.6 and Appendix E, section E.6 provides the maximum received levels with distance graphs.

Table 6-6: Behavioural disturbance, TTS and PTS Onset Threshold Ranges for Sheet Piling at Location 4

Hearing Group	$SEL_{24\ hour}$ (Weighted) Threshold [dB re 1µ Pa².s]		Distance [m]		SPL Behavioural [dB re 1µ Pa]	Distance [m]
	TTS	PTS	TTS	PTS		
Turtle	189	204	<50	<50	166	<50
Dugongs	175	190	<50	<50	160	<50
Dolphins	170	185	<50	<50	160	<50
Fish	186	201	<50	<50	RISK	10's of metres

6.6 Behavioural Ranges for LAT, MSL and HAT

Darwin Harbour can experience large tidal swings, with up to 8m between Low Astronomical Tide (LAT) and Highest Astronomical Tide (HAT), although typically tidal ranges are approximately 6m between spring low and high tides, and approximately 2m between neap low and high tides.

Table 6-7 presents the behavioural ranges for LAT, MSL and HAT which have been given as these are representative of likely behavioural disturbances for a point in time[12] for turtles, dugongs, and dolphins.

The highest differential behavioural ranges between LAT and HAT were found to be at Location 2 and Location 3 where the water is deeper

Note: Low risk ratings in Table 6-7 are for nearfield (10's of metres) distances while Moderate risk ratings are for intermediate (100's of metres) distances as defined in [5].

Table 6-7: Behavioural disturbance Threshold Ranges for all locations for LAT, MSL and HAT.

Receptor Type	Sound Pressure Level (SPL) Behavioural Threshold (dB re 1µ Pa)	Threshold Range (metres) for tidal state		
		LAT	MSL	HAT
Location 1 – BHD (digging)				
Turtle	RISK	10's of metres	10's of metres	10's of metres
Dugong	120	303	454	909
Dolphin	120	303	454	909
Fish	RISK	10's of metres	10's of metres	10's of metres
Location 1 – BHD (hydraulic hammering)				
Turtle	166	<50	151	302
Dugong	160	<50	100	200
Dolphin	160	<50	100	200
Fish	RISK	10's of metres	10's of metres	100's of metres
Location 2 – THSD				
Turtle	RISK	10's of metres	10's of metres	100's of metres
Dugong	120	1,450	1,667	20,000

[12] A MSL provides a more realistic representation of cumulative $SEL_{24\ hour}$ exposures as the water levels fluctuate around MSL over a 24 hour period. The HAT and LAT $SEL_{24\ hour}$ exposures ranges are therefore not included in the study

Receptor Type	Sound Pressure Level (SPL) Behavioural Threshold (dB re 1µ Pa)	Threshold Range (metres) for tidal state		
		LAT	MSL	HAT
Dolphin	120	1,450	1,667	20,000
Fish	RISK	10's of metres	10's of metres	100's of metres
Location 3 – THSD				
Turtle	RISK	10's of metres	10's of metres	100's of metres
Dugong	120	1,515	2,273	17,878
Dolphin	120	1,515	2,273	17,878
Fish	RISK	10's of metres	10's of metres	100's of metres
Location 3 – THSD and CSD				
Turtle	RISK	10's of metres	10's of metres	100's of metres
Dugong	120	3,000	3,181	20,000
Dolphin	120	3,000	3,181	20,000
Fish	RISK	10's of metres	10's of metres	100's of metres
Location 4 – Sheet Piling				
Turtle	166	<50	<50	N/A
Dugong	160	<50	<50	N/A
Dolphin	160	<50	<50	N/A
Fish	RISK	10's of metres	10's of metres	10's of metres

7 Conclusion

An underwater noise model has been developed to predict potential noise levels at distance from noise sources associated with the Project. The noise sources modelled in the report are representative of the Project design and construction. As noted in sections 5.1 and 5.2 the noise sources have been selected based on the best information available at the time of the study. Even so the information available in the public domain shows that noise sources with similar specifications can vary depending as described in section 5.2.

APPENDIX A Reference Documents

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APPENDIX A Abbreviations, Acronyms and Symbols

dB	Decibel
CMST	Centre of Marine Science and Technology
HAT	Highest Astronomical Tide
HF	High Frequency
Hz	Hertz
kHz	Kilo Hertz
LAT	Lowest Astronomical Tide
LE,24h	Sound Exposure Level Cumulative 24 hours
LF	Low Frequency
LPK	Peak Sound Pressure Level
M	Metre
MASDP	Middle Arm Sustainable Development Precinct
MSL	Mean Sea Level
ms	Milliseconds
NOAA	National Oceanic and Atmospheric
Pa	Pascals
PTS	Permanent Treshold Shift
RMS	Root Mean Square
s	Seconds
SEL	Sound Exposure Level [dB re 1µPa^2.s]
SELcum	Cumulative Sound Exposure Level
SL	Source Level [dB re 1µPa @ 1m] or [dB re 1µPa^2.s @ 1m]
SPL	Sound Pressure Level [dB re 1µPa]

TTS	Temporary Treshold Shift
µPa	Micro Pascal
µPa2-s	Micro Pascal Square Second
W(f)	Weighting function

APPENDIX B
PTS and TTS Contours

B.1 Location 1 – BHD

Figure 7-1 :Location 1 – BHD (Digging) TTS and PTS Contours for Turtles (MSL)

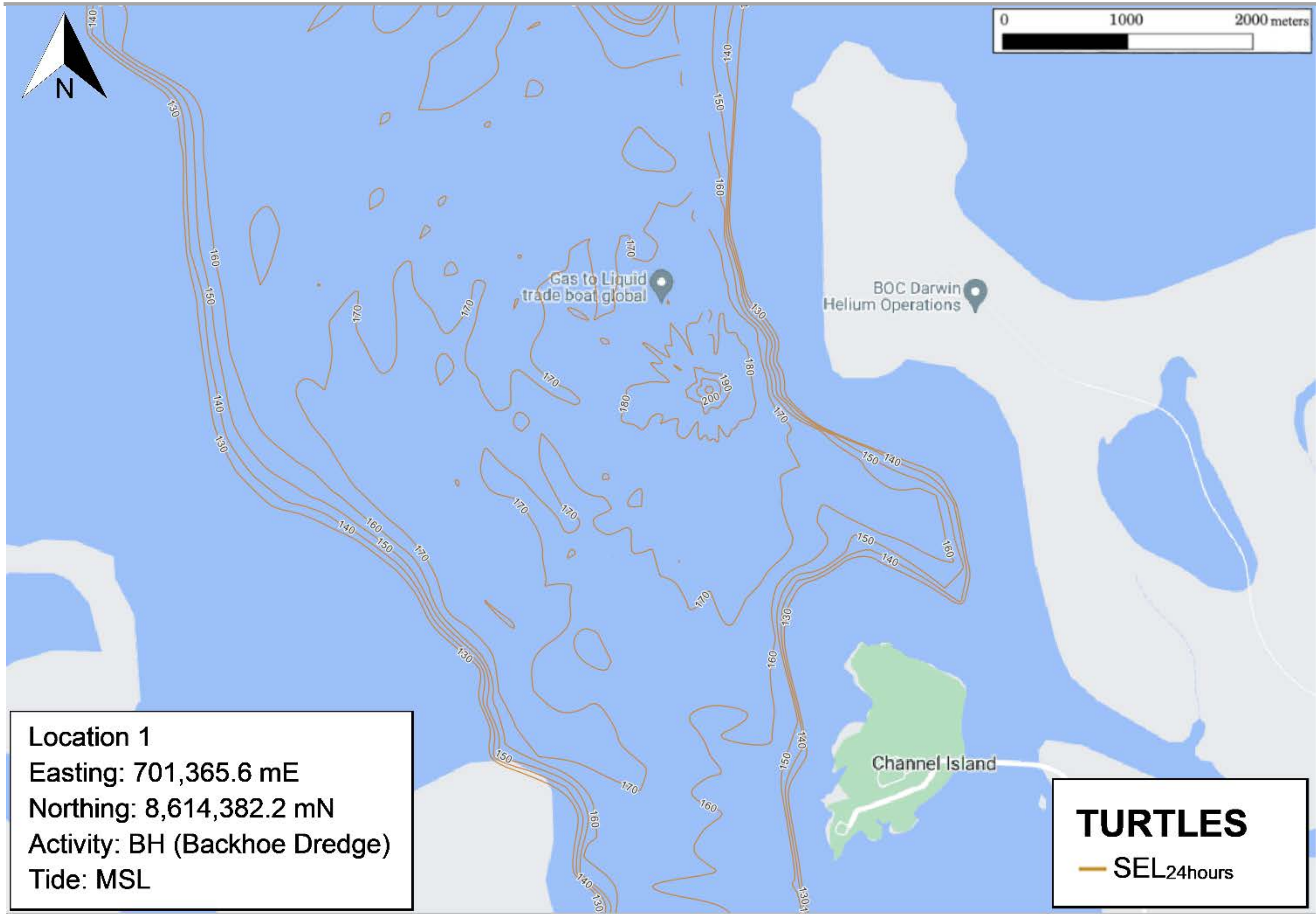

Figure 7-2 : Location 1 – BHD (Digging) SEL$_{24\ hours}$ Contours for Turtles (MSL)

Figure 7-3 : Location 1 – BHD (Digging) TTS and PTS Contours for Dolphins (MSL)

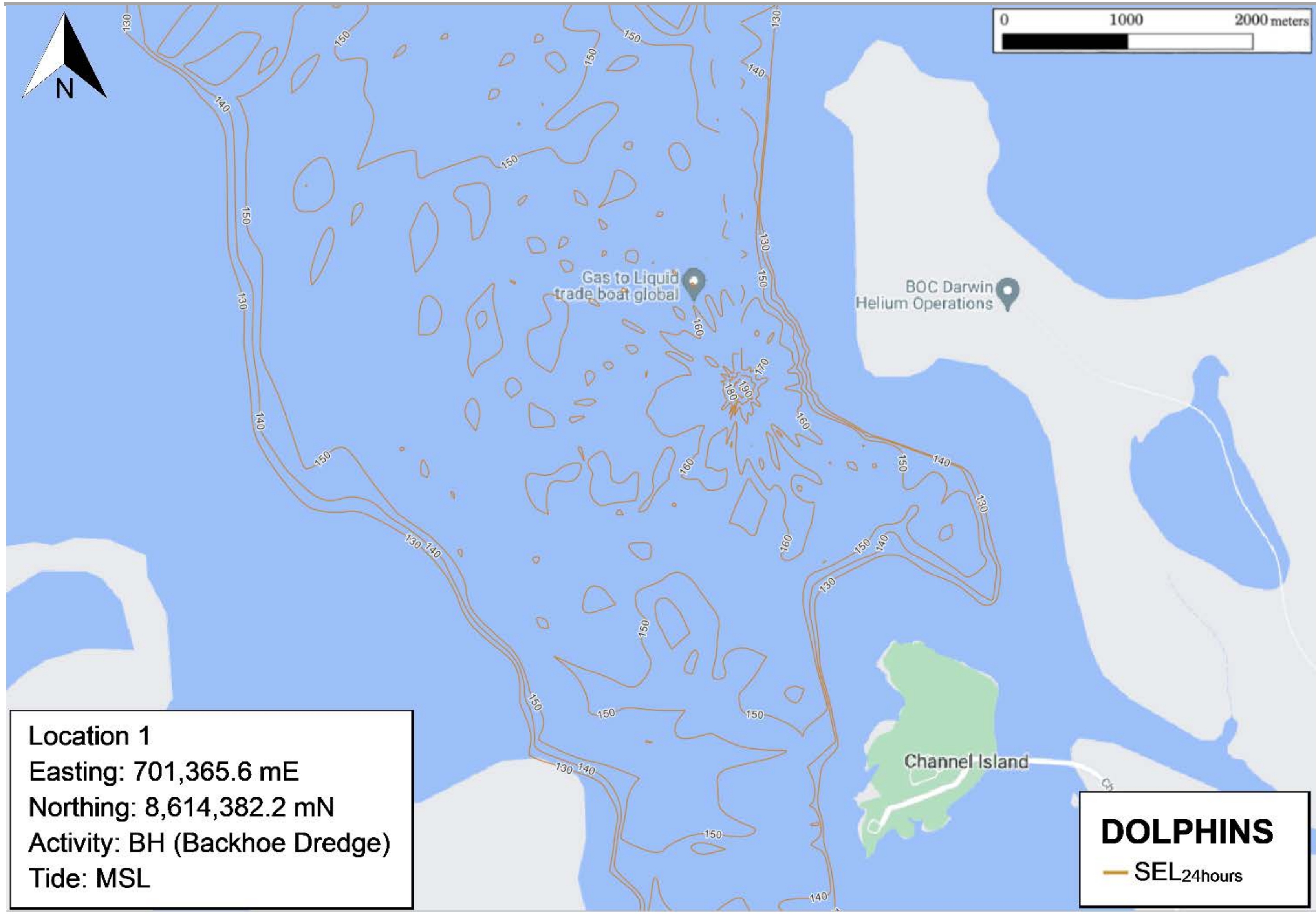

Figure 7-4 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Dolphins (MSL)

Figure 7-5 : Location 1 – BHD (Digging) TTS and PTS Contours for Sirenians (MSL)

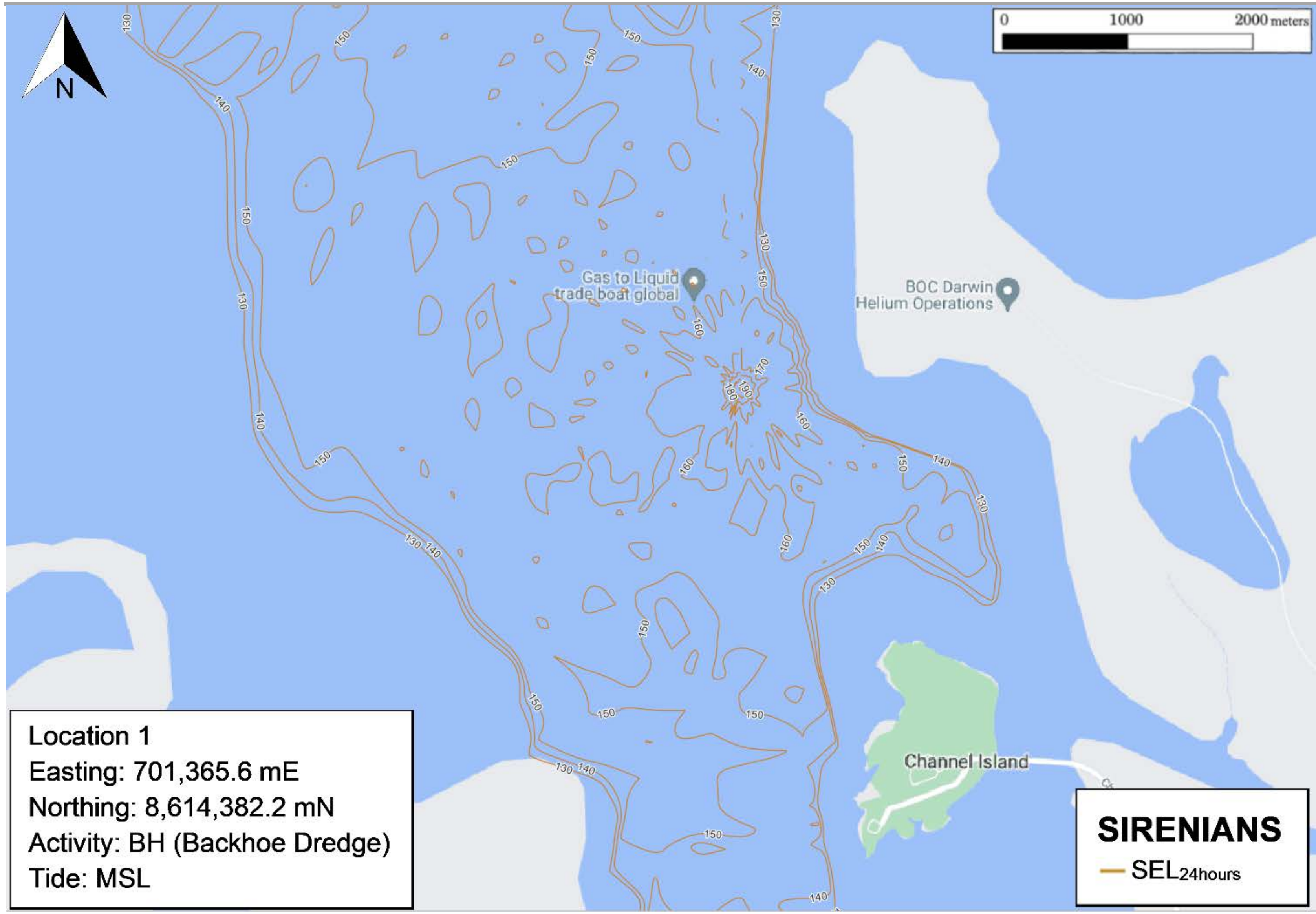

Figure 7-6 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Sirenians (MSL)

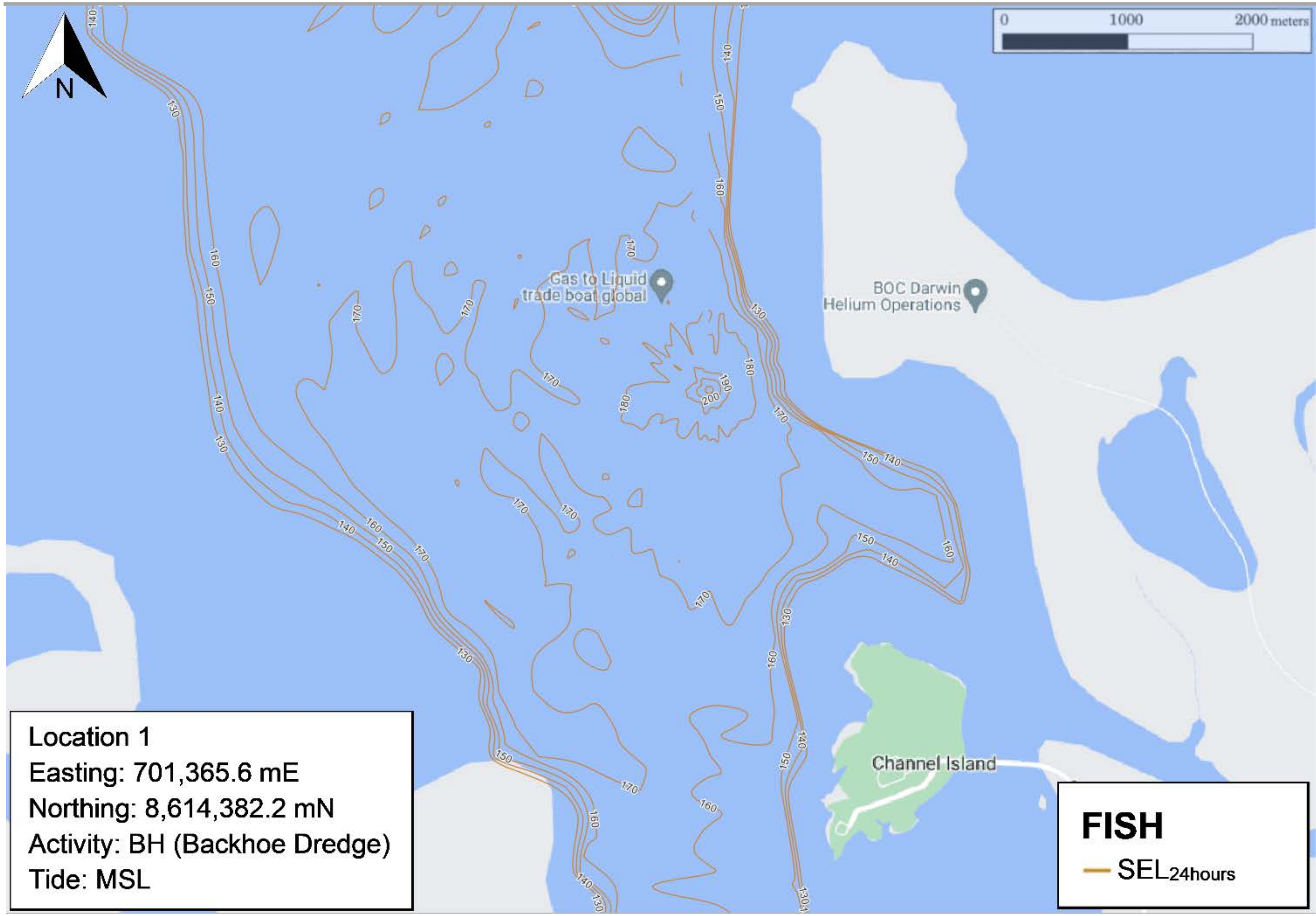

Figure 7-7 : Location 1 – BHD (Digging) $SEL_{24\ hours}$ Contours for Fish (MSL)

B.2 Location 1 – BHD (Hammer)

Figure 7-8 :Location 1 - BHD (Hammer) TTS and PTS Contours for Turtles (MSL)

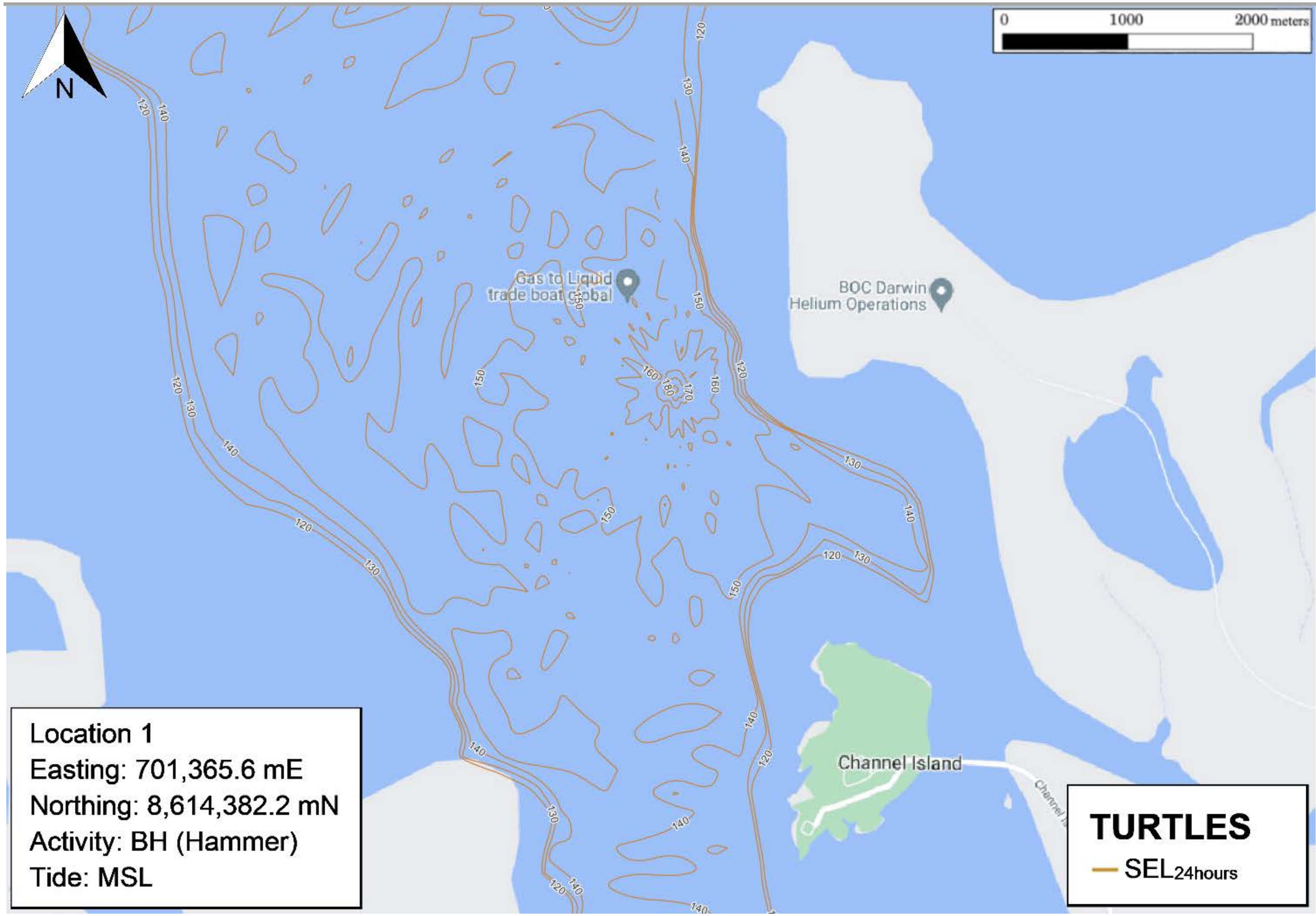

Figure 7-9 : Location 1 – BHD (Hammer) SEL$_{24\ hours}$ Contours for Turtles (MSL)

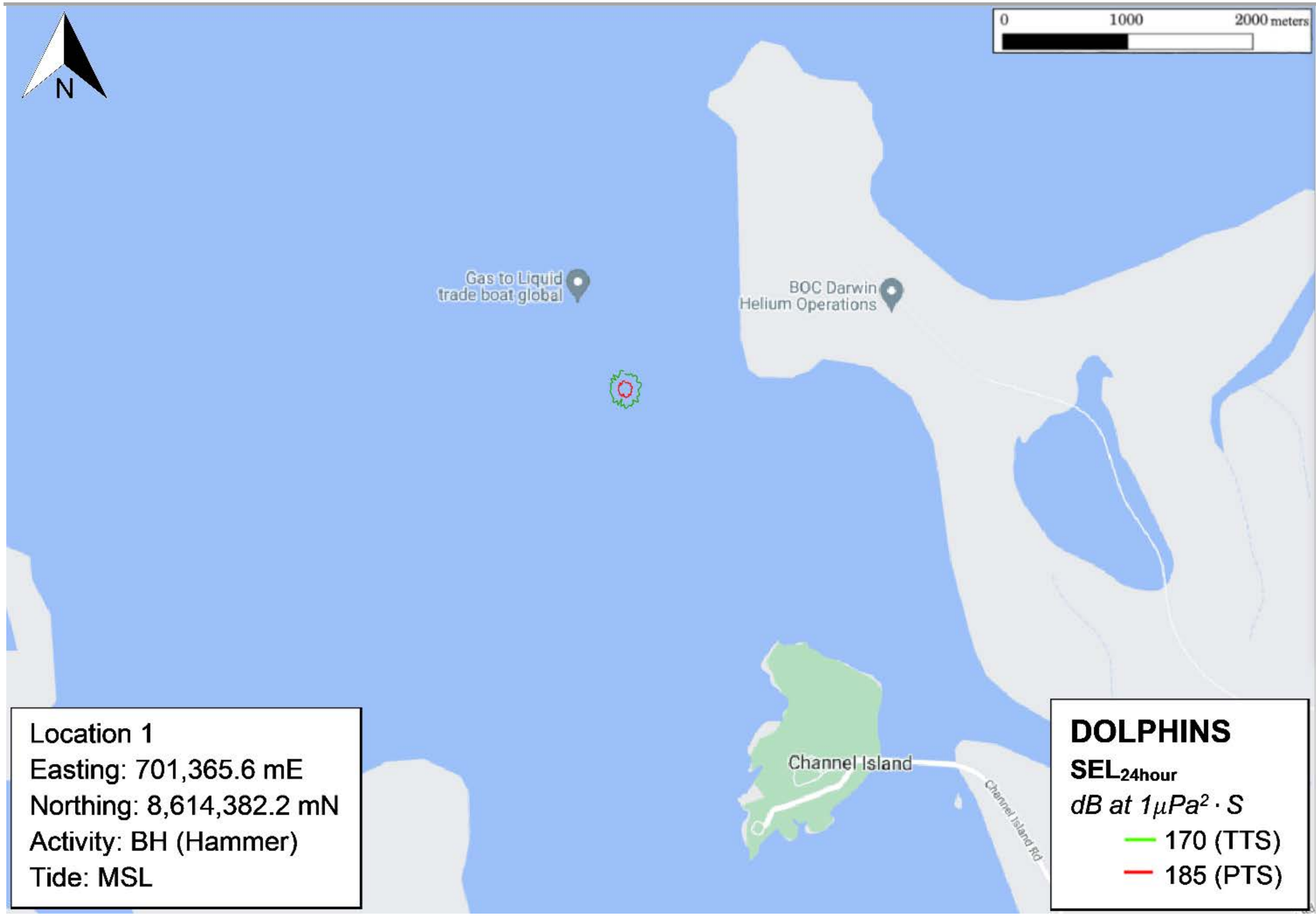

Figure 7-10 : Location 1 – BHD (Hammer) TTS and PTS Contours for Dolphins (MSL)

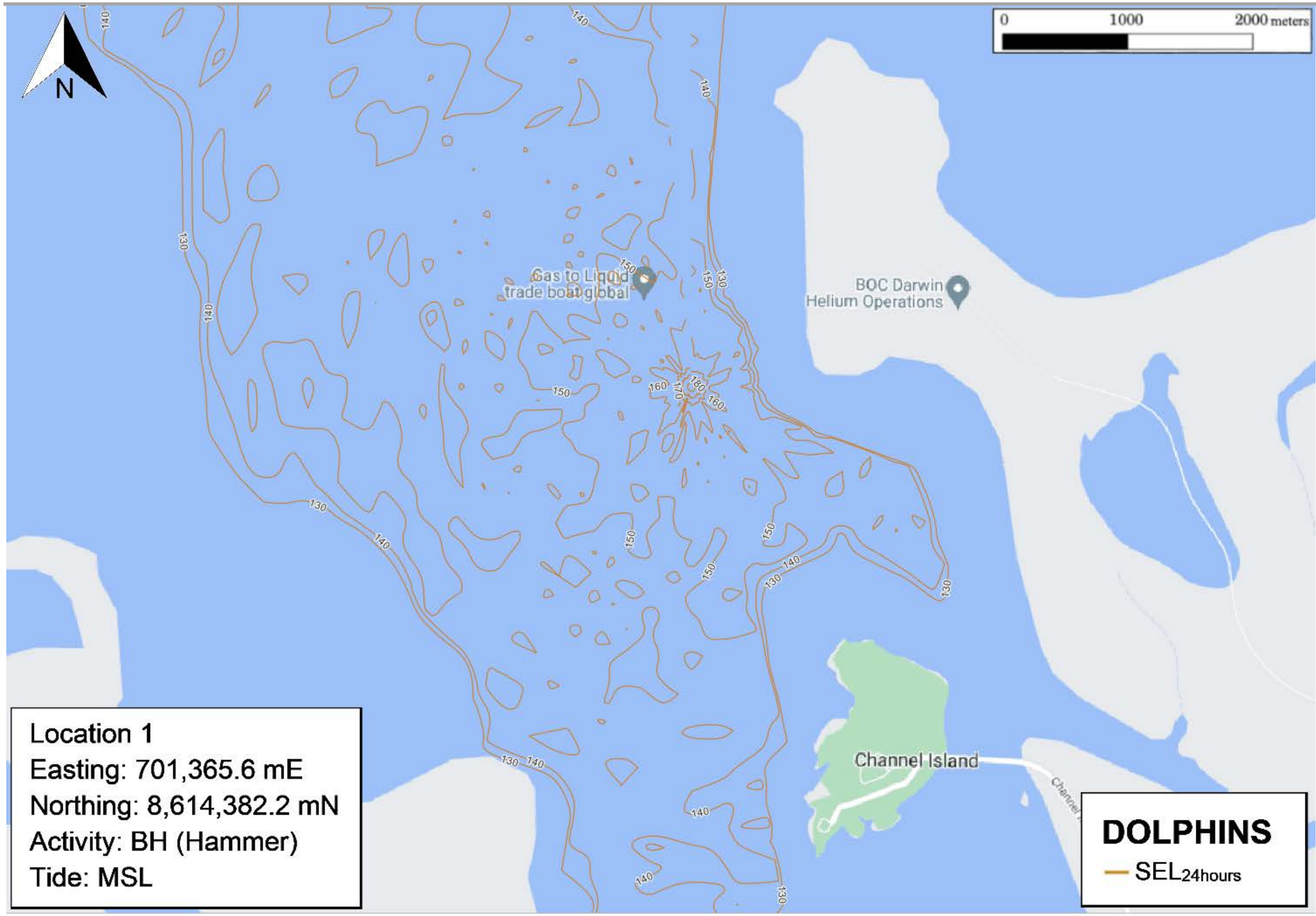

Figure 7-11 : Location 1 – BHD (Hammer) $SEL_{24\ hours}$ Contours for Dolphins (MSL)

Figure 7-12 : Location 1 – BHD (Hammer) TTS and PTS Contours for Sirenians (MSL)

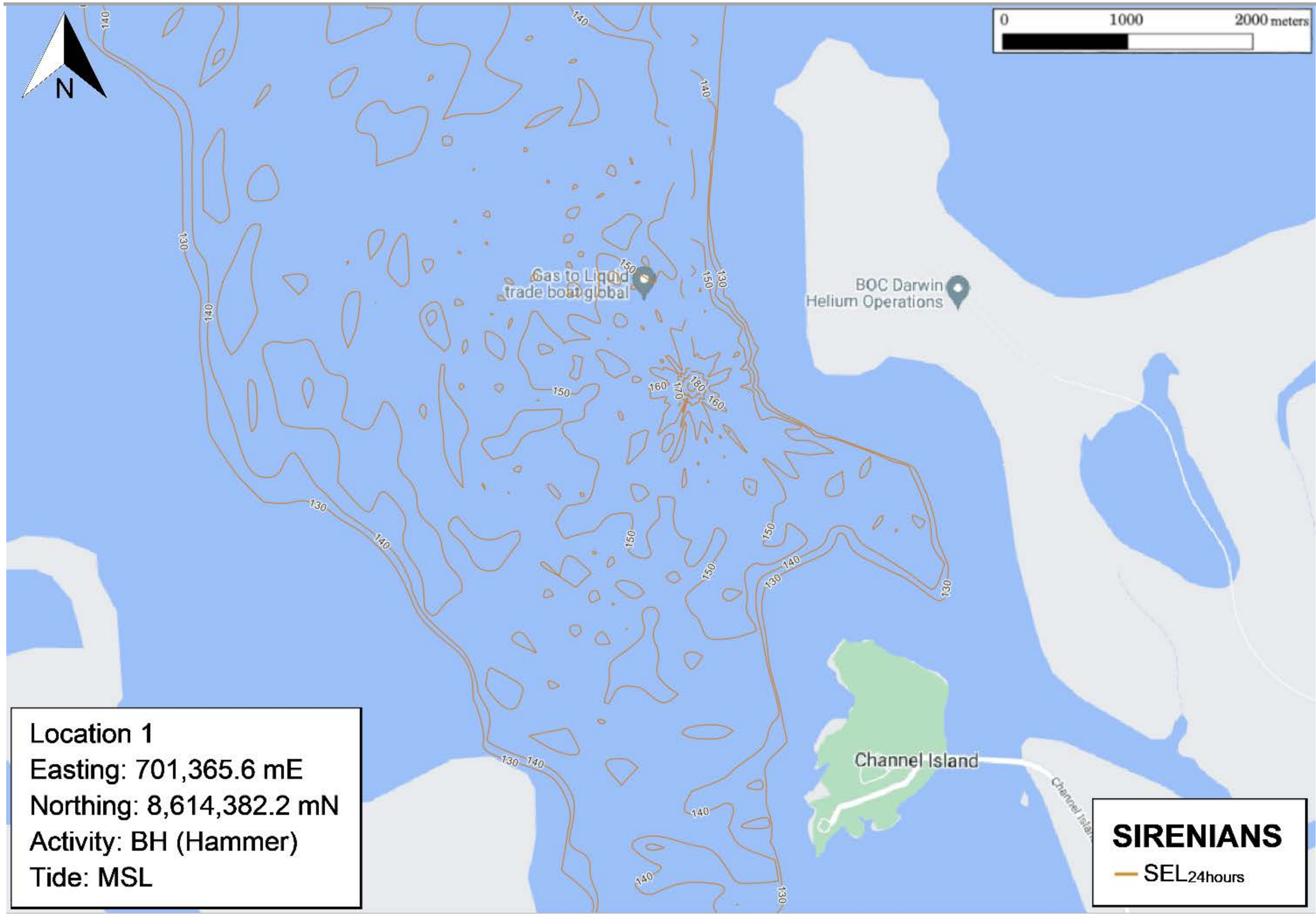

Figure 7-13 : Location 1 – BHD (Hammer) SEL$_{24\ hours}$ Contours for Sirenians (MSL)

Figure 7-14 : Location 1 – BHD (Hammer) TTS and PTS Contours for Fish (MSL)

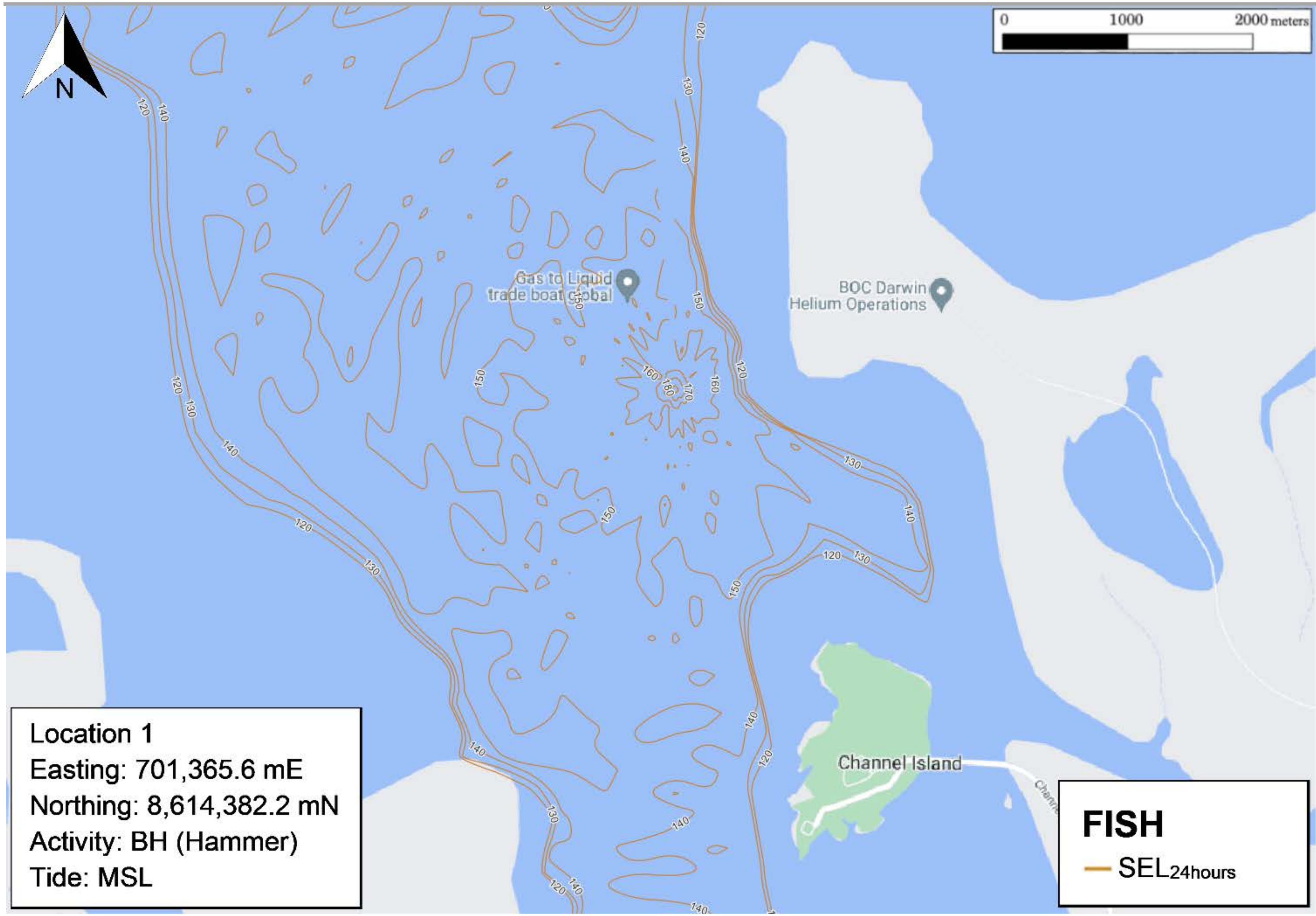

Figure 7-15 : Location 1 – BHD (Hammer) $SEL_{24\ hours}$ Contours for Fish (MSL)

B.3 Location 2 – TSHD

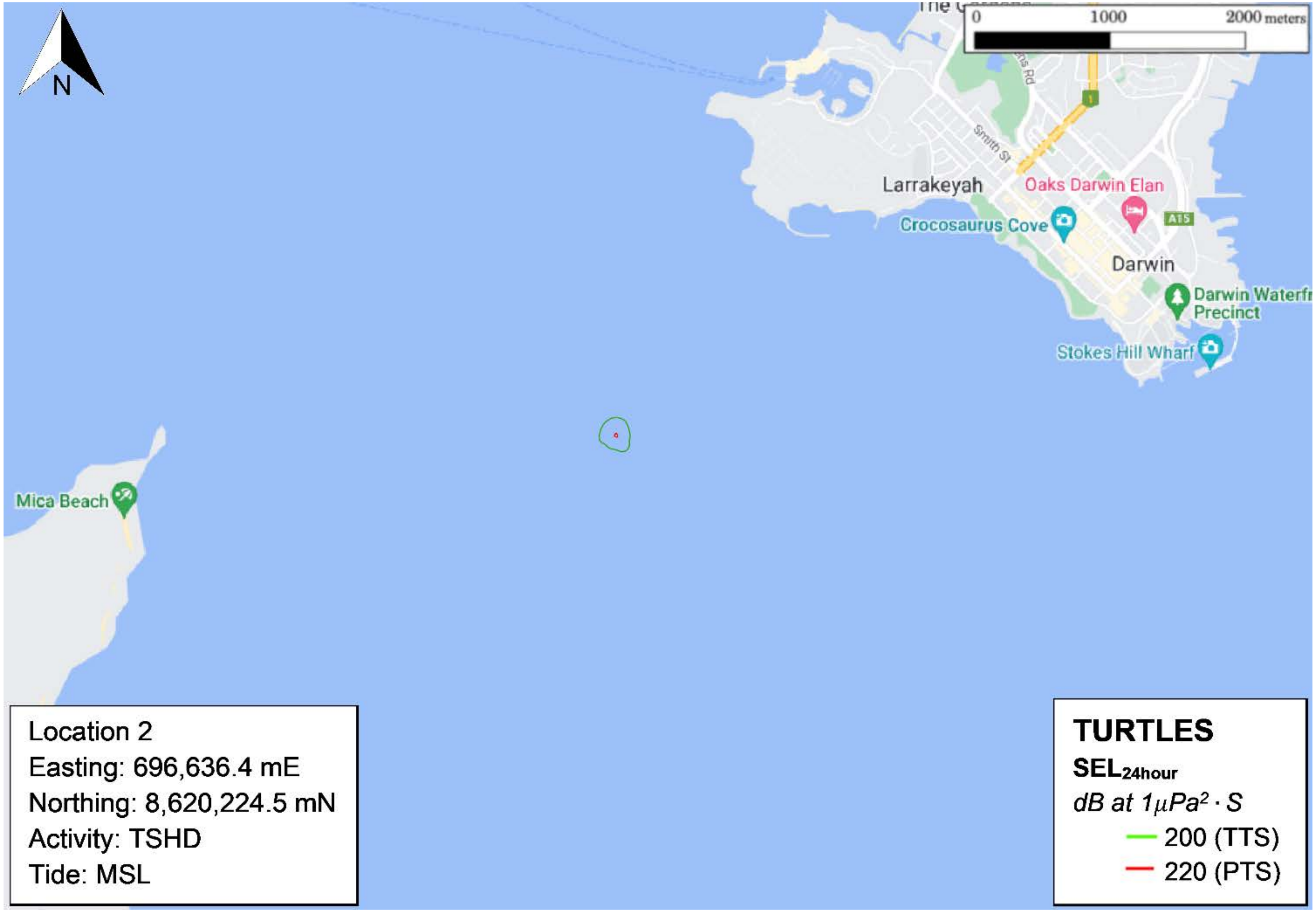

Figure 7-16 :Location 2 – TSHD TTS and PTS Contours for Turtles (MSL)

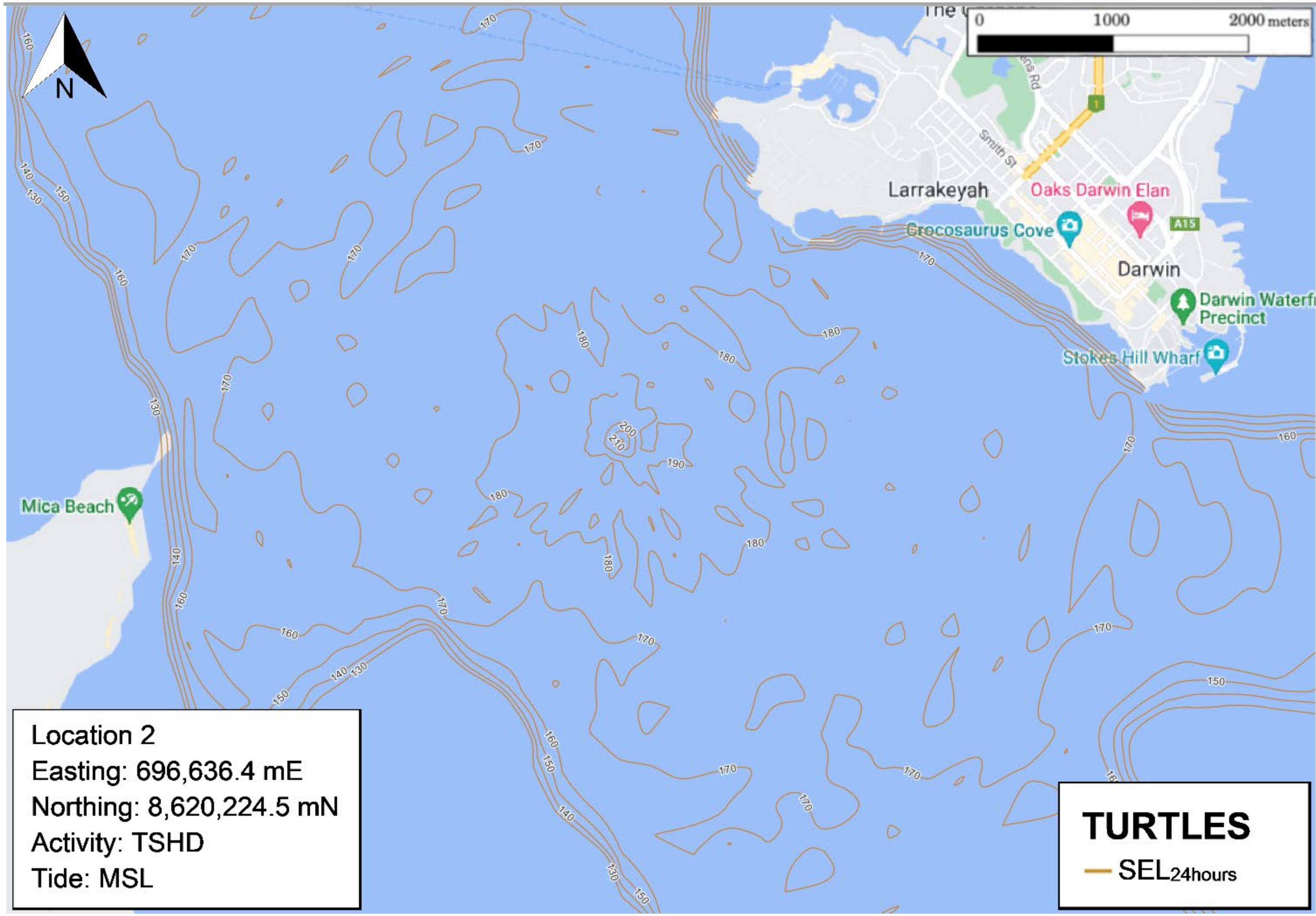

Figure 7-17 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Turtles (MSL)

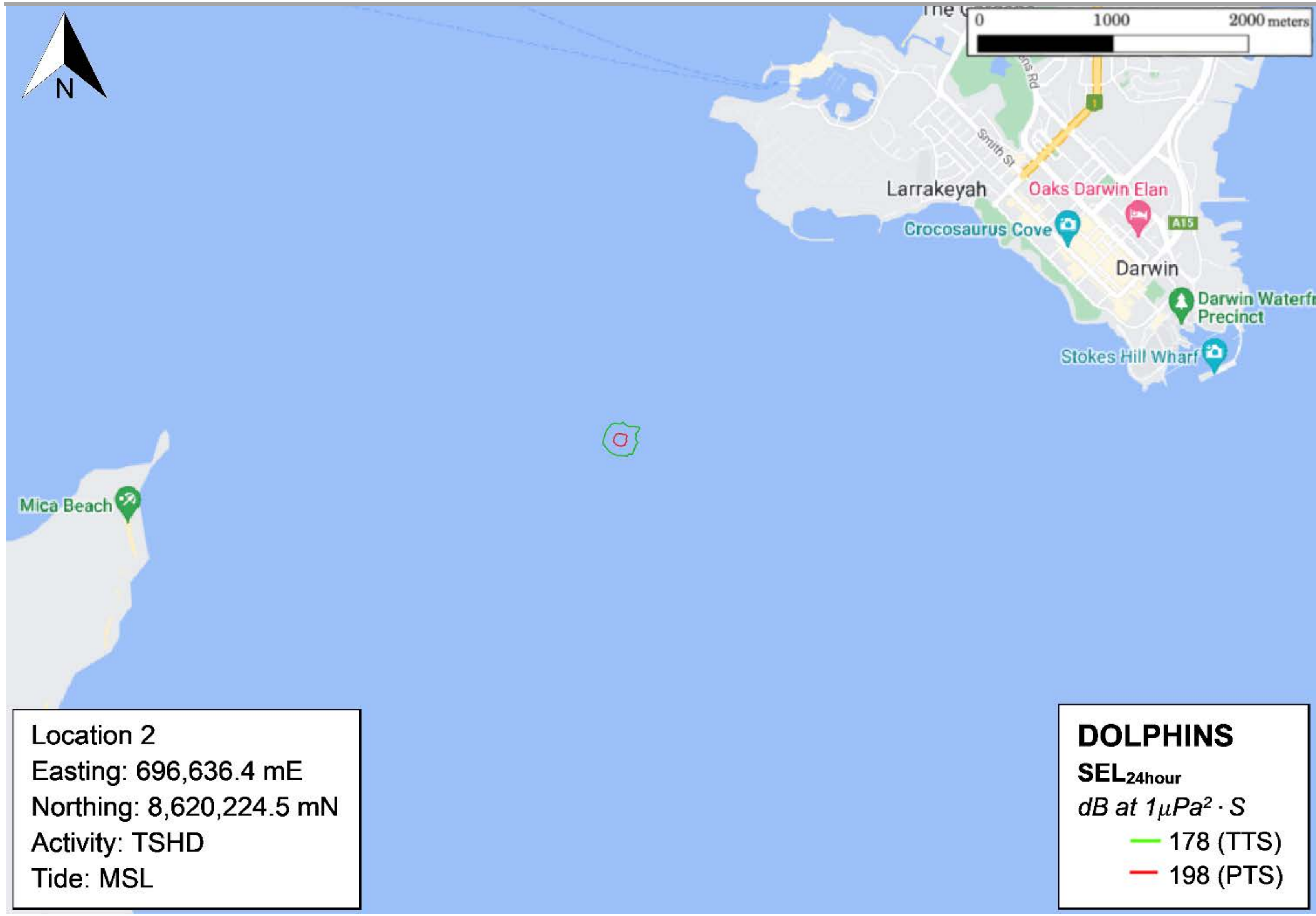

Figure 7-18 : Location 2 – TSHD TTS and PTS Contours for Dolphins (MSL)

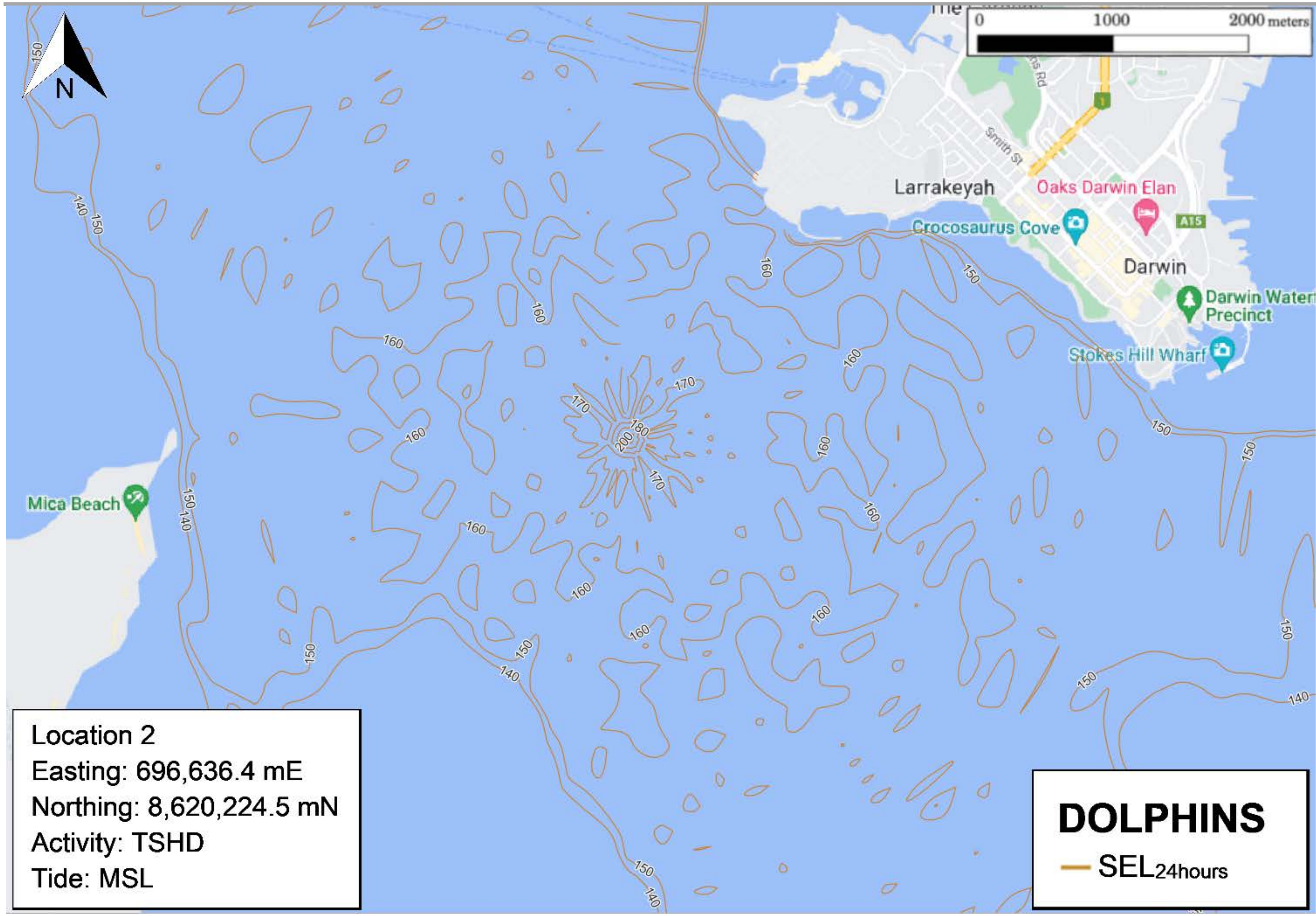

Figure 7-19 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Dolphins (MSL)

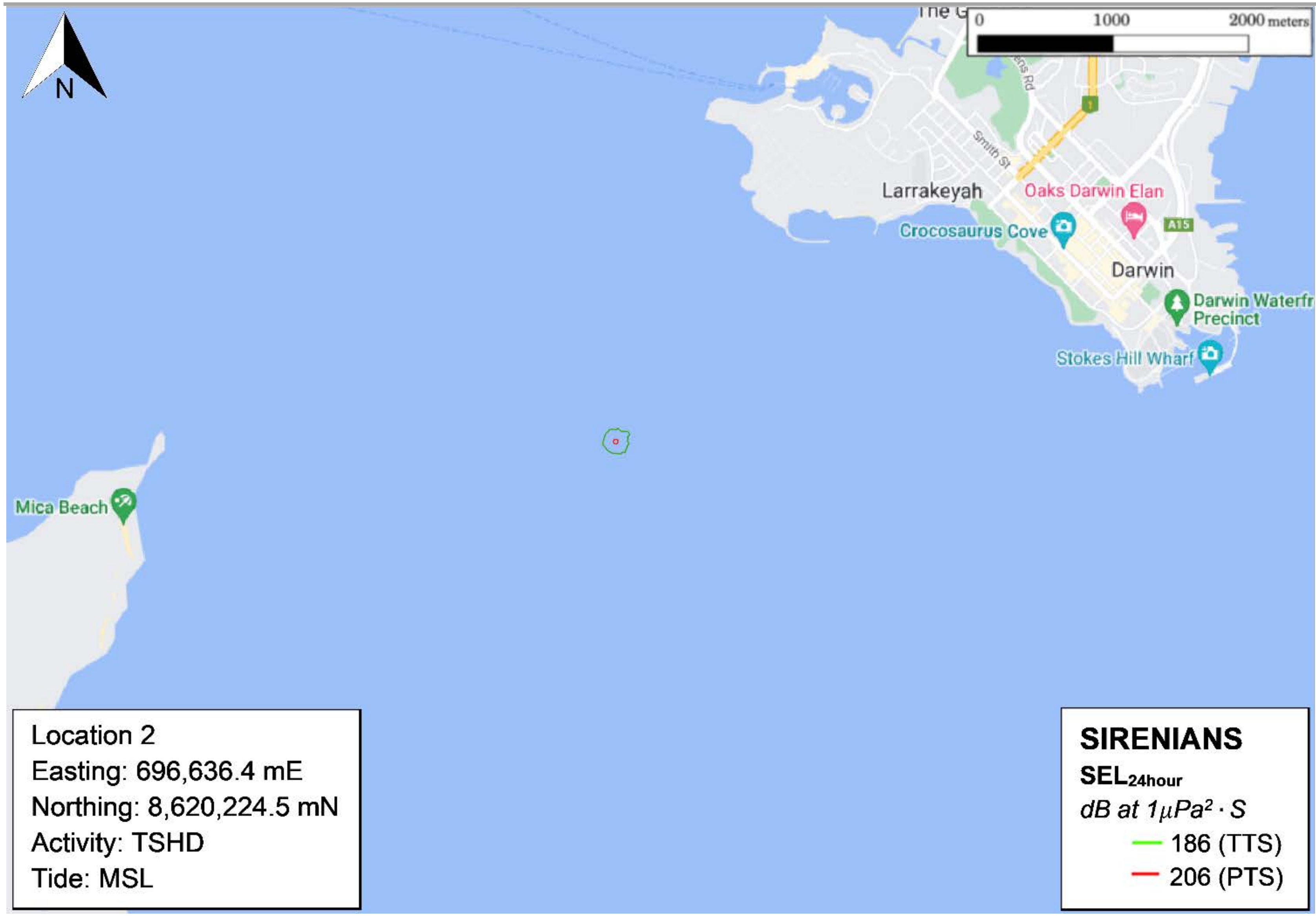

Figure 7-20 : Location 2 – TSHD TTS and PTS Contours for Sirenians (MSL)

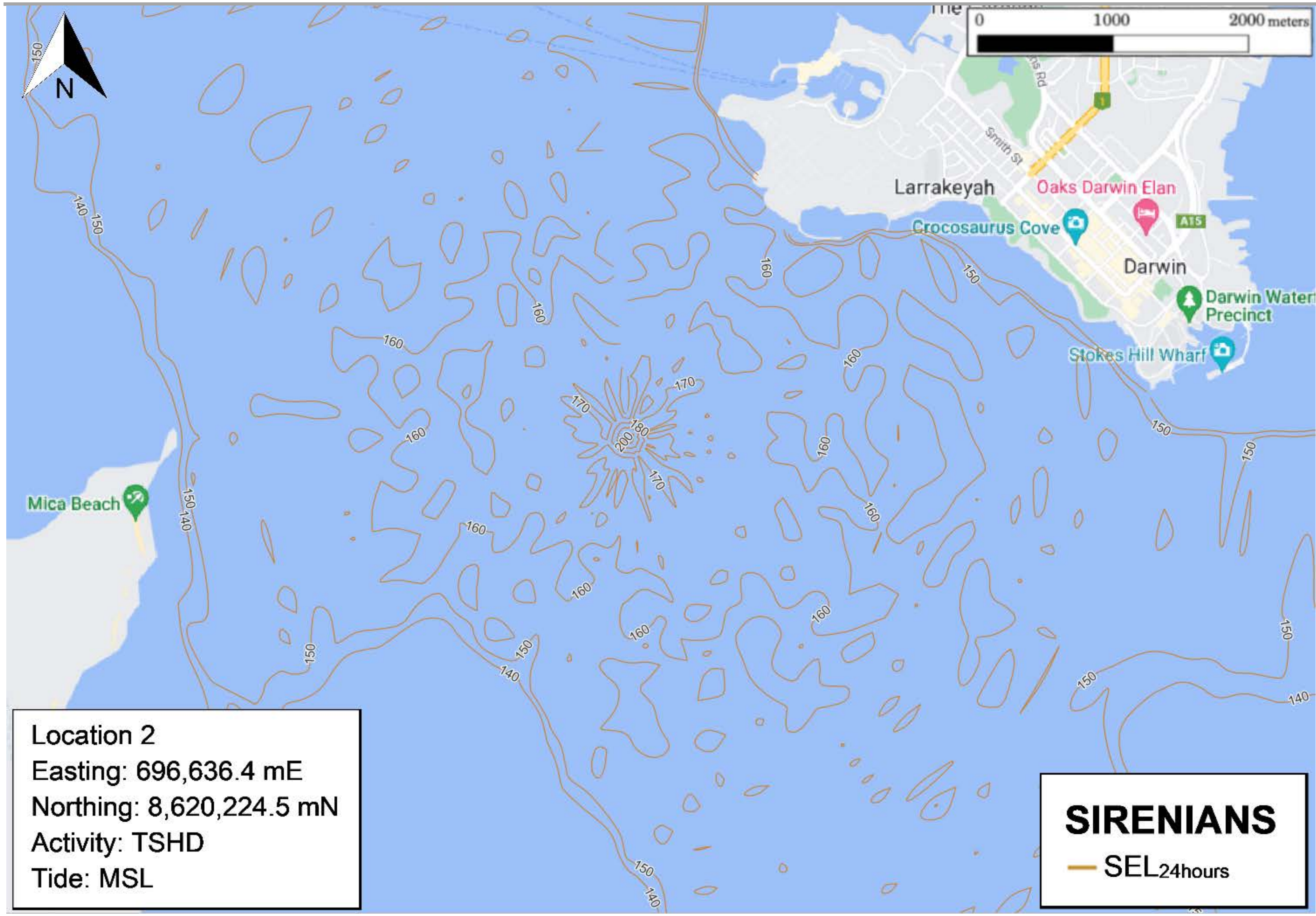

Figure 7-21 : Location 2 – TSHD SEL$_{24\ hours}$ Contours for Sirenians (MSL)

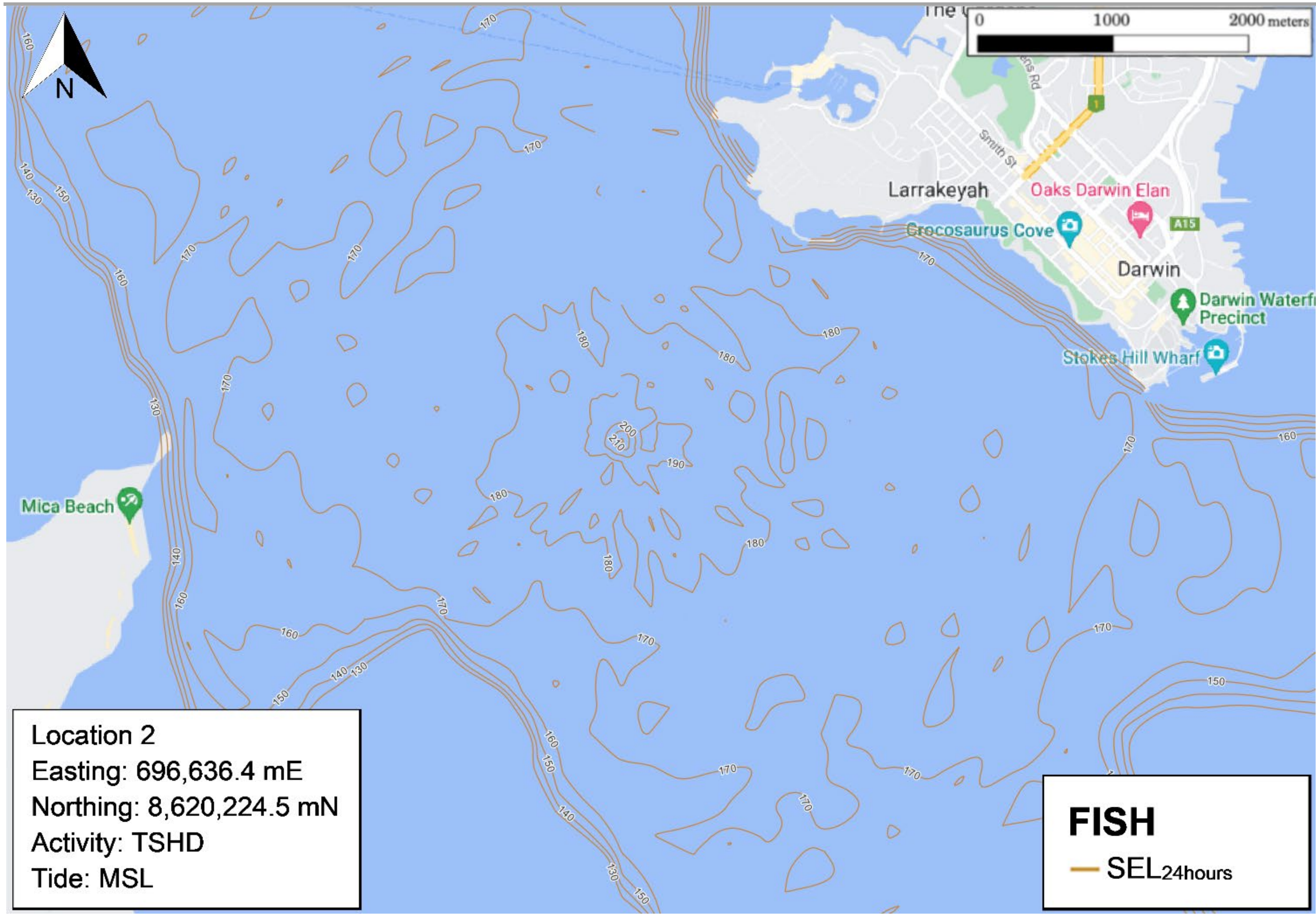

Figure 7-22 : Location 2 – TSHD $SEL_{24\ hours}$ Contours for Fish (MSL)

B.4 Location 3 – TSHD

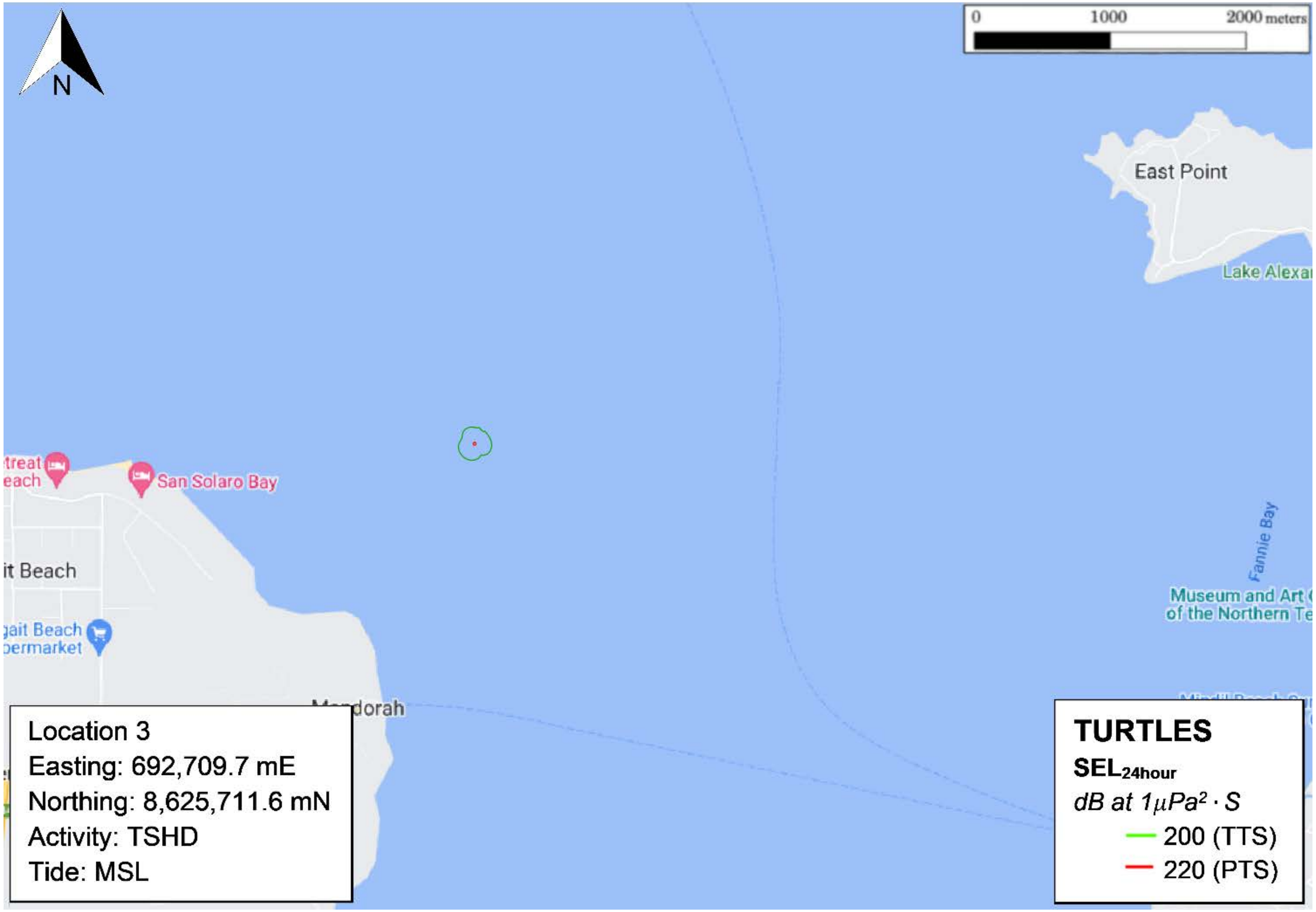

Figure 7-23 :Location 3 – TSHD TTS and PTS Contours for Turtles (MSL)

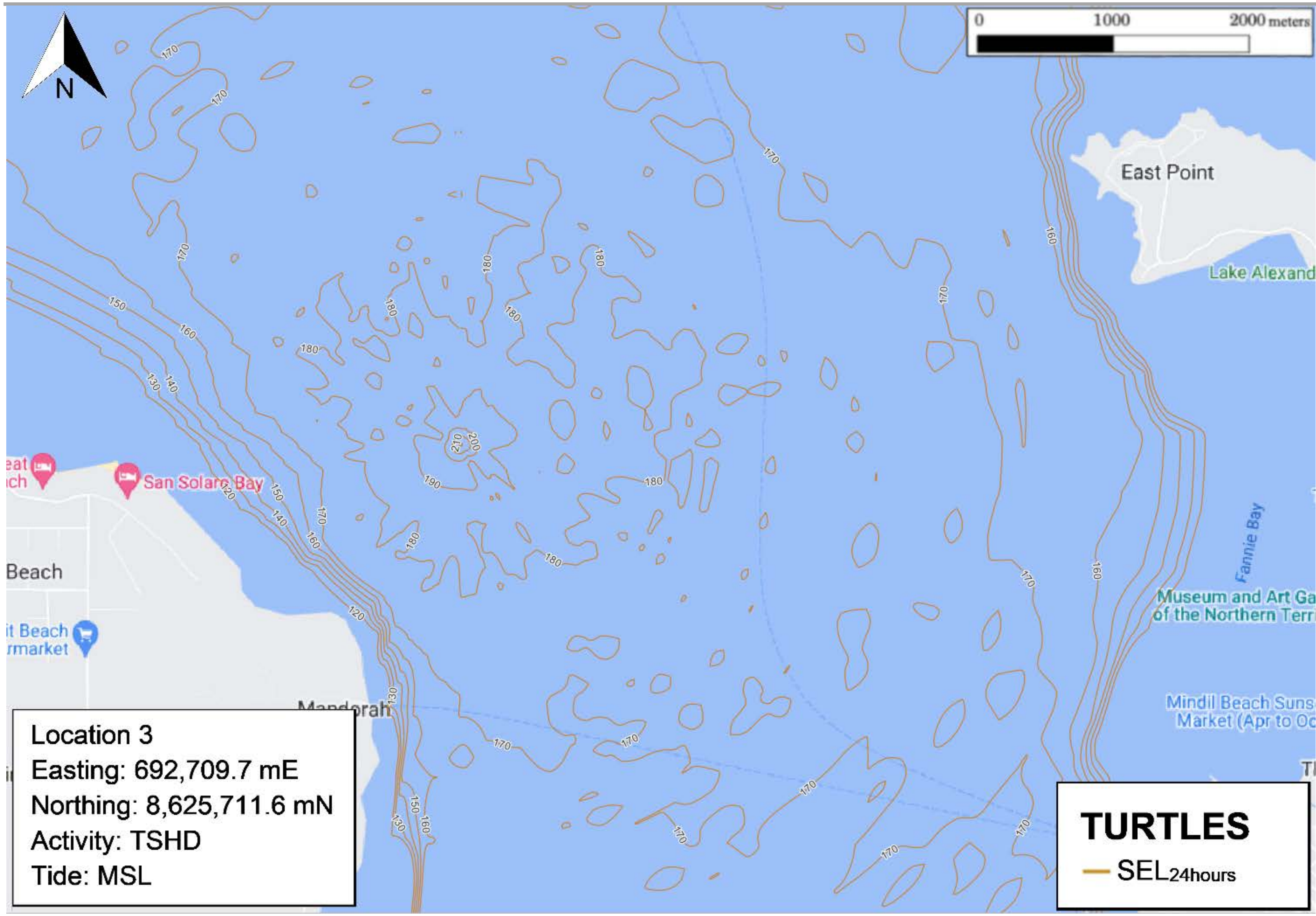

Figure 7-24 : Location 3 – TSHD $SEL_{24\ hours}$ Contours for Turtles (MSL)

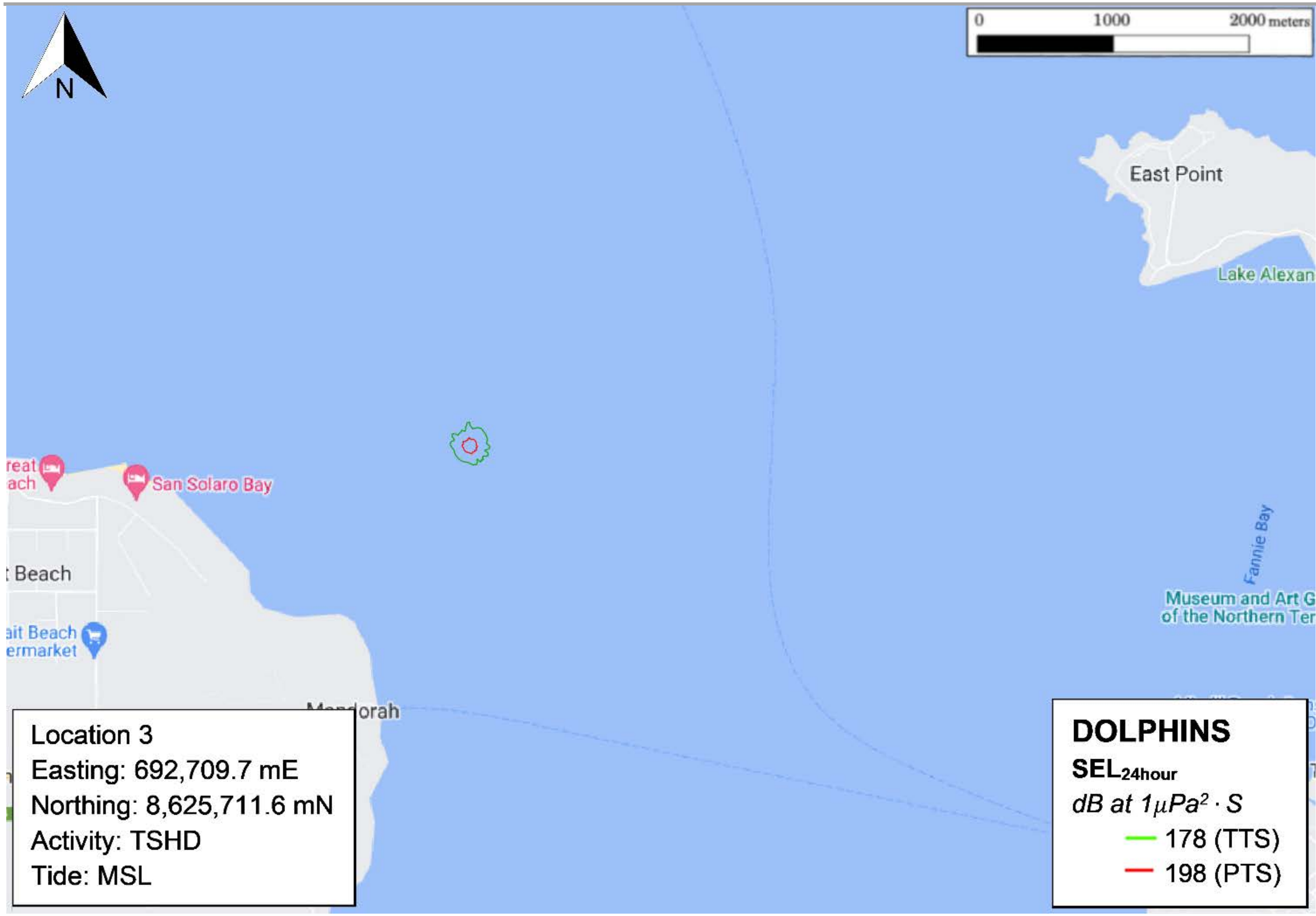

Figure 7-25 : Location 3 – TSHD TTS and PTS Contours for Dolphins (MSL)

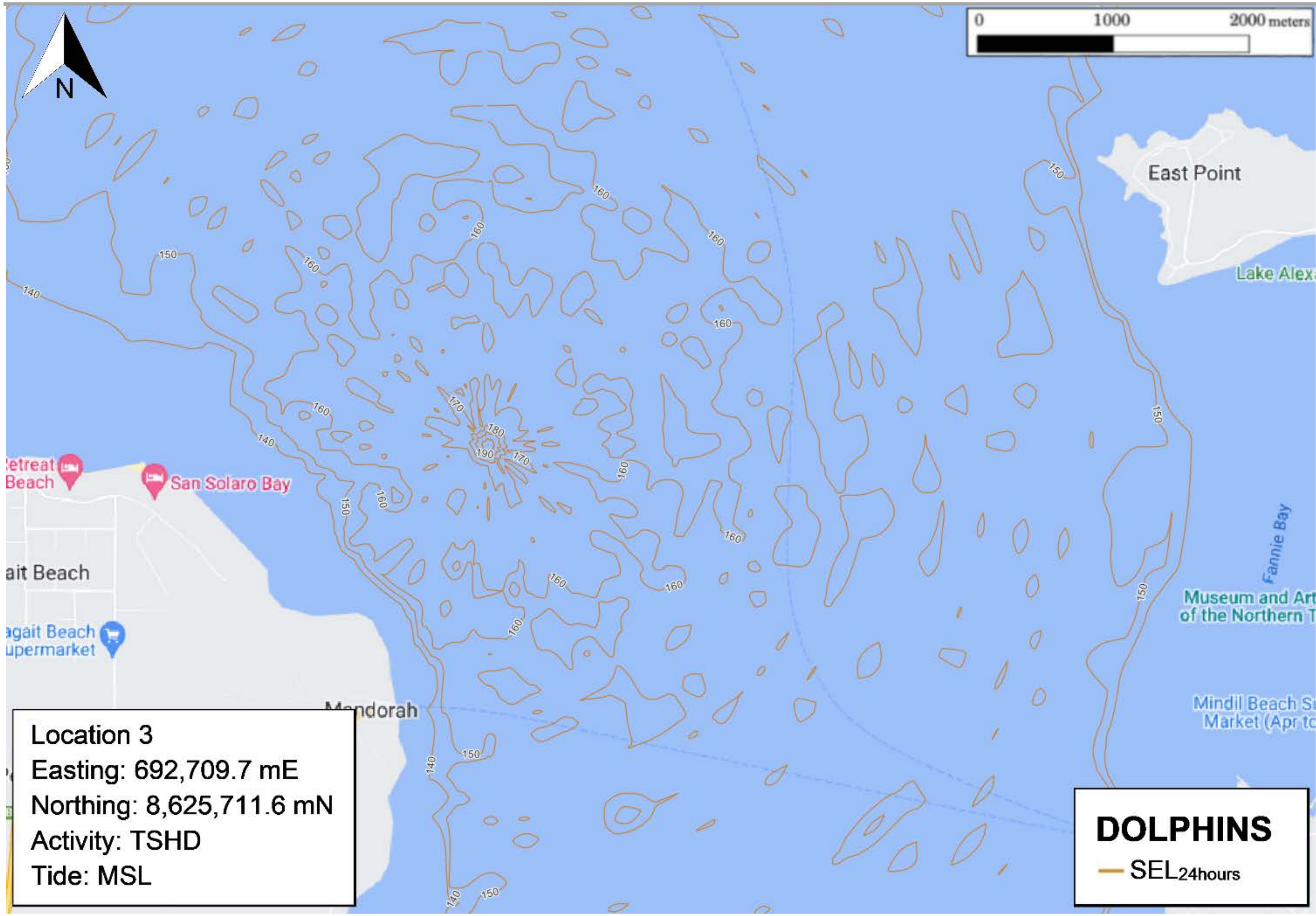

Figure 7-26 : Location 3 – TSHD $SEL_{24\ hours}$ Contours for Dolphins (MSL)

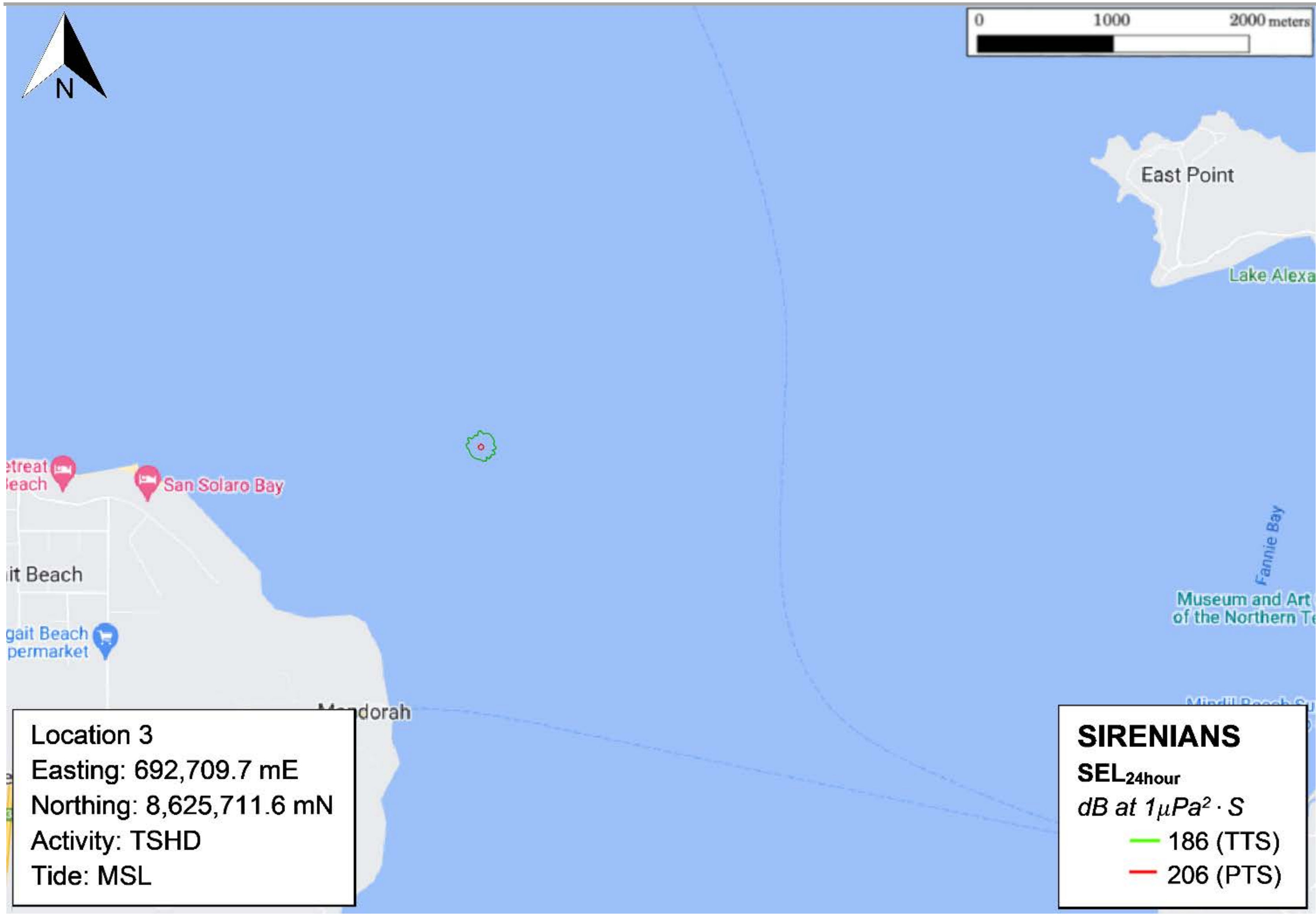

Figure 7-27 : Location 3 – TSHD TTS and PTS Contours for Sirenians (MSL)

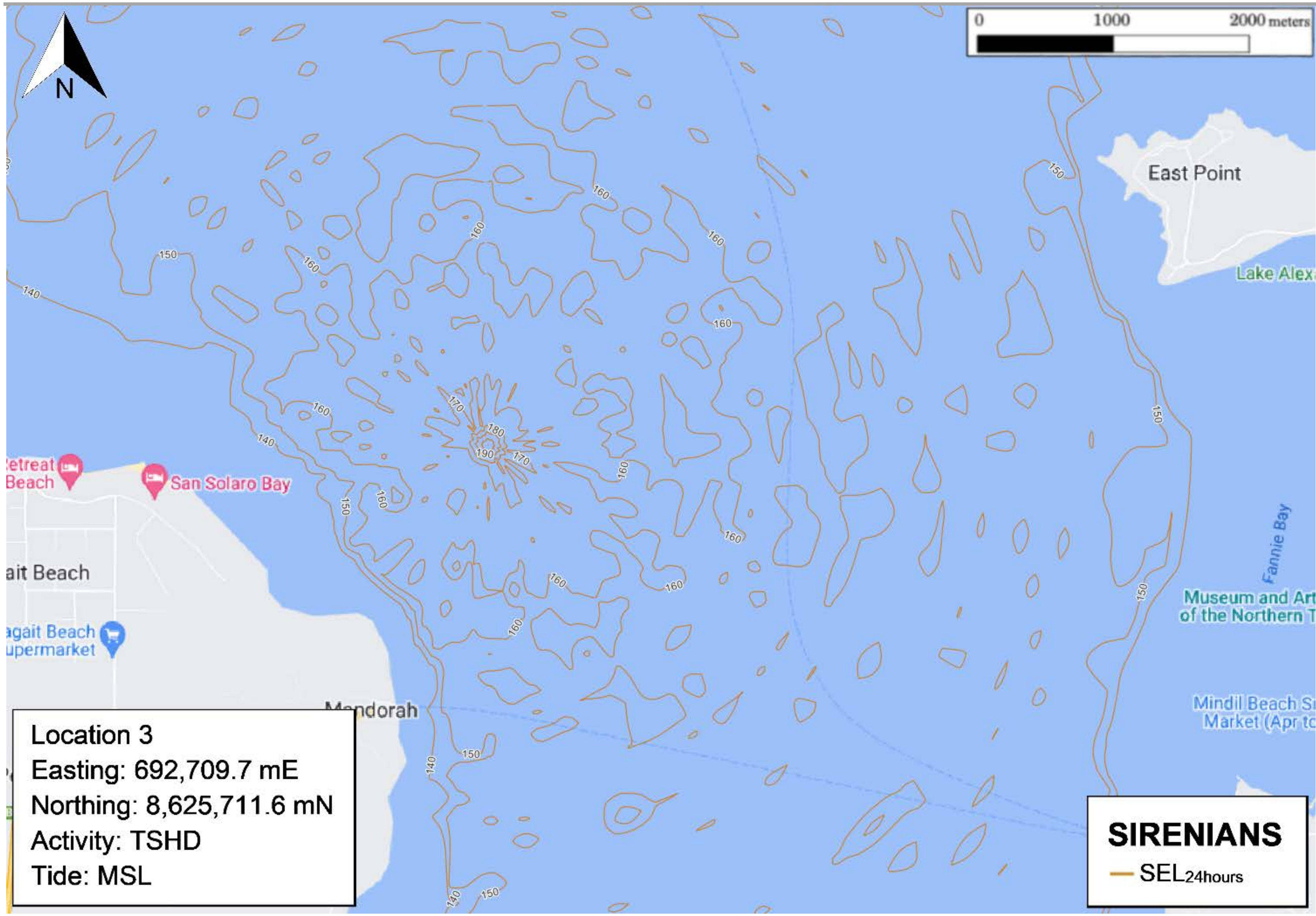

Figure 7-28 : Location 3 – TSHD SEL$_{24\ hours}$ Contours for Sirenians (MSL)

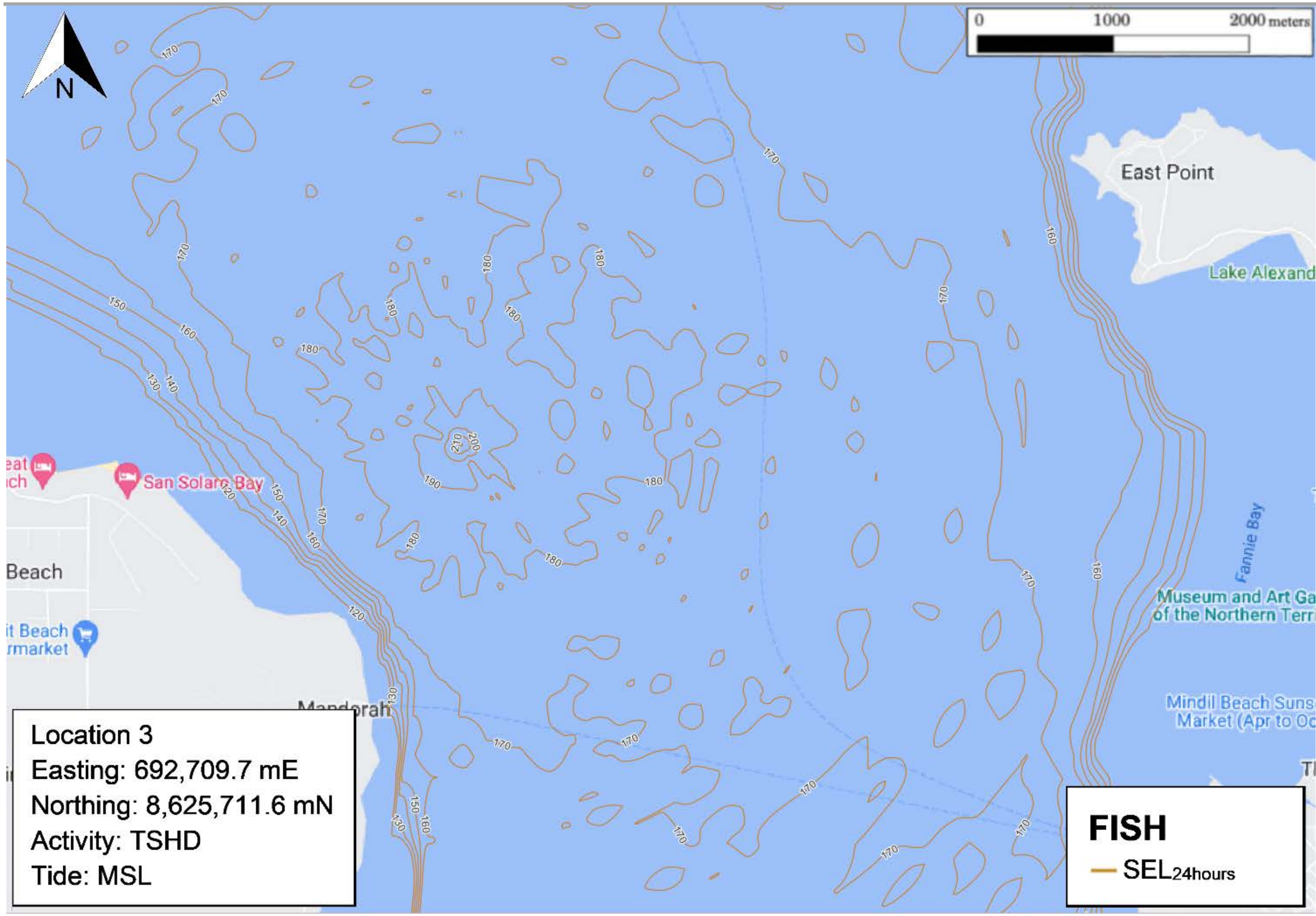

Figure 7-29 : Location 3 – TSHD SEL$_{24\ hours}$ Contours for Fish (MSL)

B.5 Location 3 – TSHD and CSD

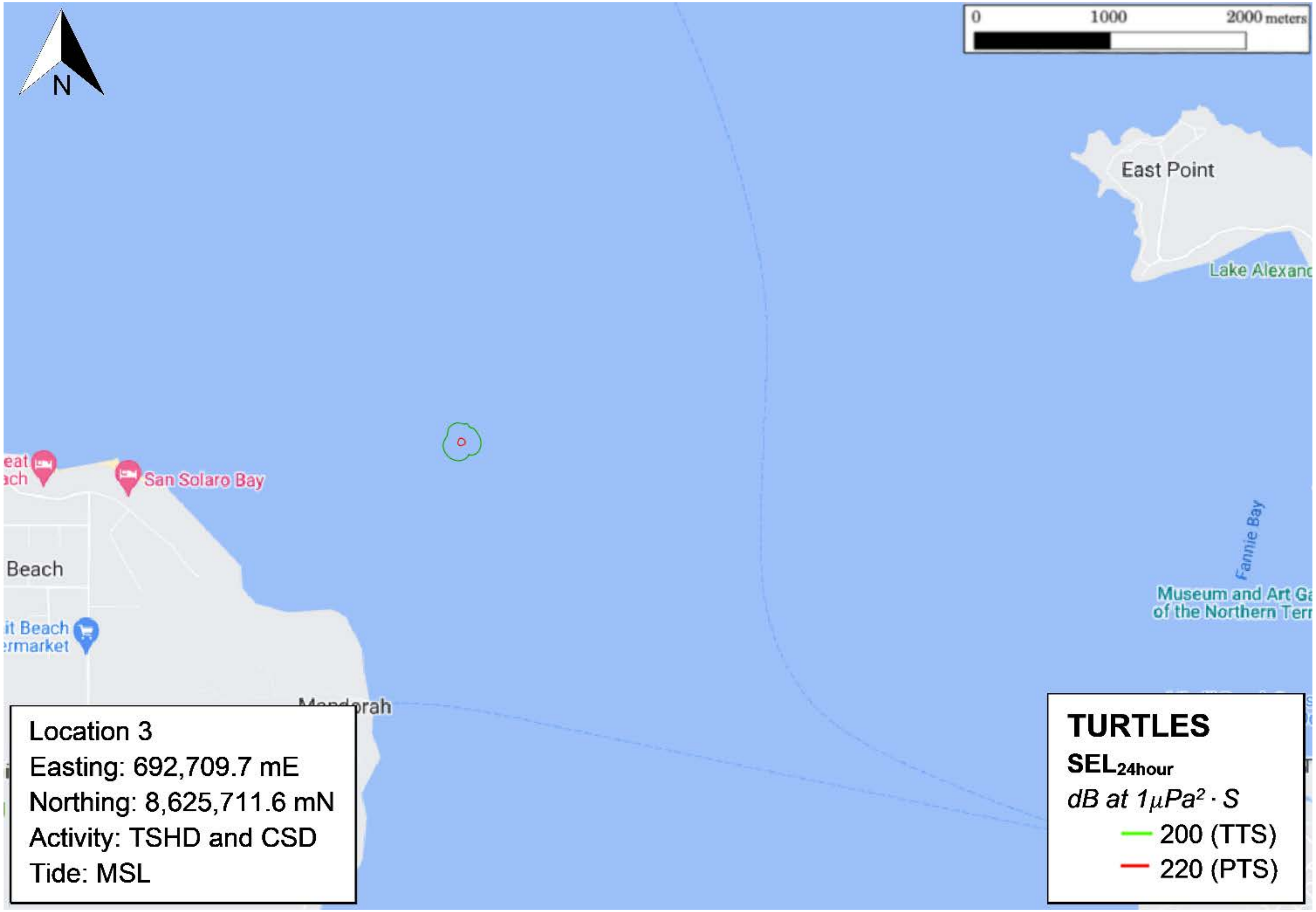

Figure 7-30 :Location 3 – TSHD and CSD TTS and PTS Contours for Turtles (MSL)

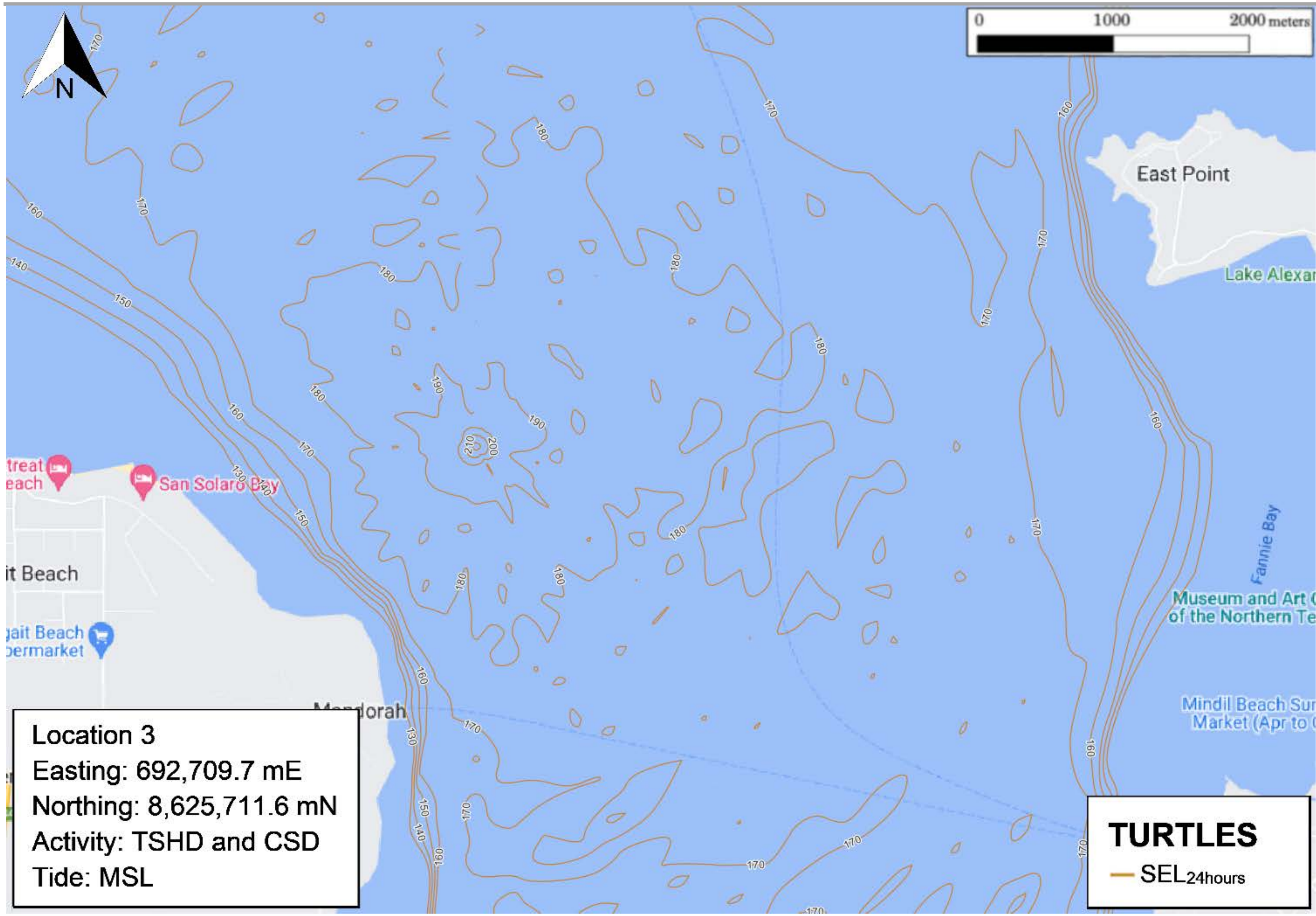

Figure 7-31 : Location 3 – TSHD and CSD $SEL_{24\ hours}$ Contours for Turtles (MSL)

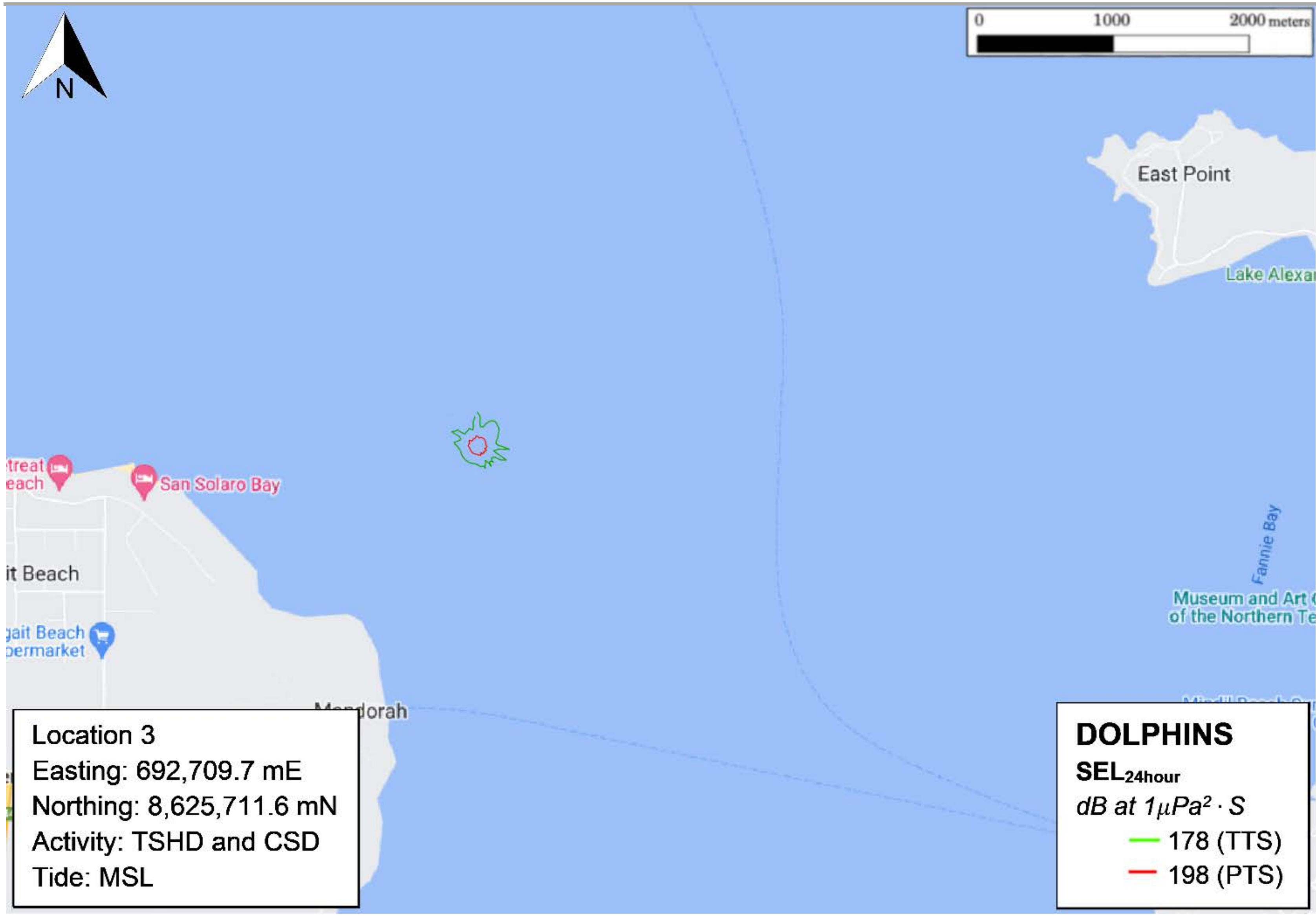

Figure 7-32 : Location 3 – TSHD and CSD TTS and PTS Contours for Dolphins (MSL)

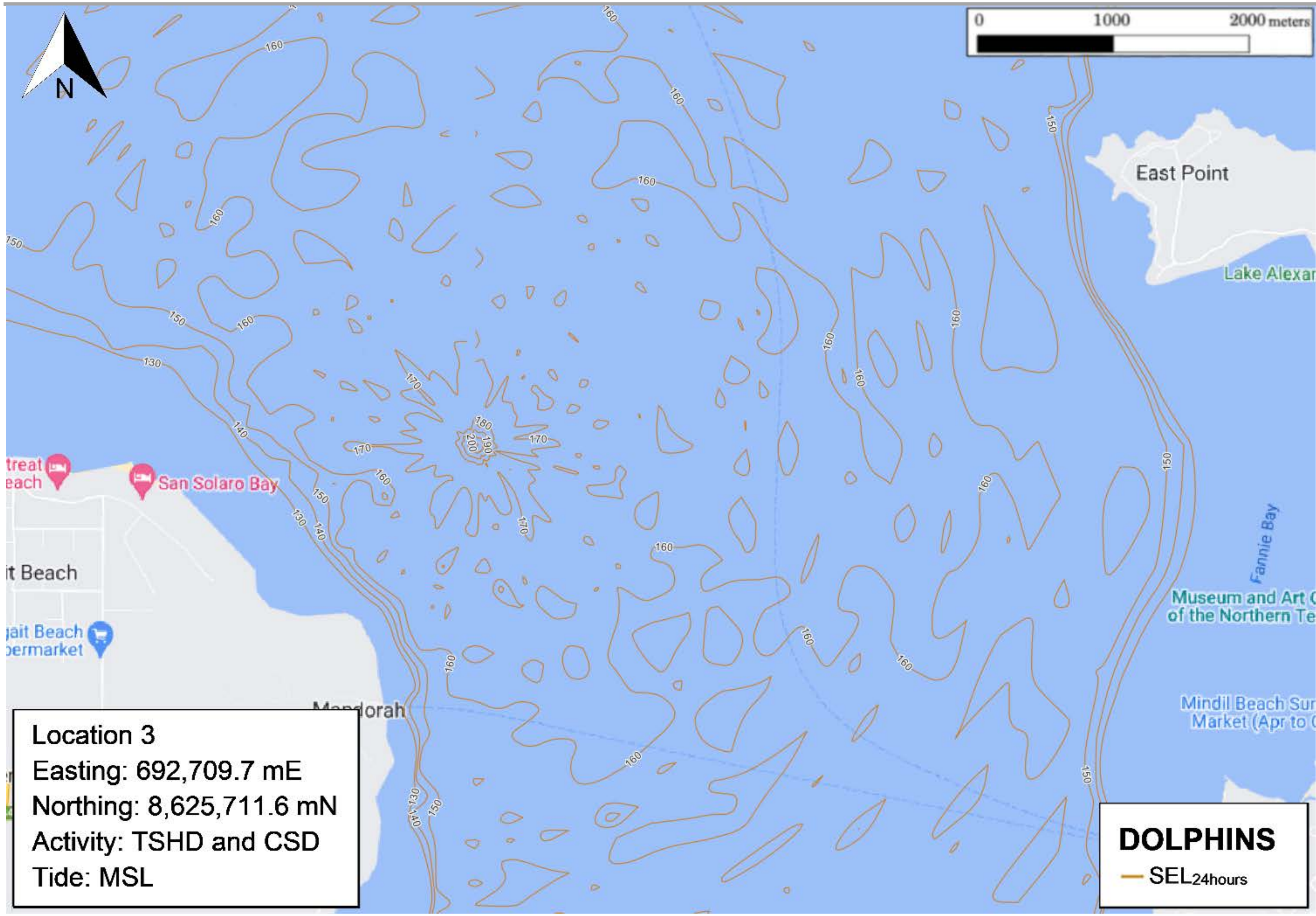

Figure 7-33 : Location 3 – TSHD and CSD SEL$_{24\ hours}$ Contours for Dolphins (MSL)

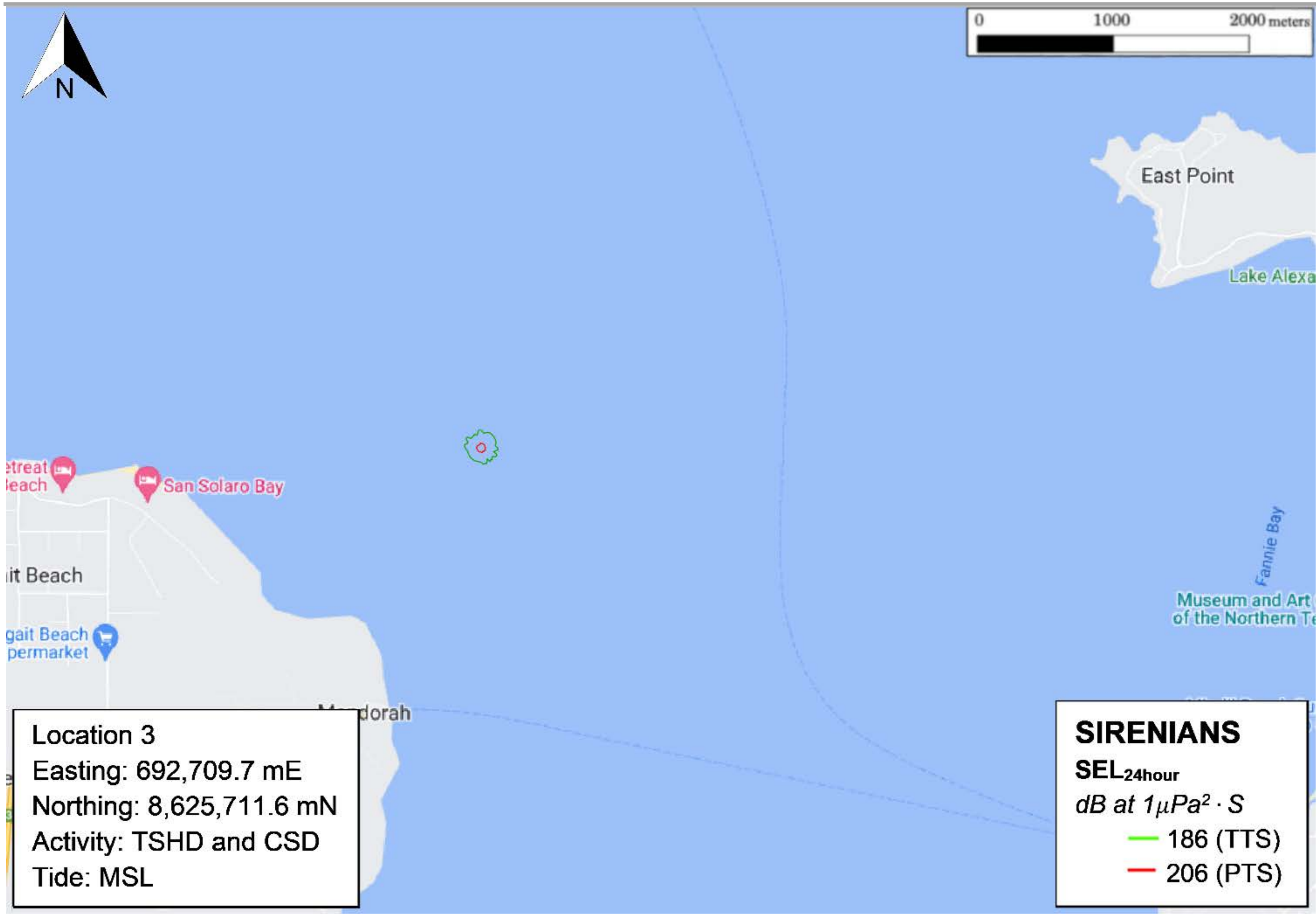

Figure 7-34 : Location 3 – TSHD and CSD TTS and PTS Contours for Sirenians (MSL)

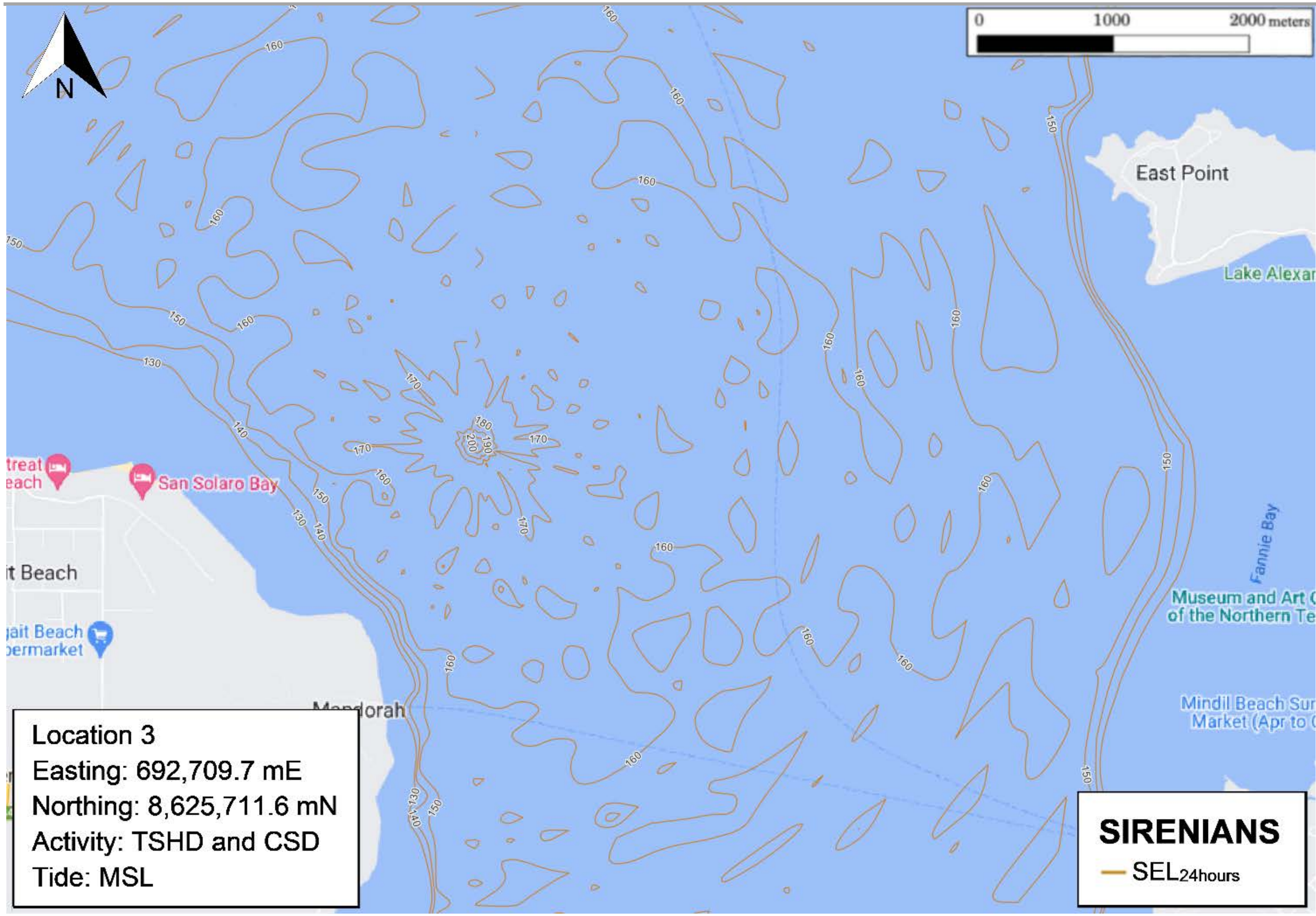

Figure 7-35 : Location 3 – TSHD and CSD SEL$_{24\ hours}$ Contours for Sirenians (MSL)

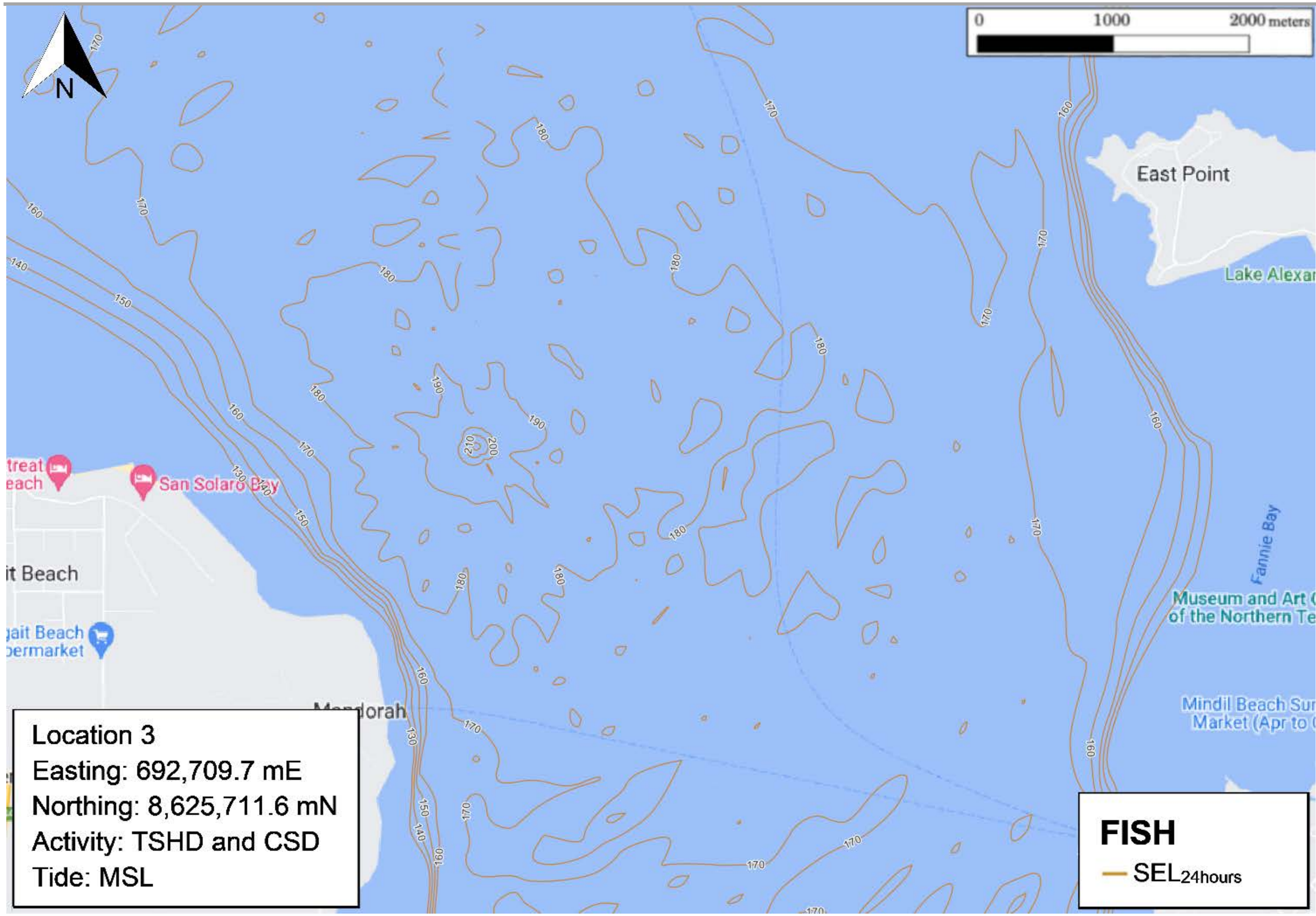

Figure 7-36 : Location 3 – TSHD and CSD $SEL_{24\ hours}$ Contours for Fish (MSL)

B.6 Location 4 – Sheet Piling

Figure 7-37 :Location 4 – Sheet Piling TTS and PTS Contours for Turtles (MSL)

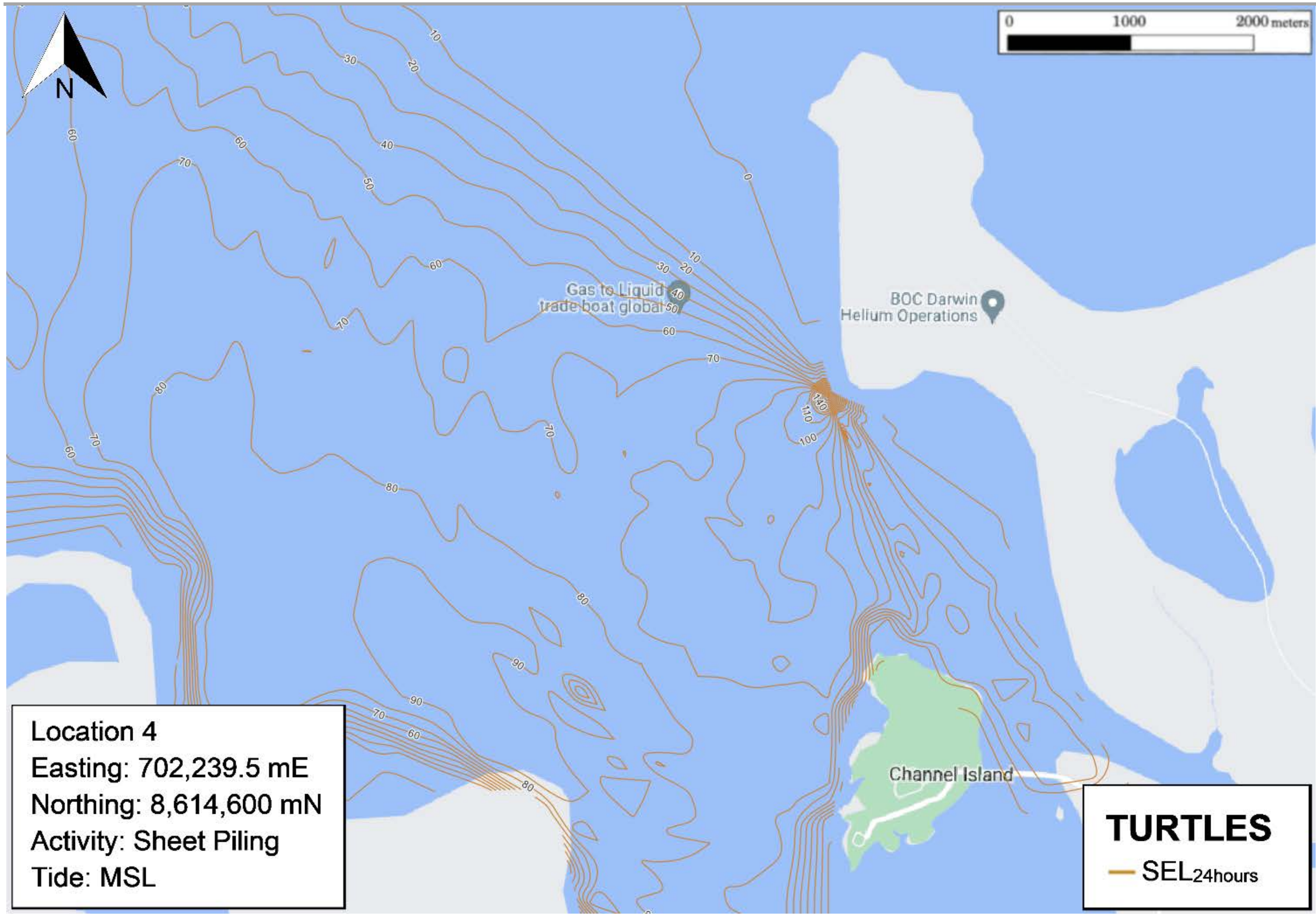

Figure 7-38 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Turtles (MSL)

Figure 7-39 : Location 4 – Sheet Piling TTS and PTS Contours for Dolphins (MSL)

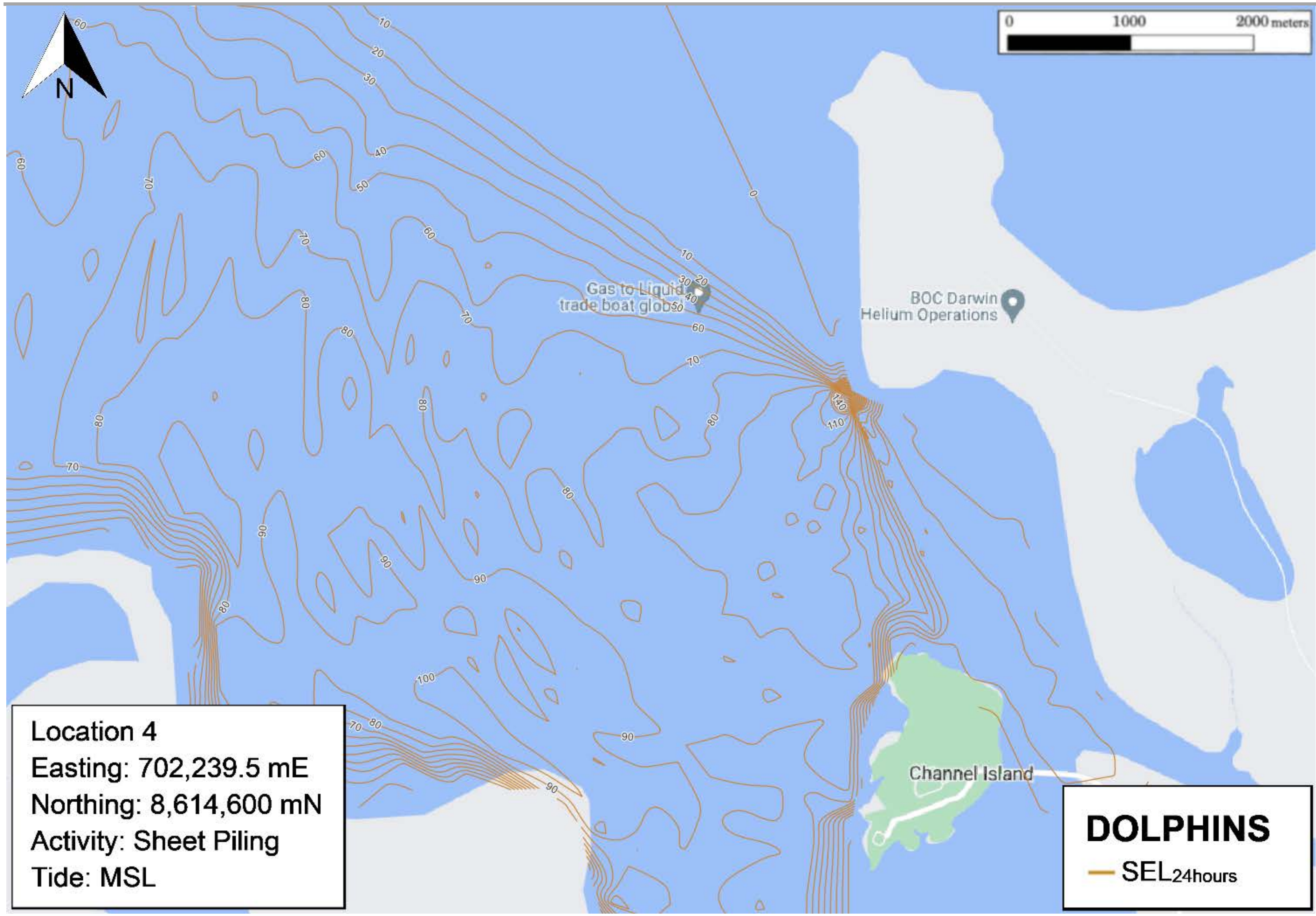

Figure 7-40 : Location 4 – Sheet Piling SEL$_{24\ hours}$ Contours for Dolphins (MSL)

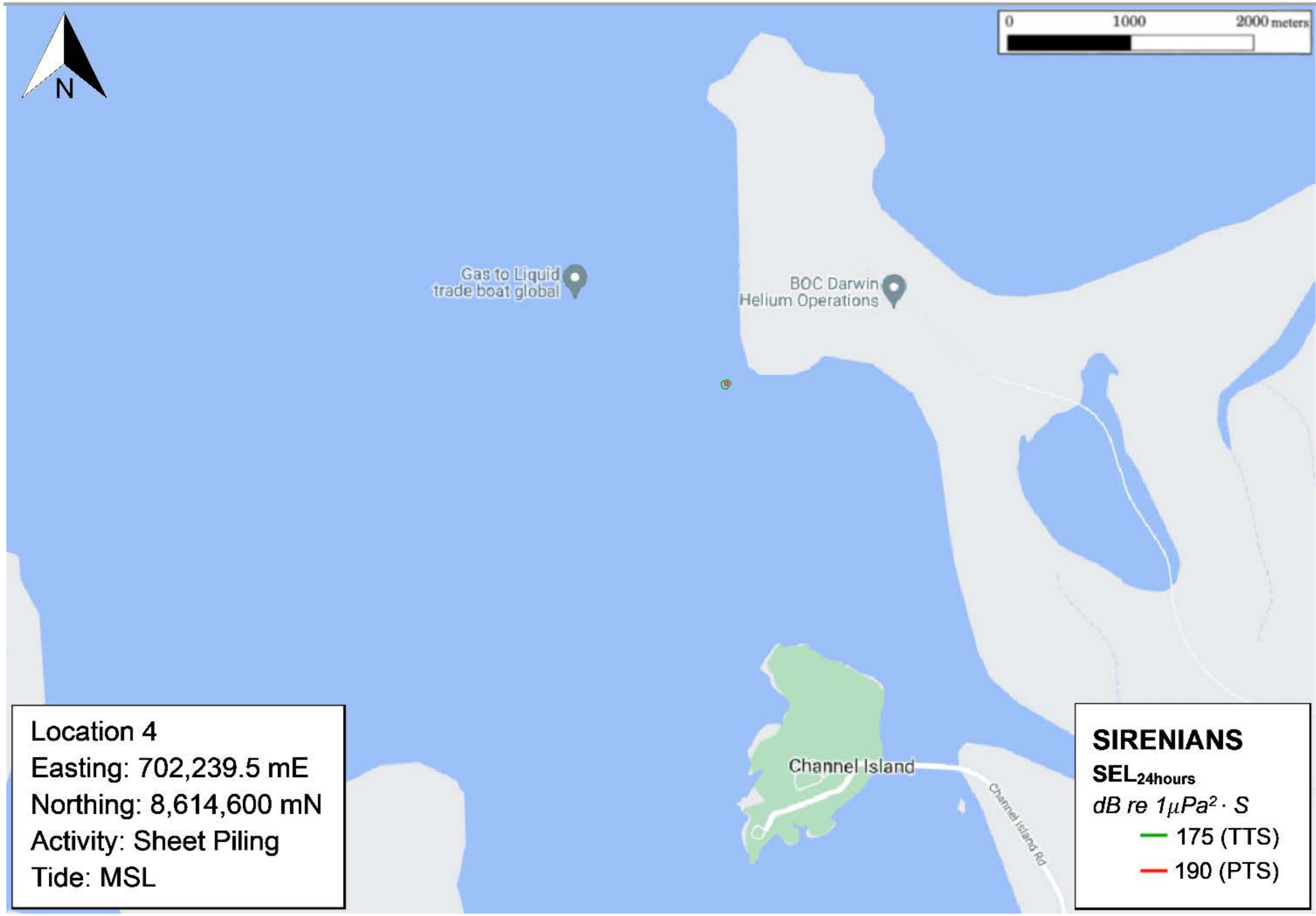

Figure 7-41 : Location 4 – Sheet Piling TTS and PTS Contours for Sirenians (MSL)

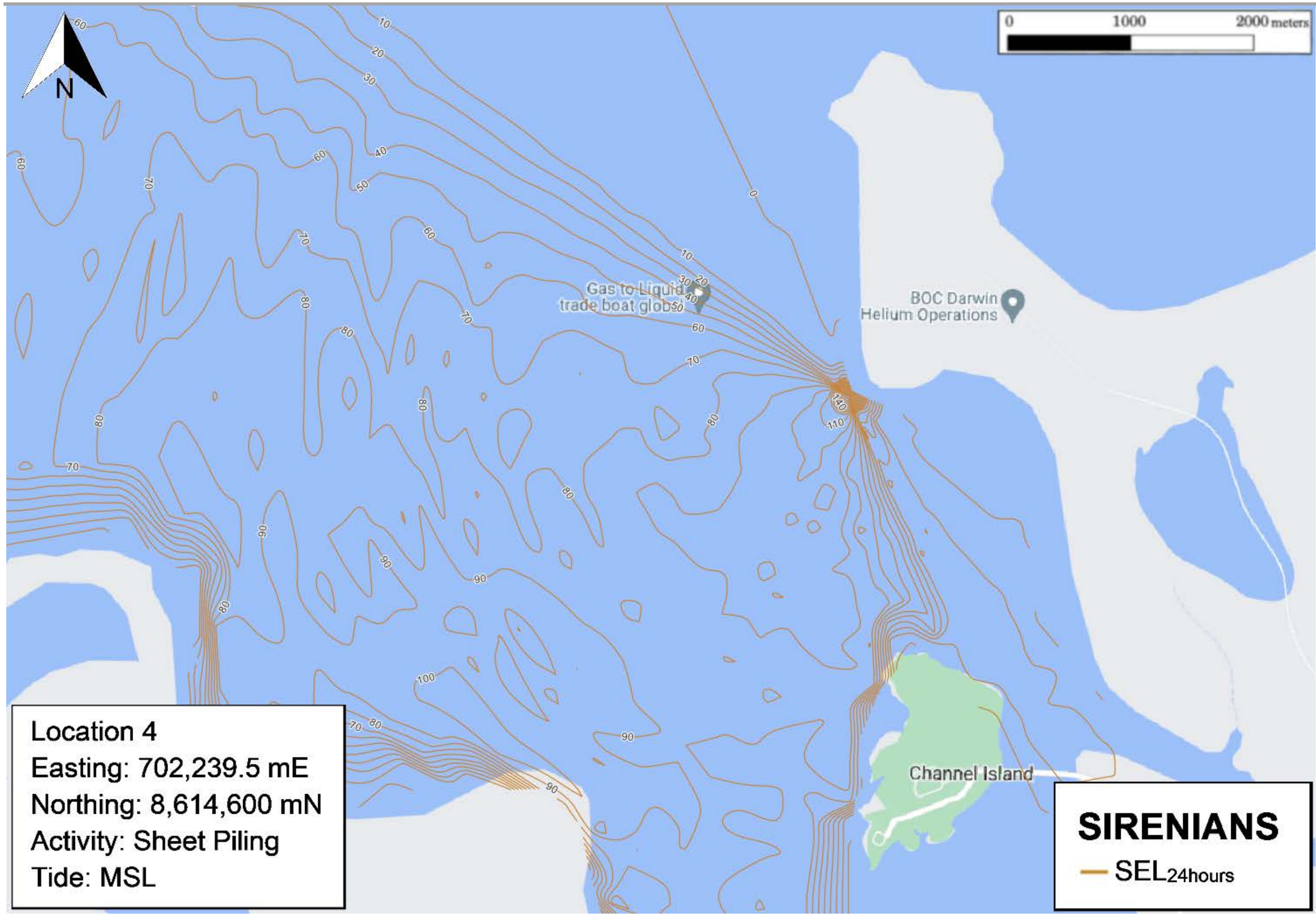

Figure 7-42 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Sirenians (MSL)

Figure 7-43 : Location 4 – Sheet Piling TTS and PTS Contours for Fish (MSL)

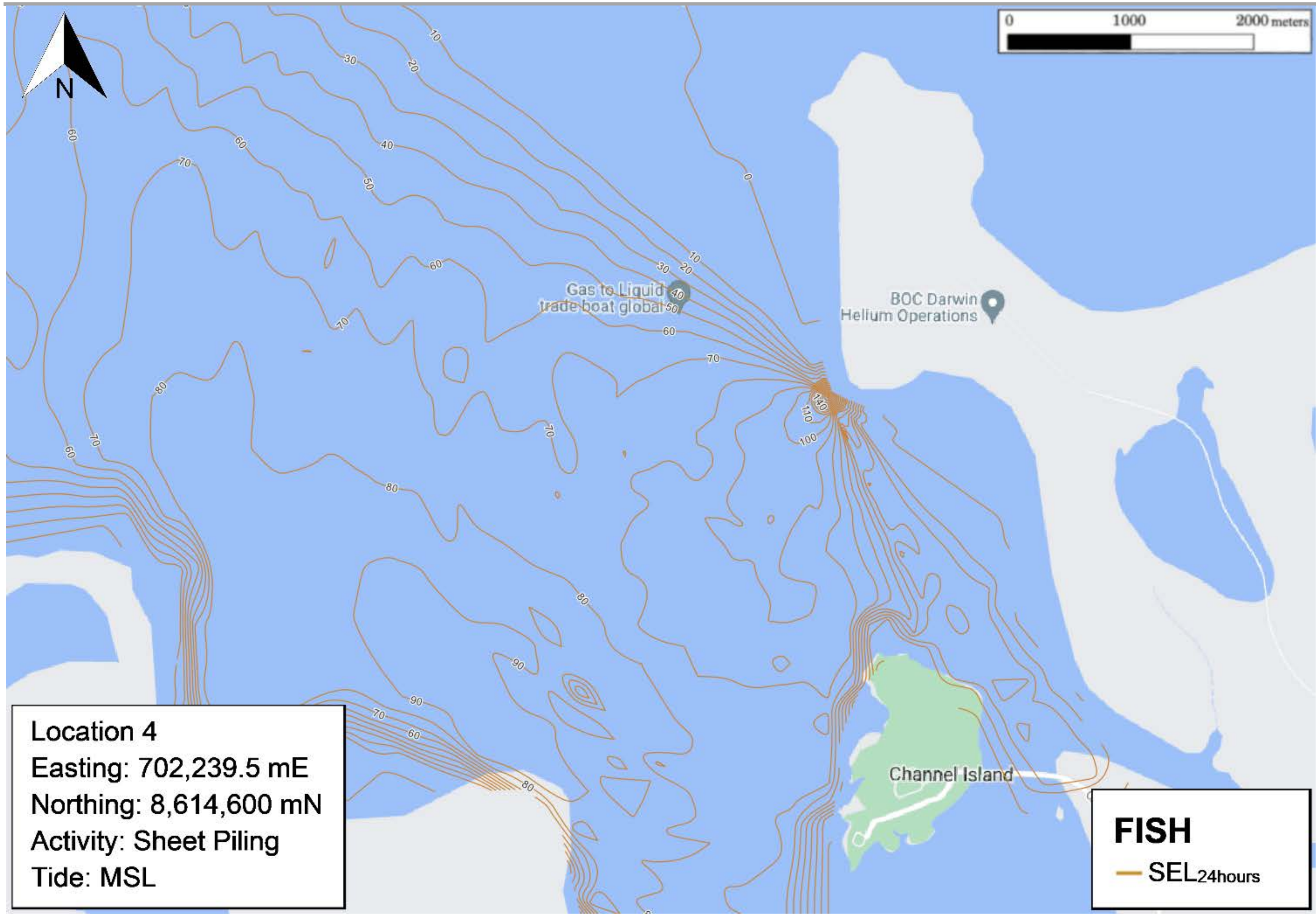

Figure 7-44 : Location 4 – Sheet Piling $SEL_{24\ hours}$ Contours for Fish (MSL)

APPENDIX C
Behavioural Contours

C.1 Location 1 – BHD

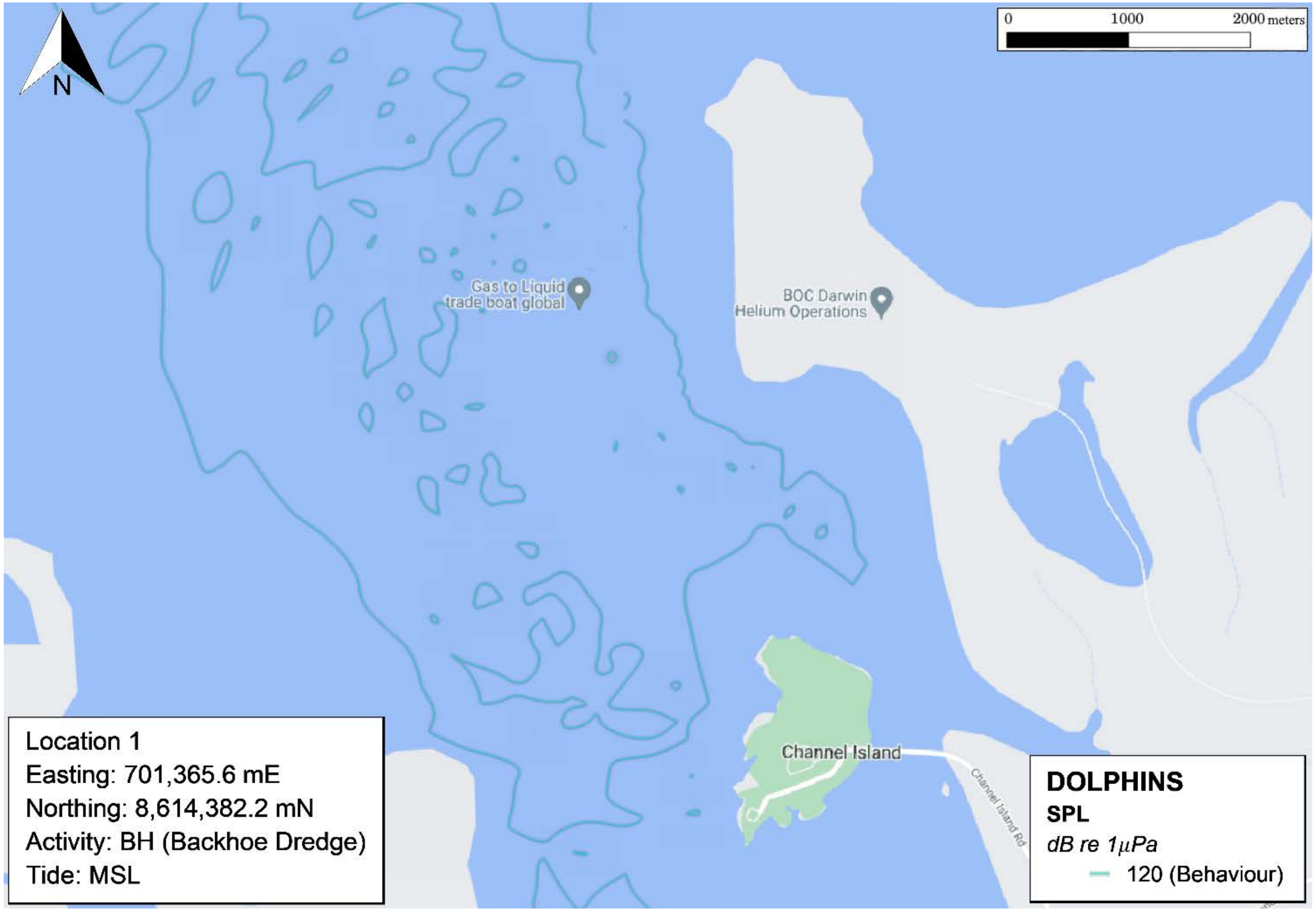

Figure 7-45 : Location 1 – BHD Behavioural Contours for Dolphins (MSL)

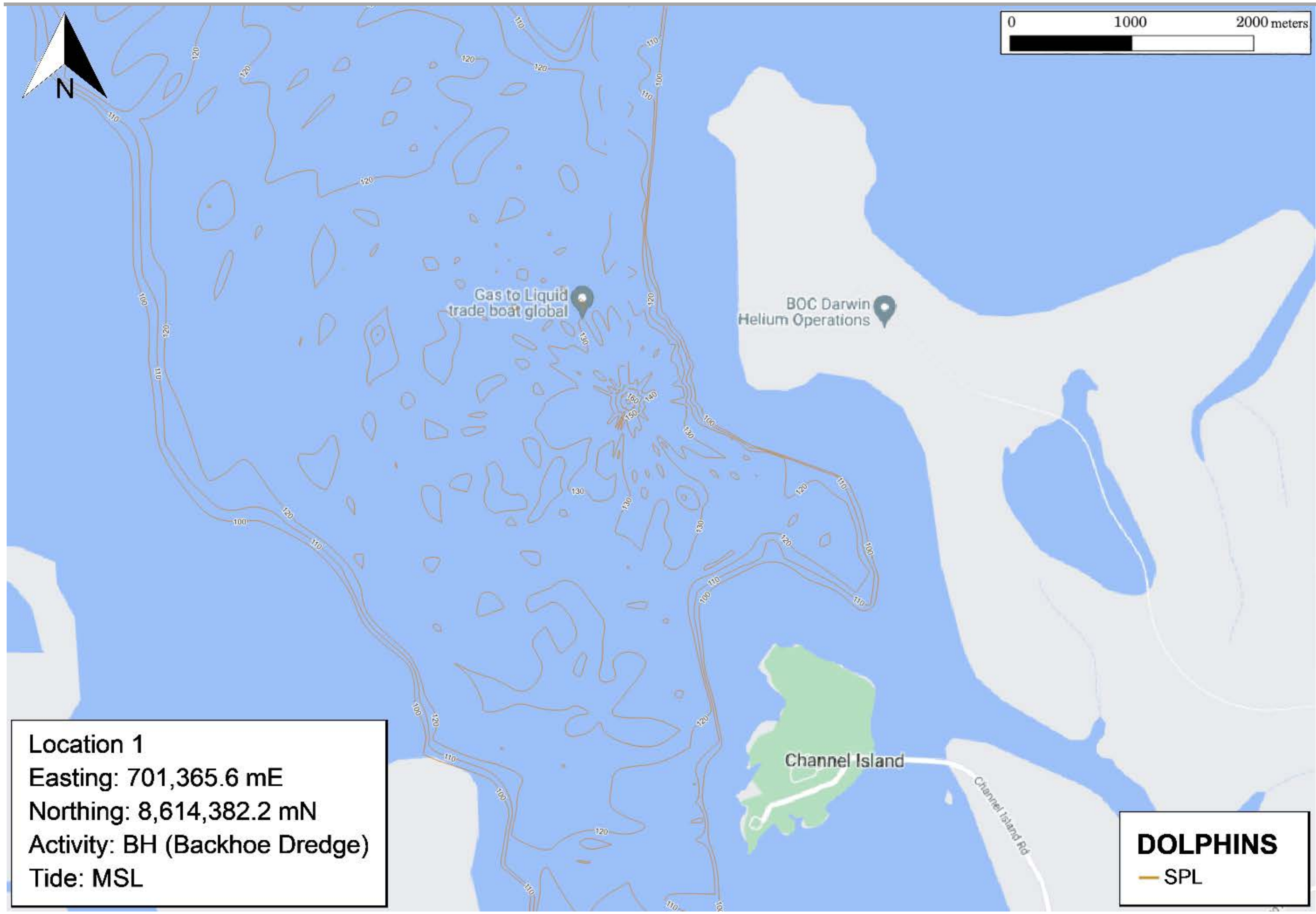

Figure 7-46 : Location 1 – BHD SPL Contours for Dolphins (MSL)

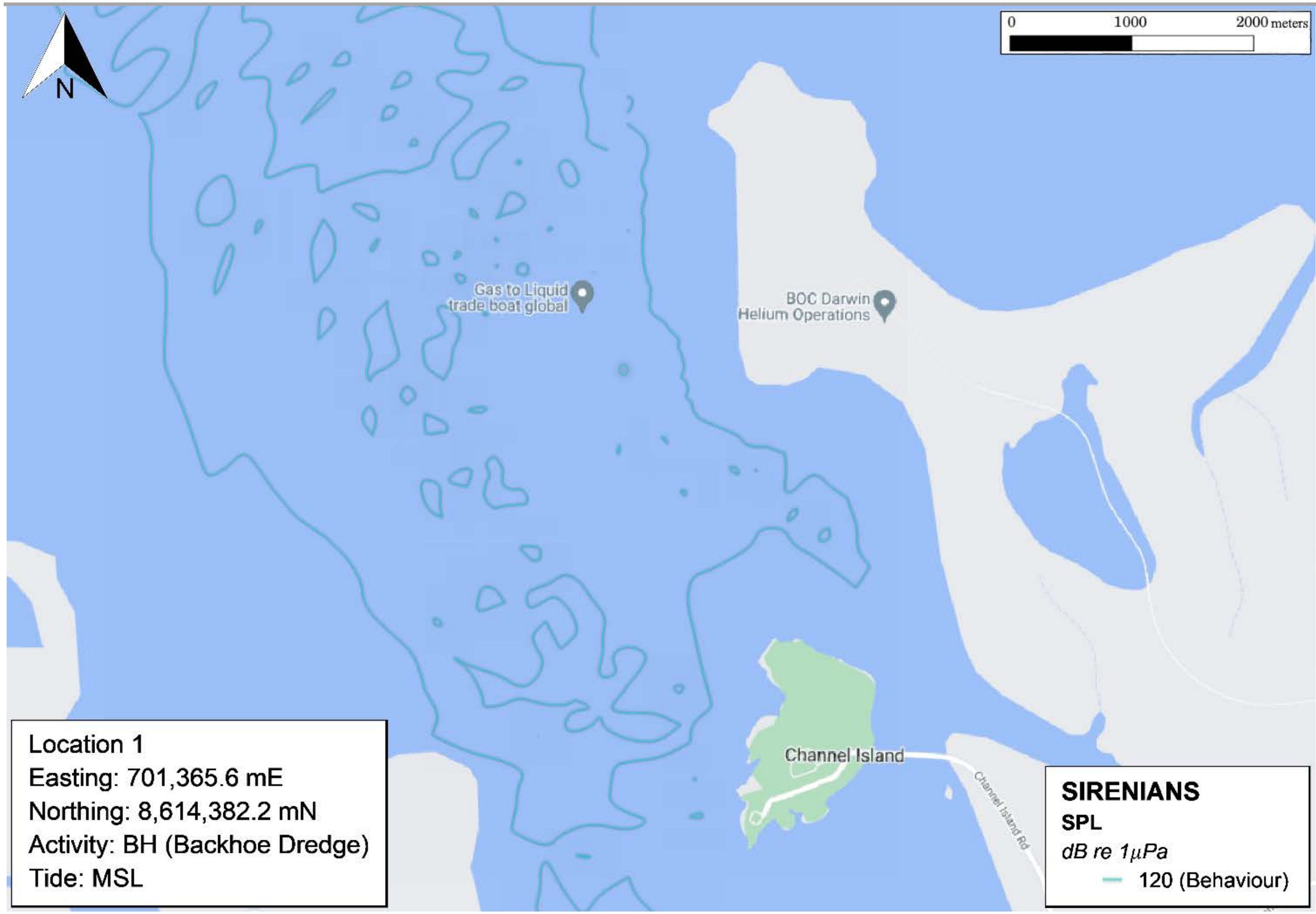

Figure 7-47 : Location 1 – BHD Behavioural Contours for Sirenians (MSL)

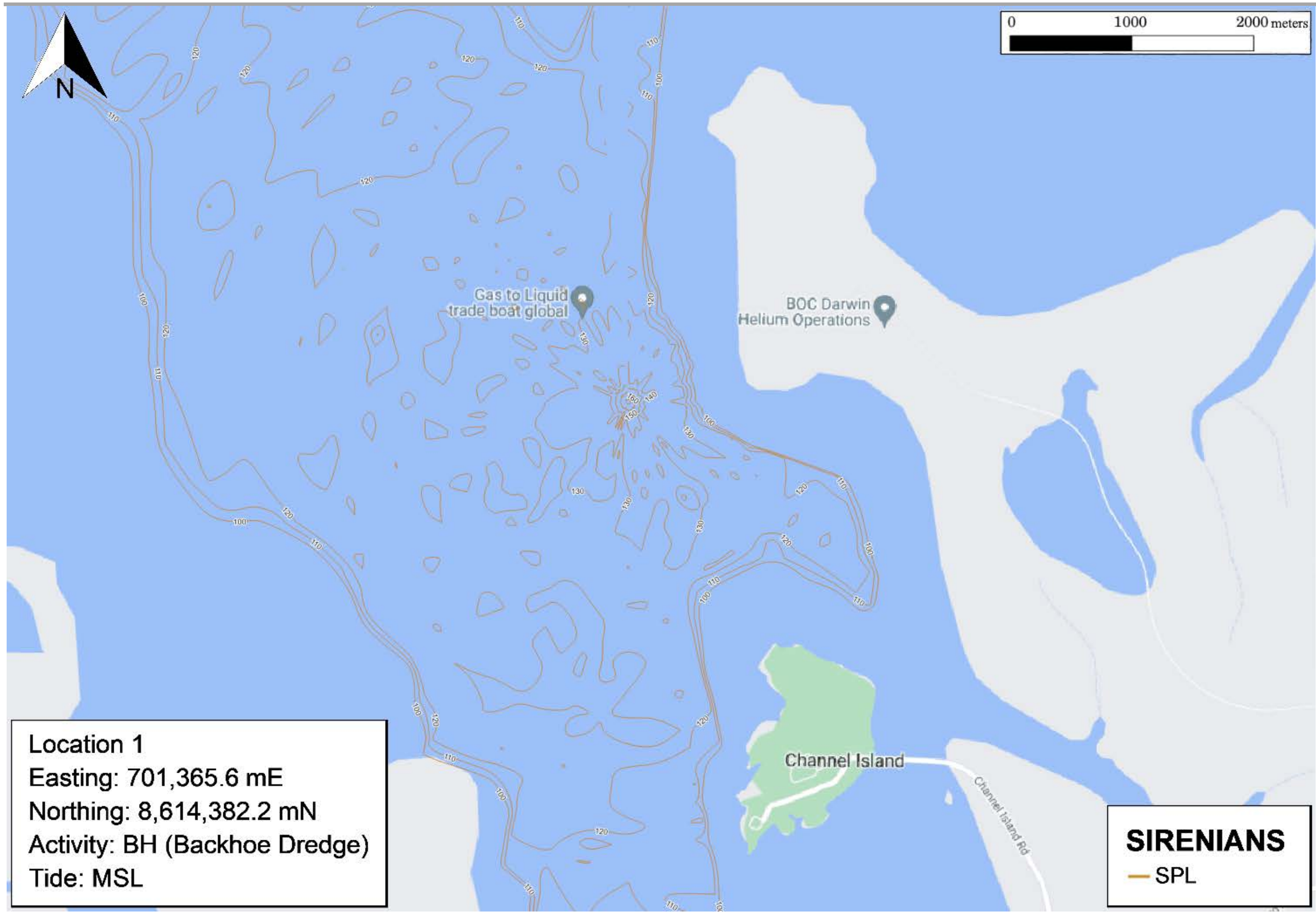

Figure 7-48 : Location 1 – BHD SPL Contours for Sirenians (MSL)

C.2 Location 1 – BHD (Hammer)

Figure 7-49 :Location 1 – BHD (Hammer) Behavioural Contours for Turtles (MSL)

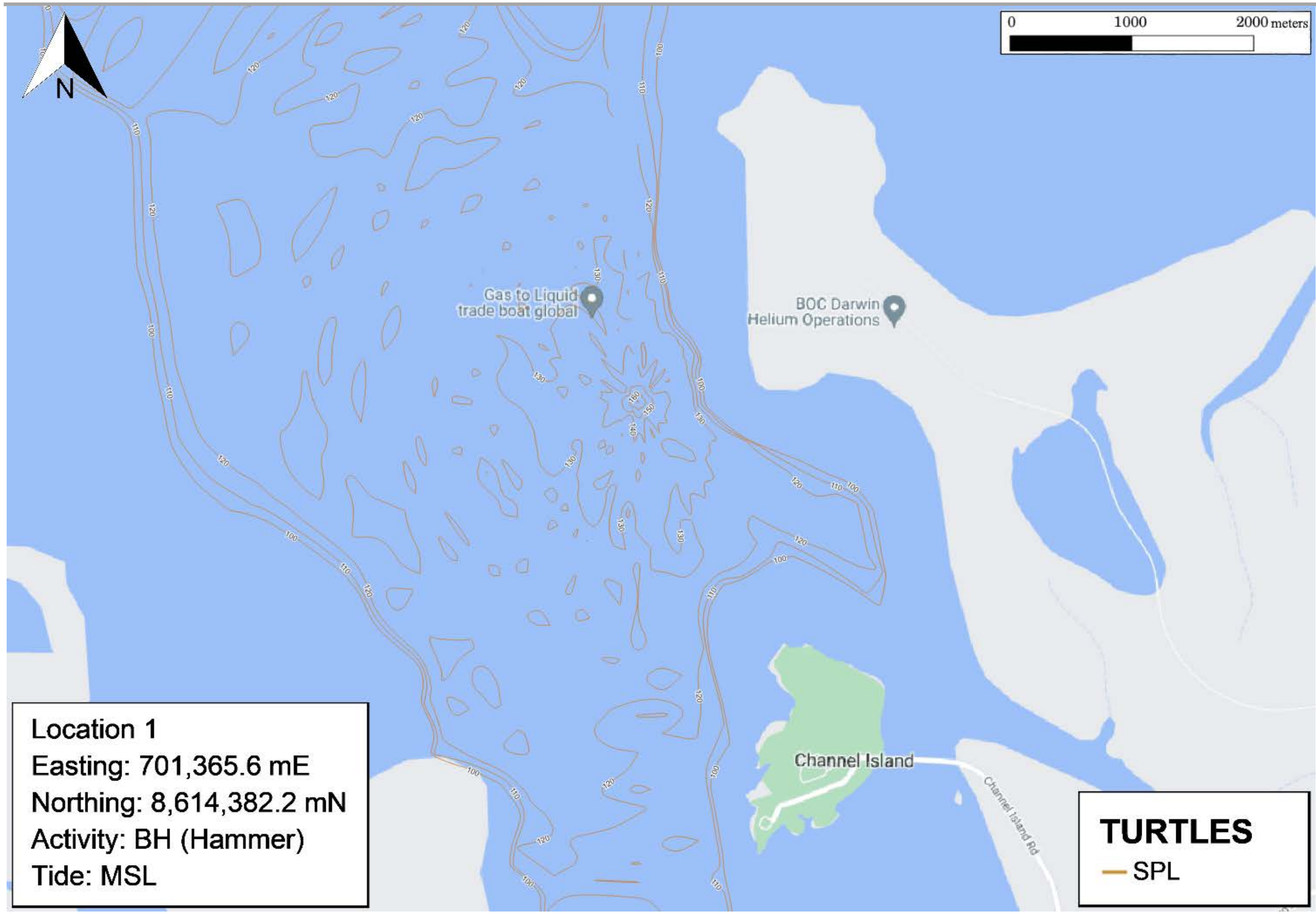

Figure 7-50 : Location 1 – BHD (Hammer) SPL Contours for Turtles (MSL)

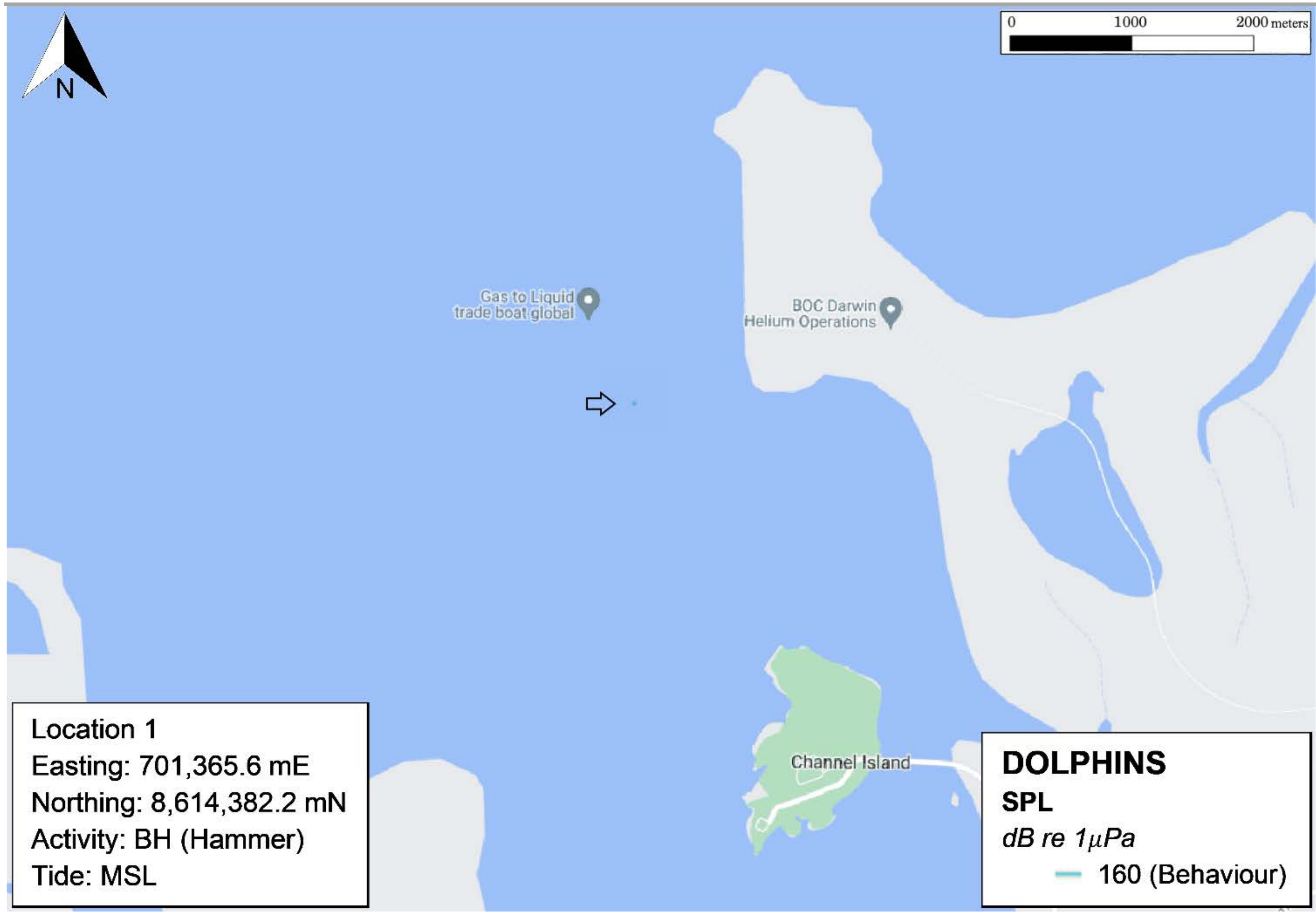

Figure 7-51 : Location 1 – BHD (Hammer) Behavioural Contours for Dolphins (MSL)

Figure 7-52 : Location 1 – BHD (Hammer) SPL Contours for Dolphins (MSL)

Figure 7-53 : Location 1 – BHD (Hammer) Behavioural Contours for Sirenians (MSL)

Figure 7-54 : Location 1 – BHD (Hammer) SPL Contours for Sirenians (MSL)

C.3 Location 2 – TSHD

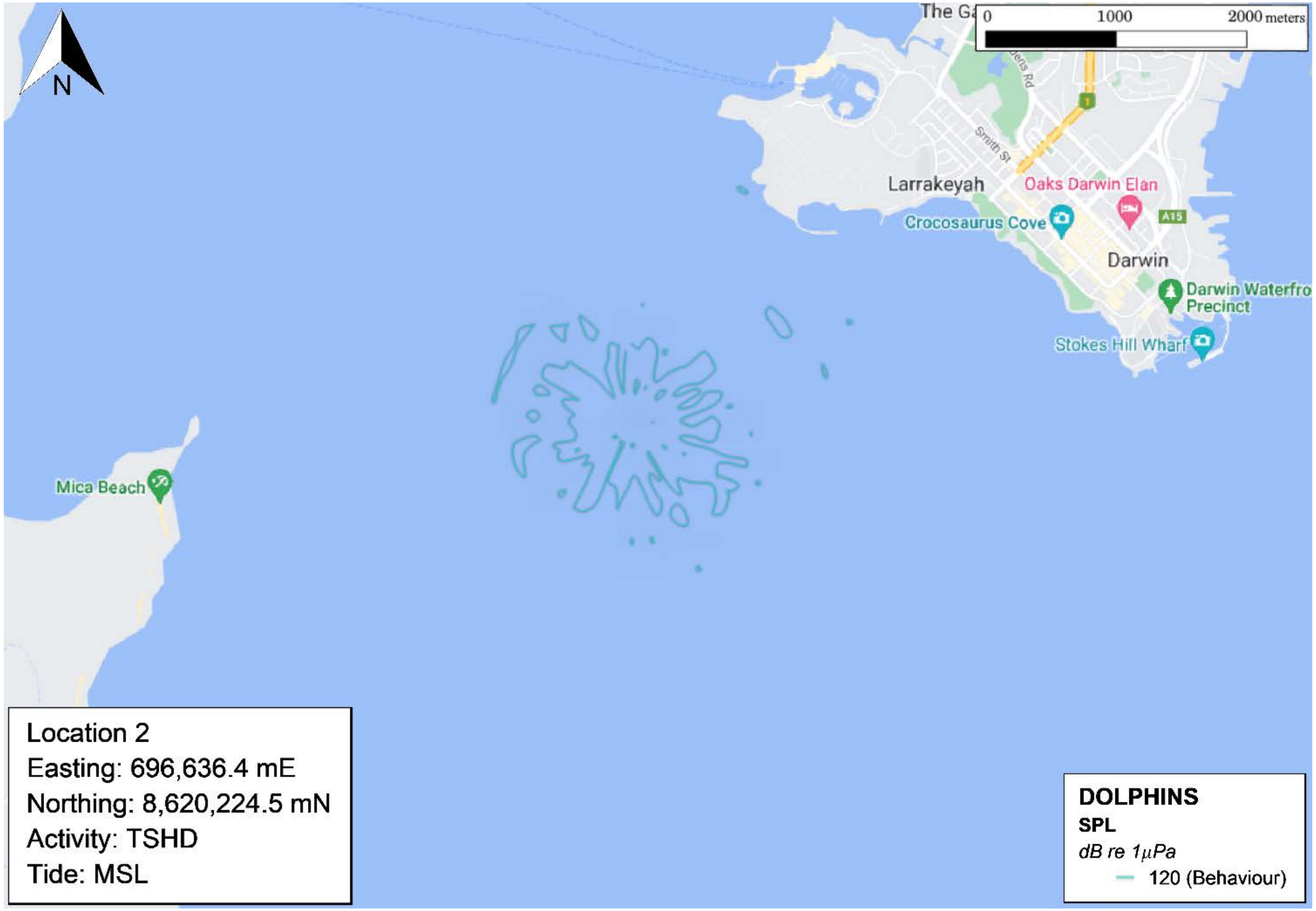

Figure 7-55 : Location 2 – TSHD Behavioural Contours for Dolphins (MSL)

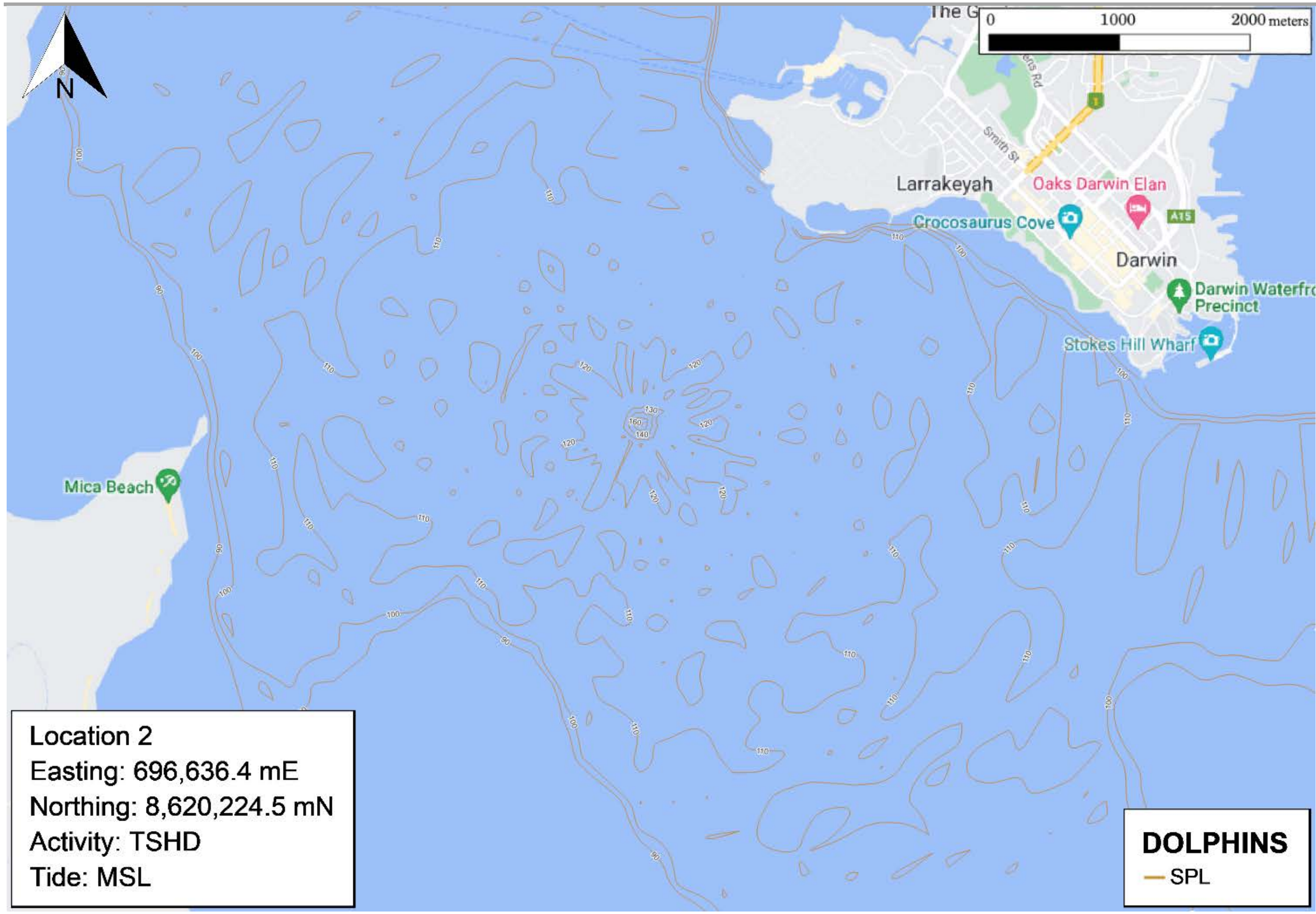

Figure 7-56 : Location 2 – TSHD SPL Contours for Dolphins (MSL)

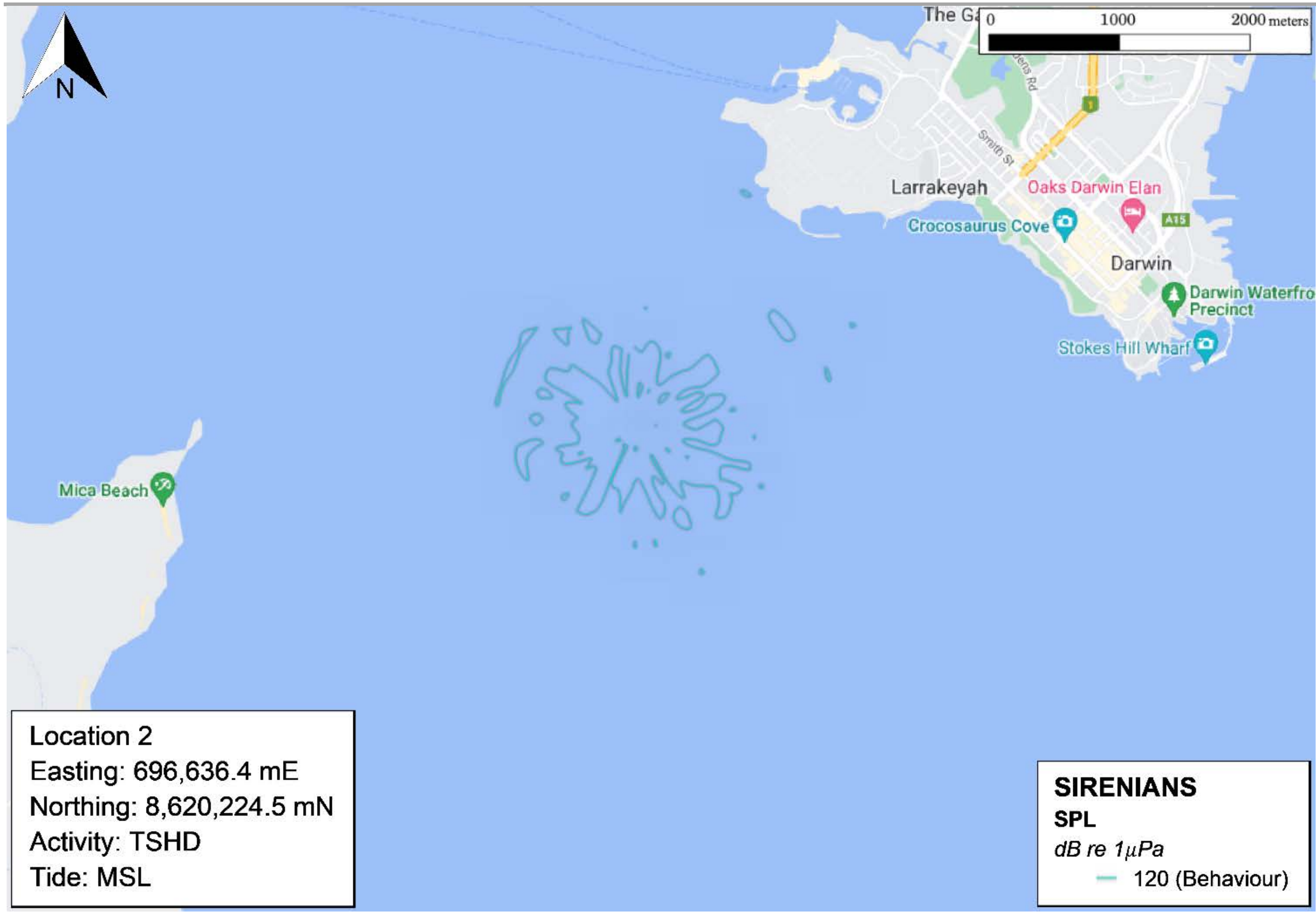

Figure 7-57 : Location 2 – TSHD Behavioural Contours for Sirenians (MSL)

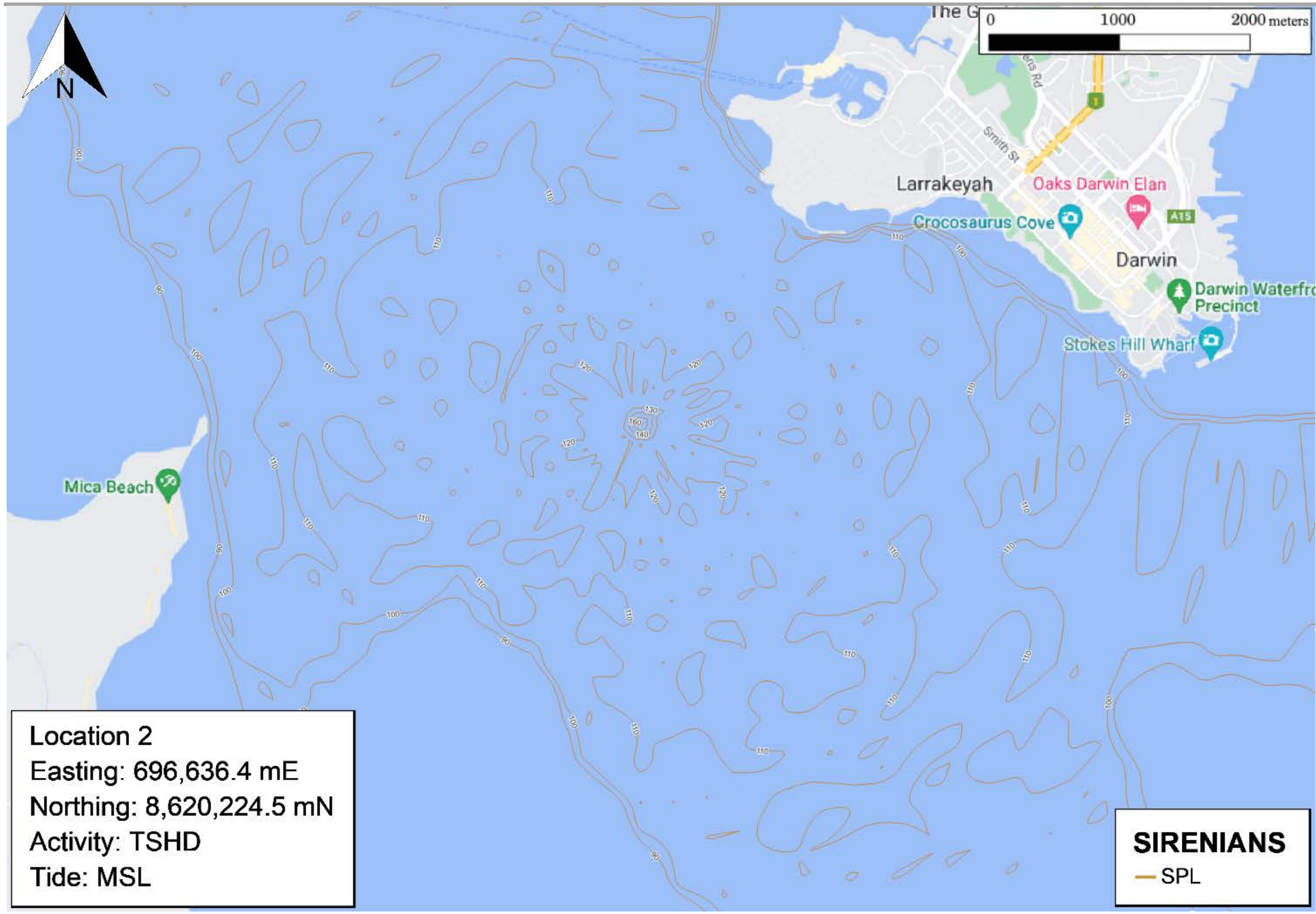

Figure 7-58 : Location 2 – TSHD SPL Contours for Sirenians (MSL)

C.4 Location 3 – TSHD

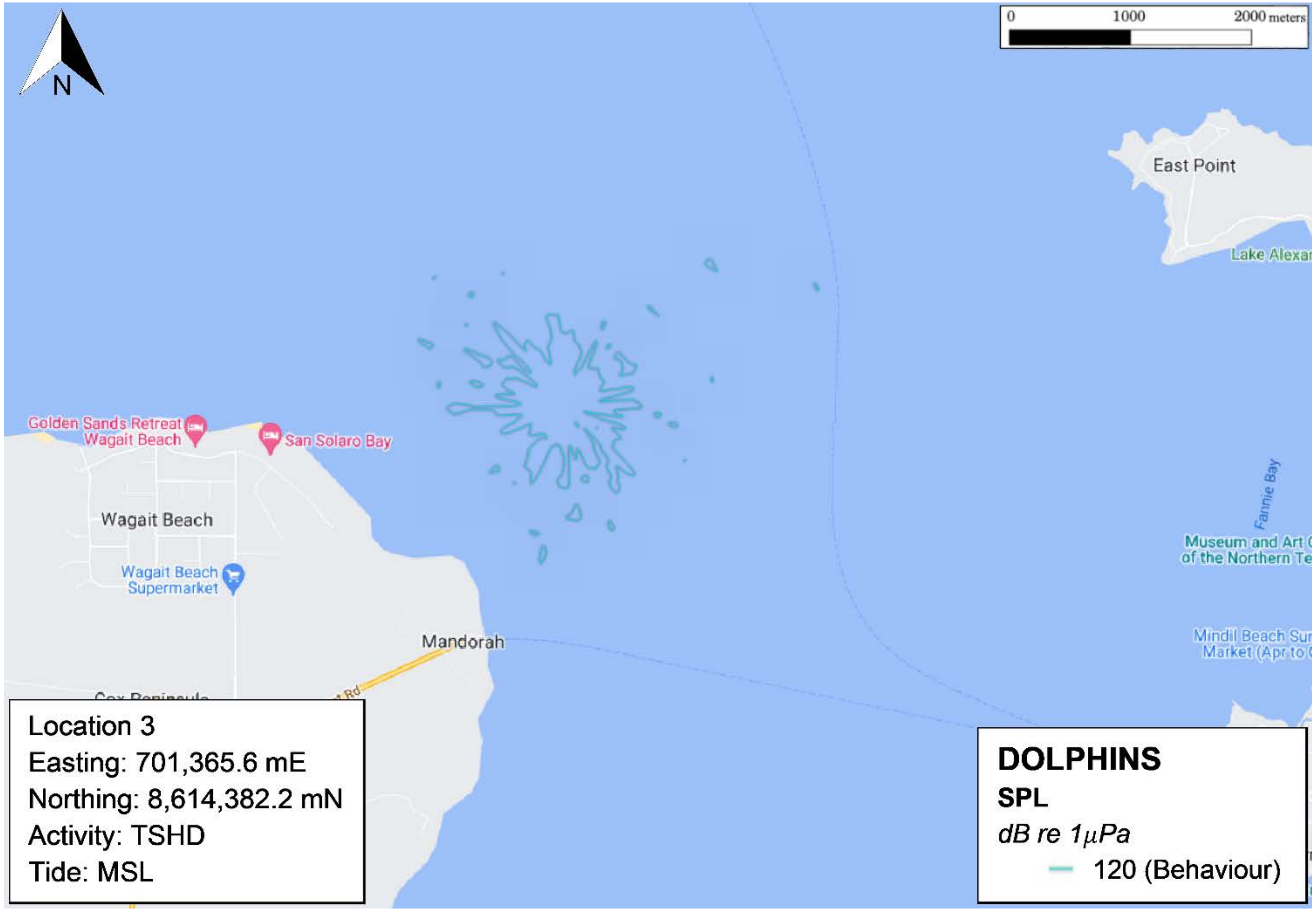

Figure 7-59 : Location 3 – TSHD Behavioural Contours for Dolphins (MSL)

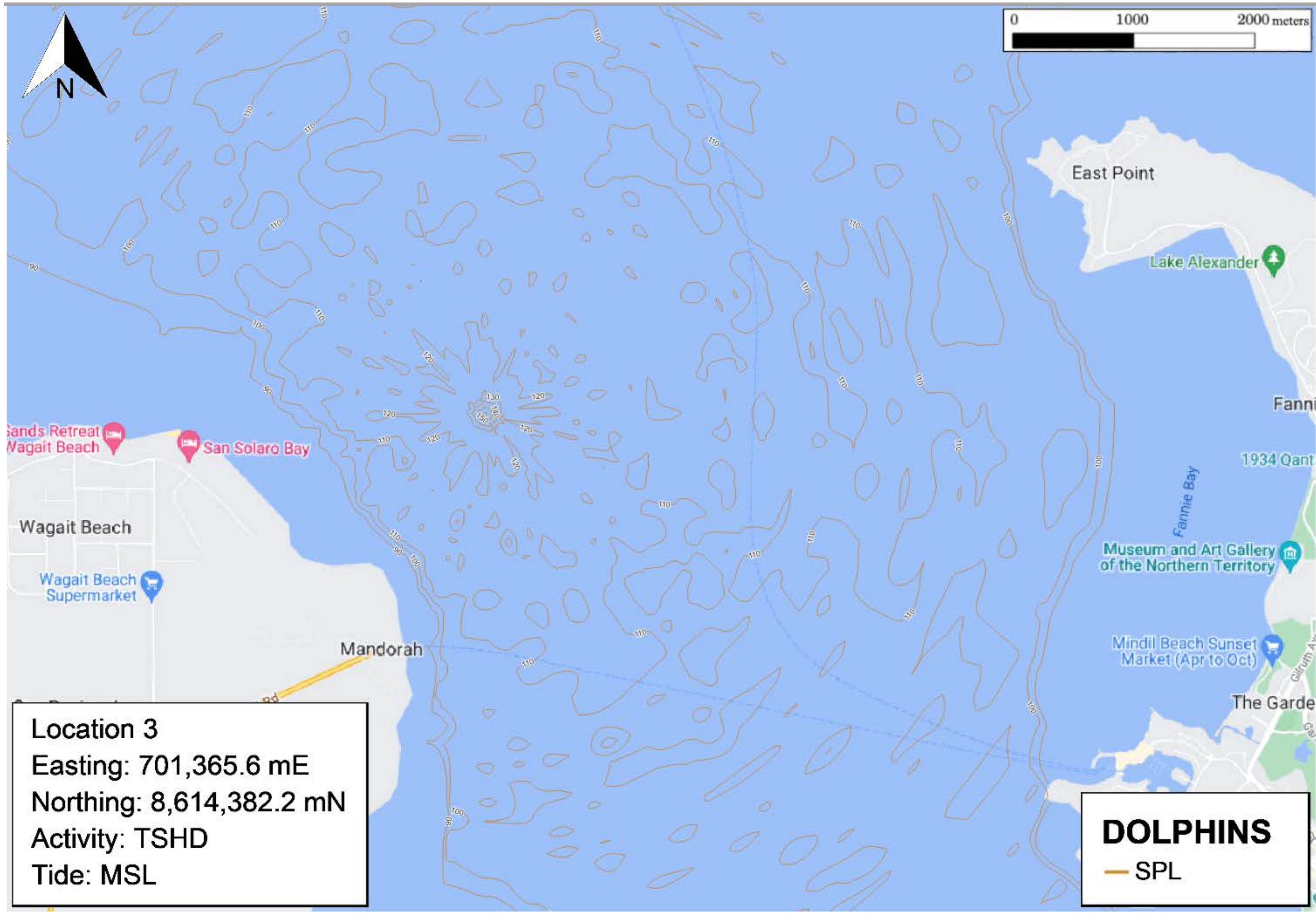

Figure 7-60 : Location 3 – TSHD SPL Contours for Dolphins (MSL)

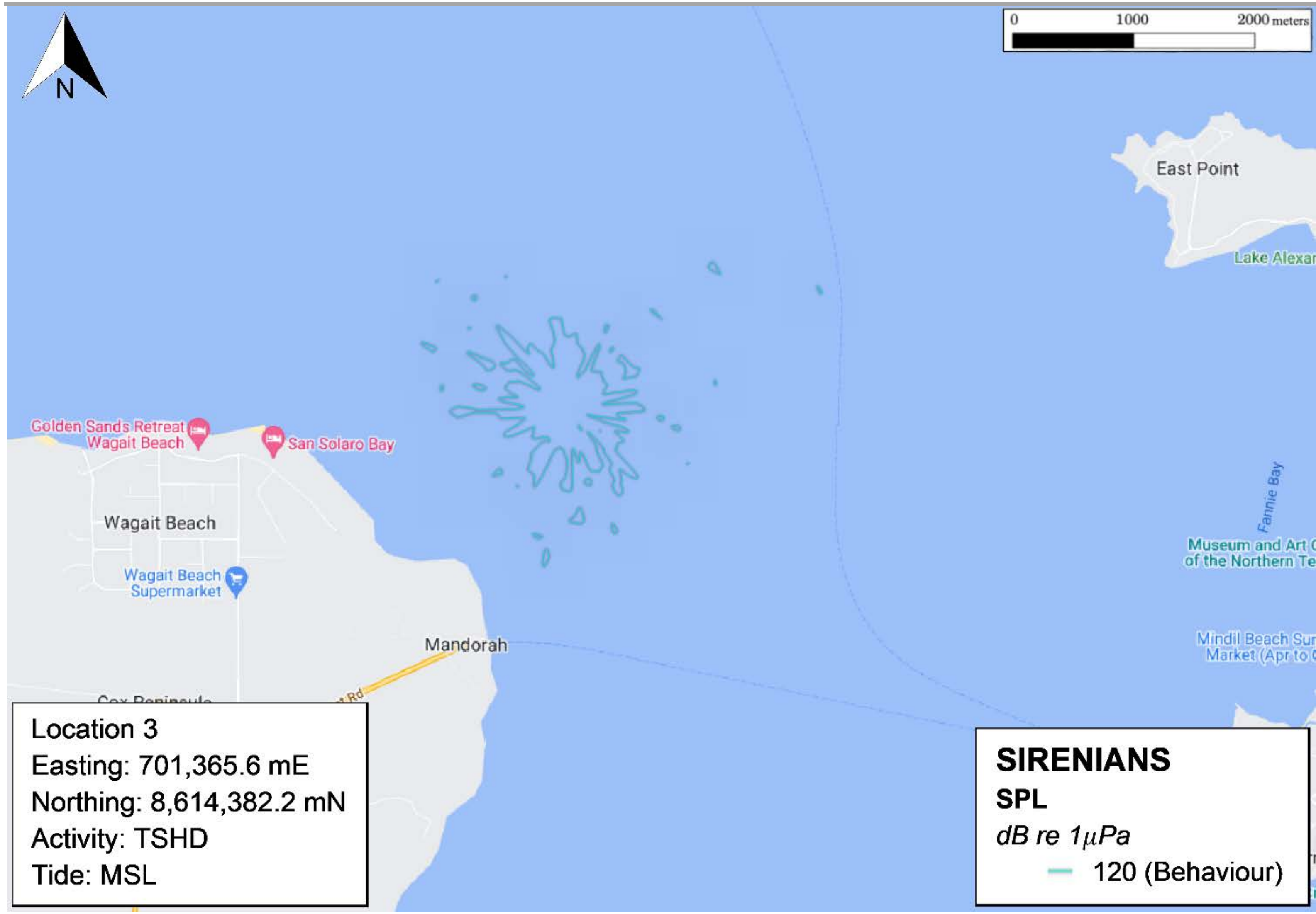

Figure 7-61 : Location 3 – TSHD Behavioural Contours for Sirenians (MSL)

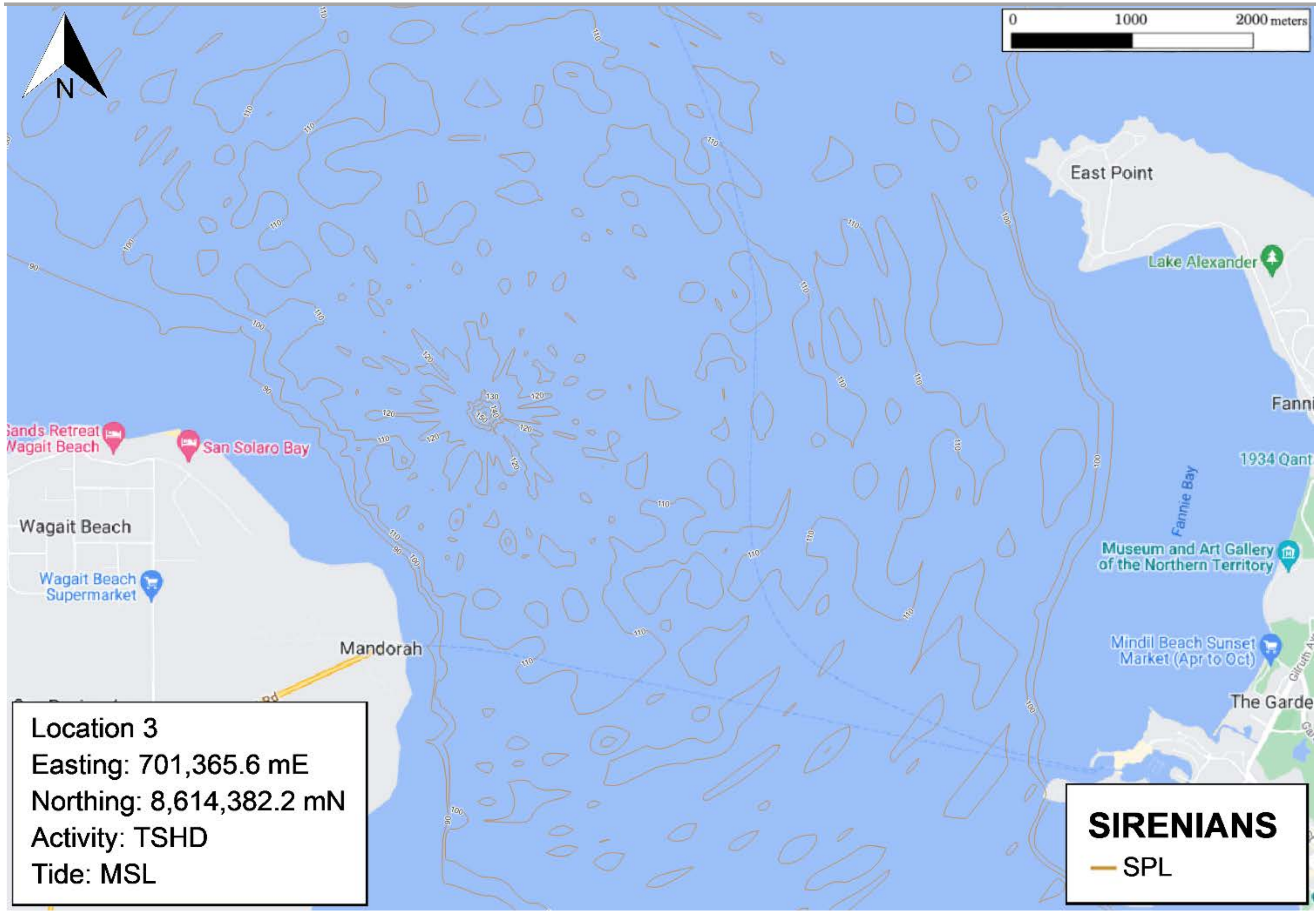

Figure 7-62 : Location 3 – TSHD SPL Contours for Sirenians (MSL)

C.5 Location 3 – TSHD and CSD

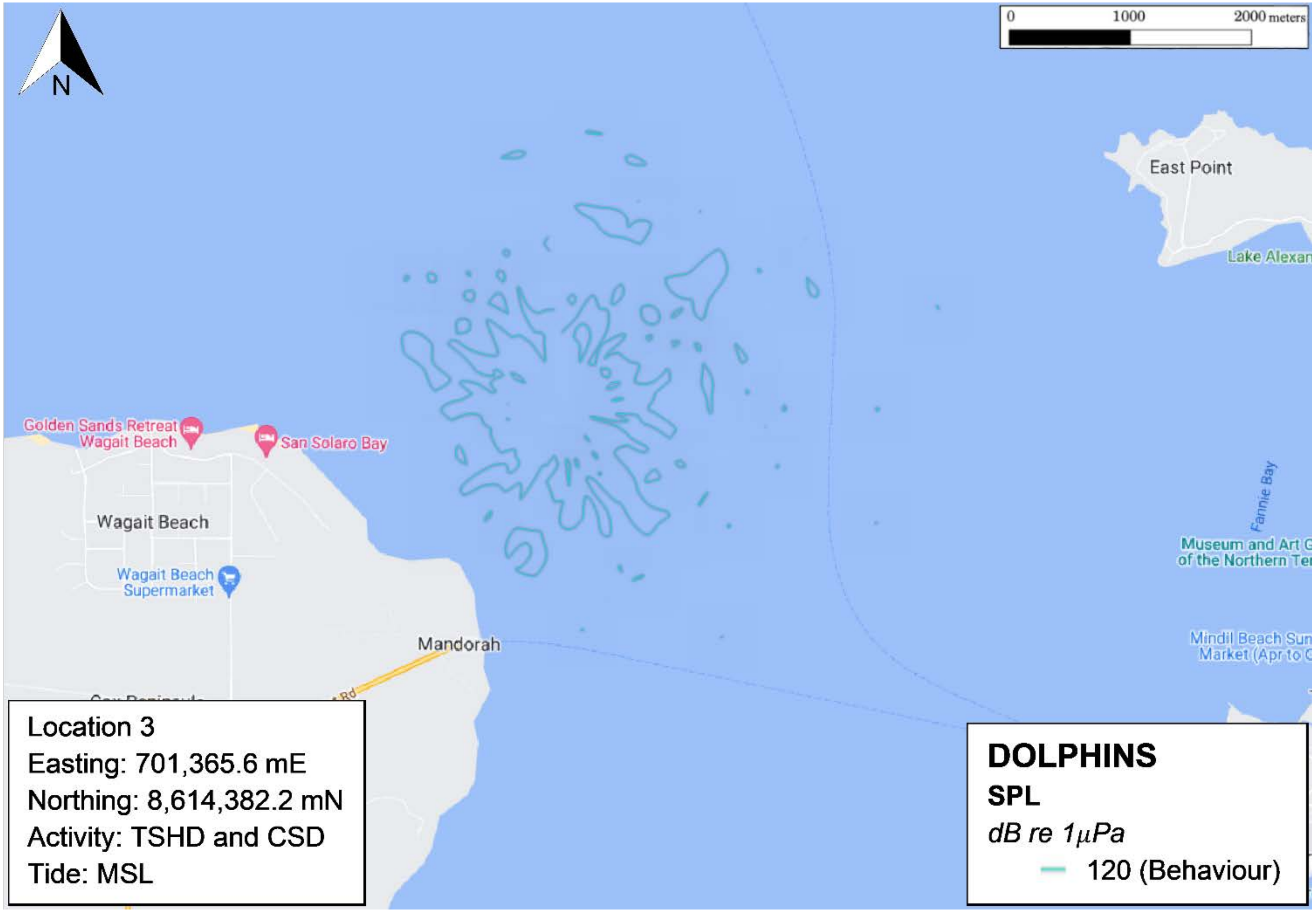

Figure 7-63 : Location 3 – TSHD and CSD Behavioural Contours for Dolphins (MSL)

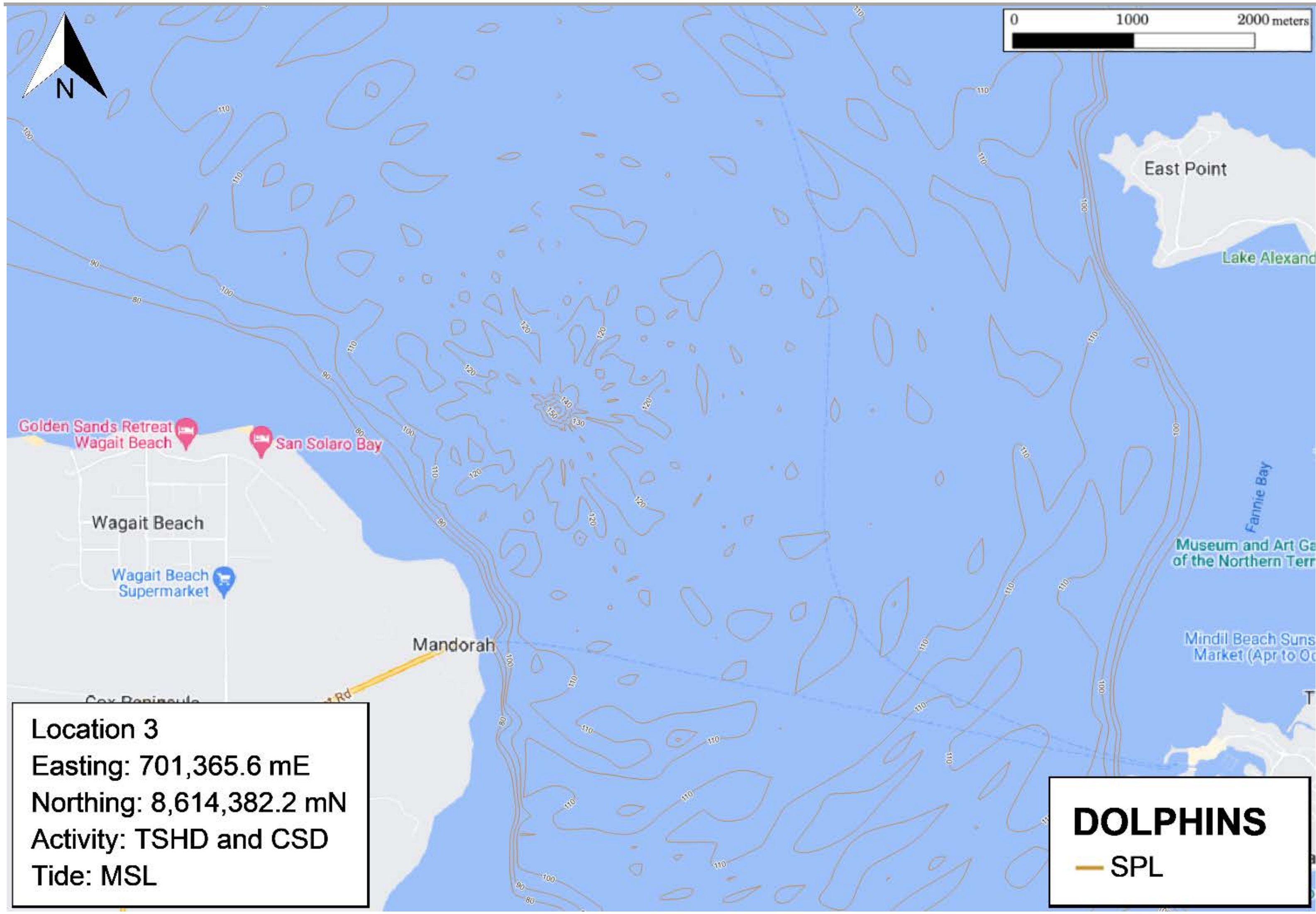

Figure 7-64 : Location 3 – TSHD and CSD SPL Contours for Dolphins (MSL)

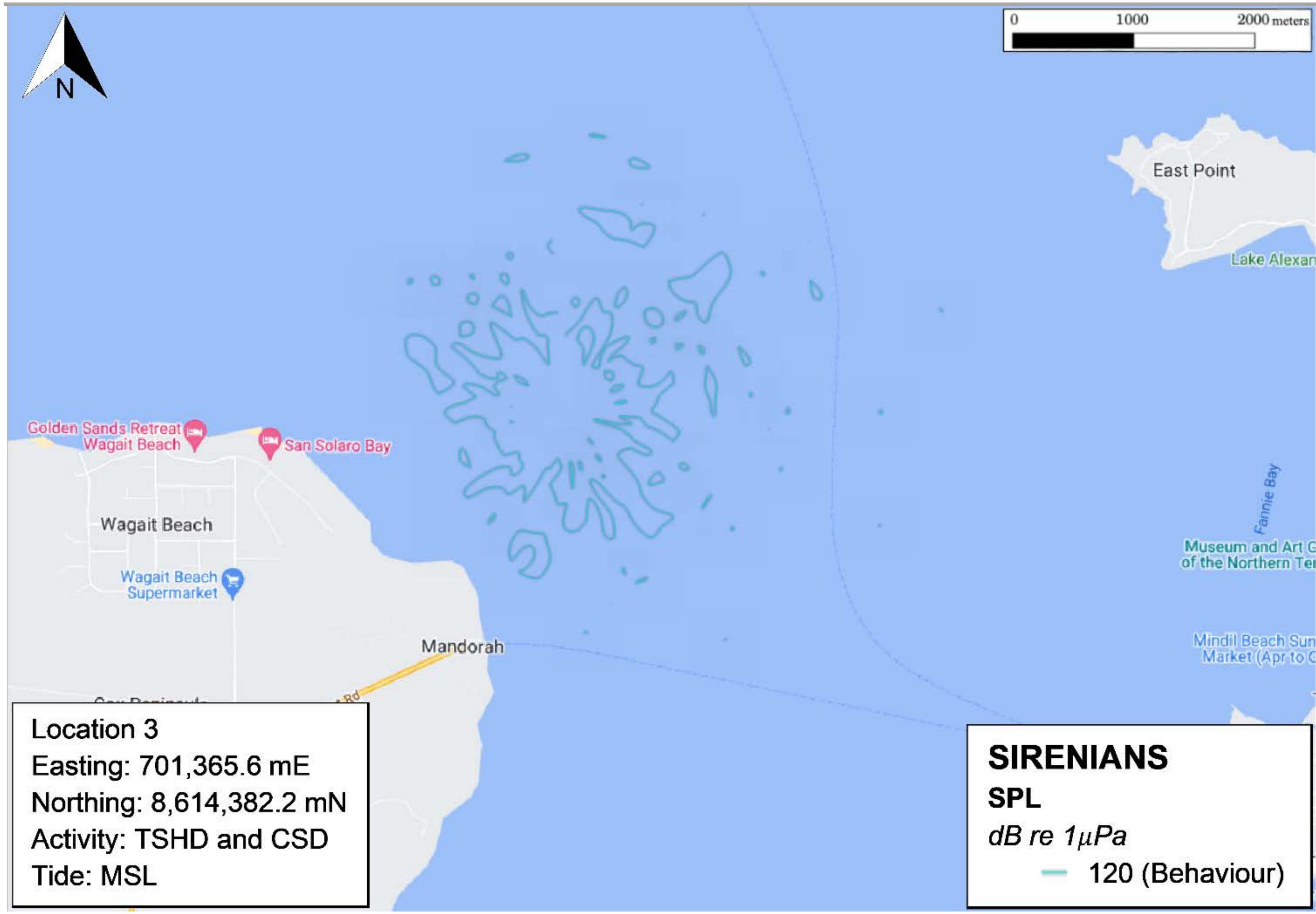

Figure 7-65 : Location 3 – TSHD and CSD Behavioural Contours for Sirenians (MSL)

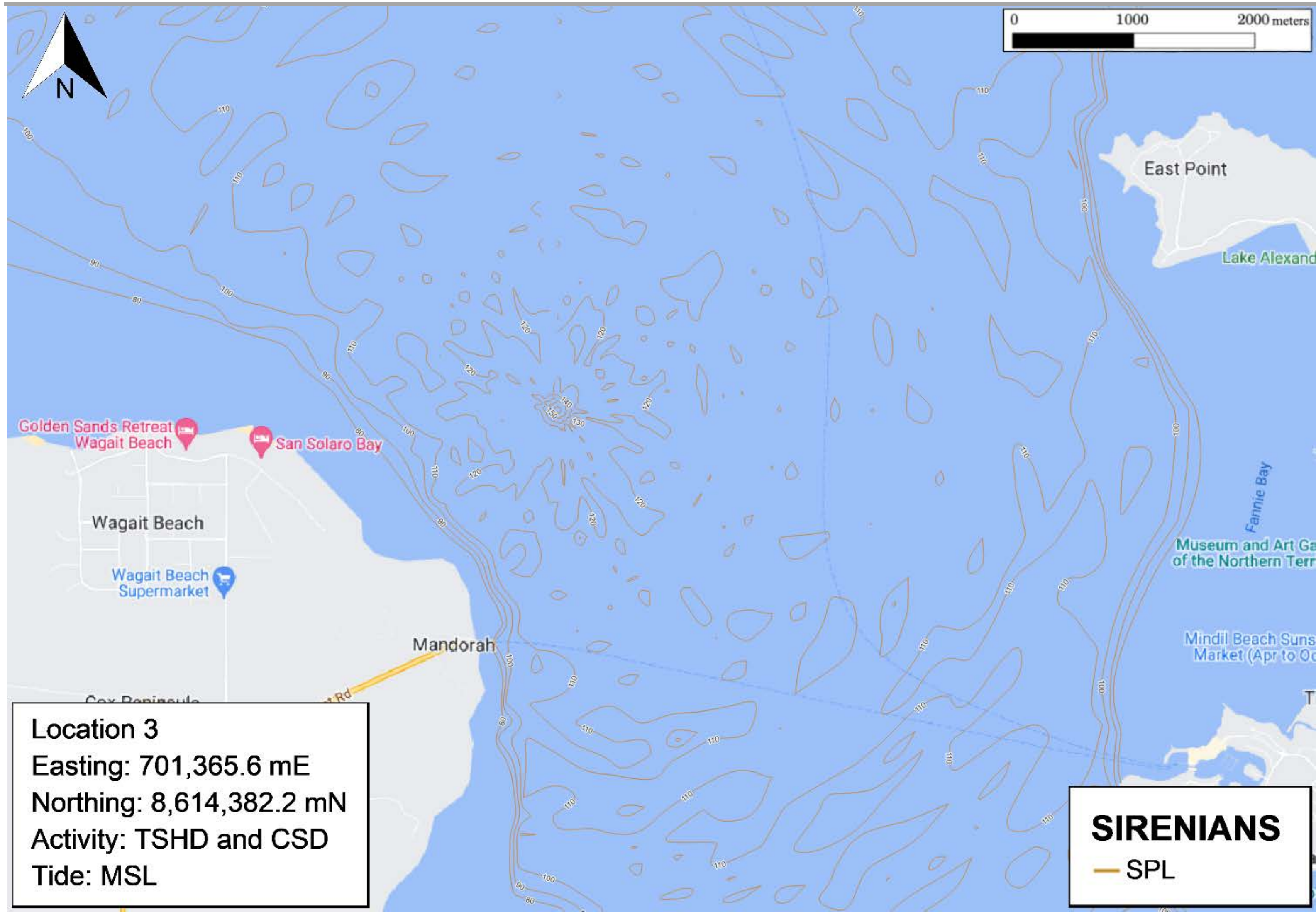

Figure 7-66 : Location 3 – TSHD and CSD SPL Contours for Sirenians (MSL)

C.6 Location 4 – Sheet Piling

Figure 7-67 :Location 3 – Sheet Piling Behavioural Contours for Turtles (MSL)

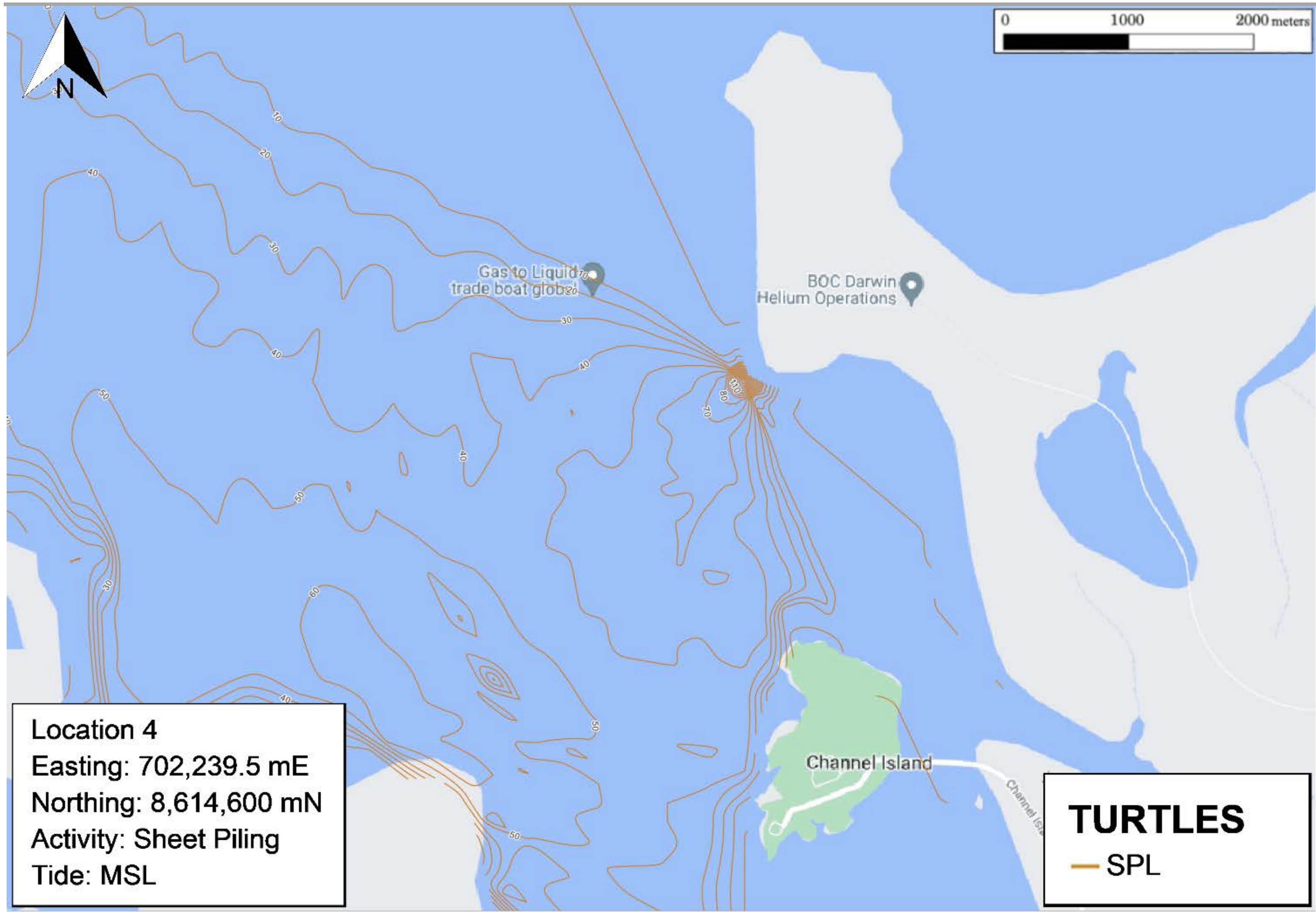

Figure 7-68 : Location 3 – Sheet Piling SPL Contours for Turtles (MSL)

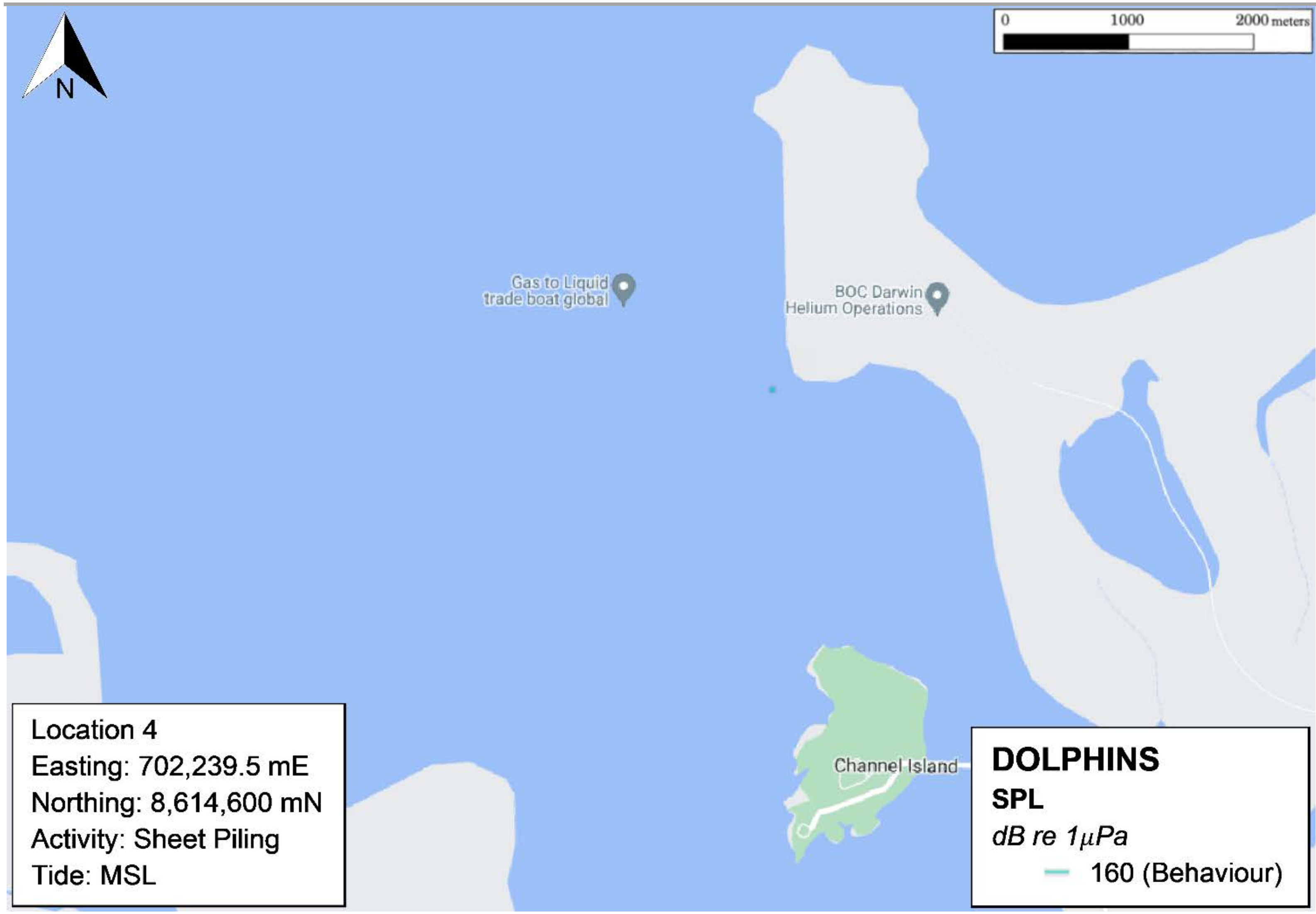

Figure 7-69 : Location 3 – Sheet Piling Behavioural Contours for Dolphins (MSL)

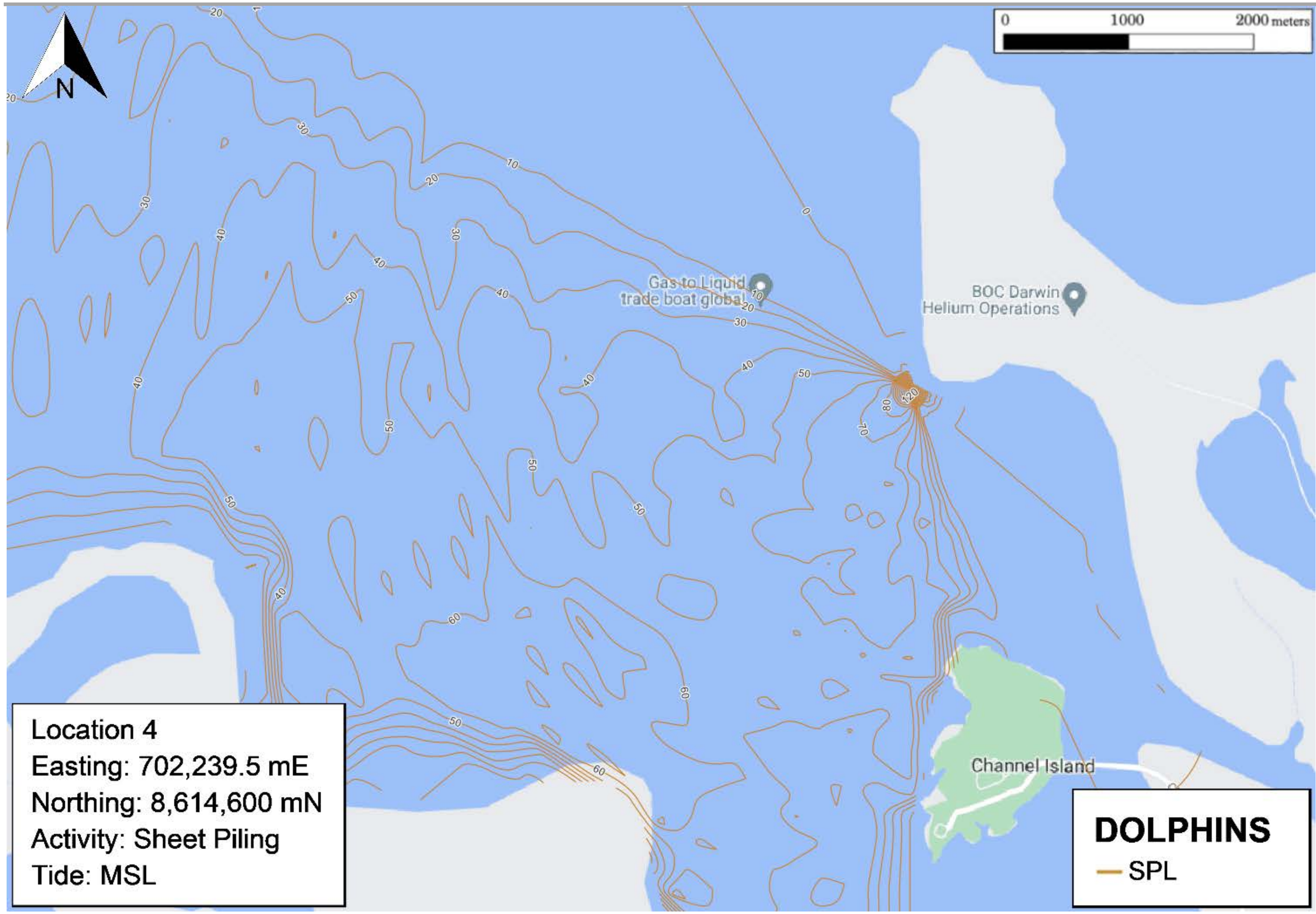

Figure 7-70 : Location 3 – Sheet Piling SPL Contours for Dolphins (MSL)

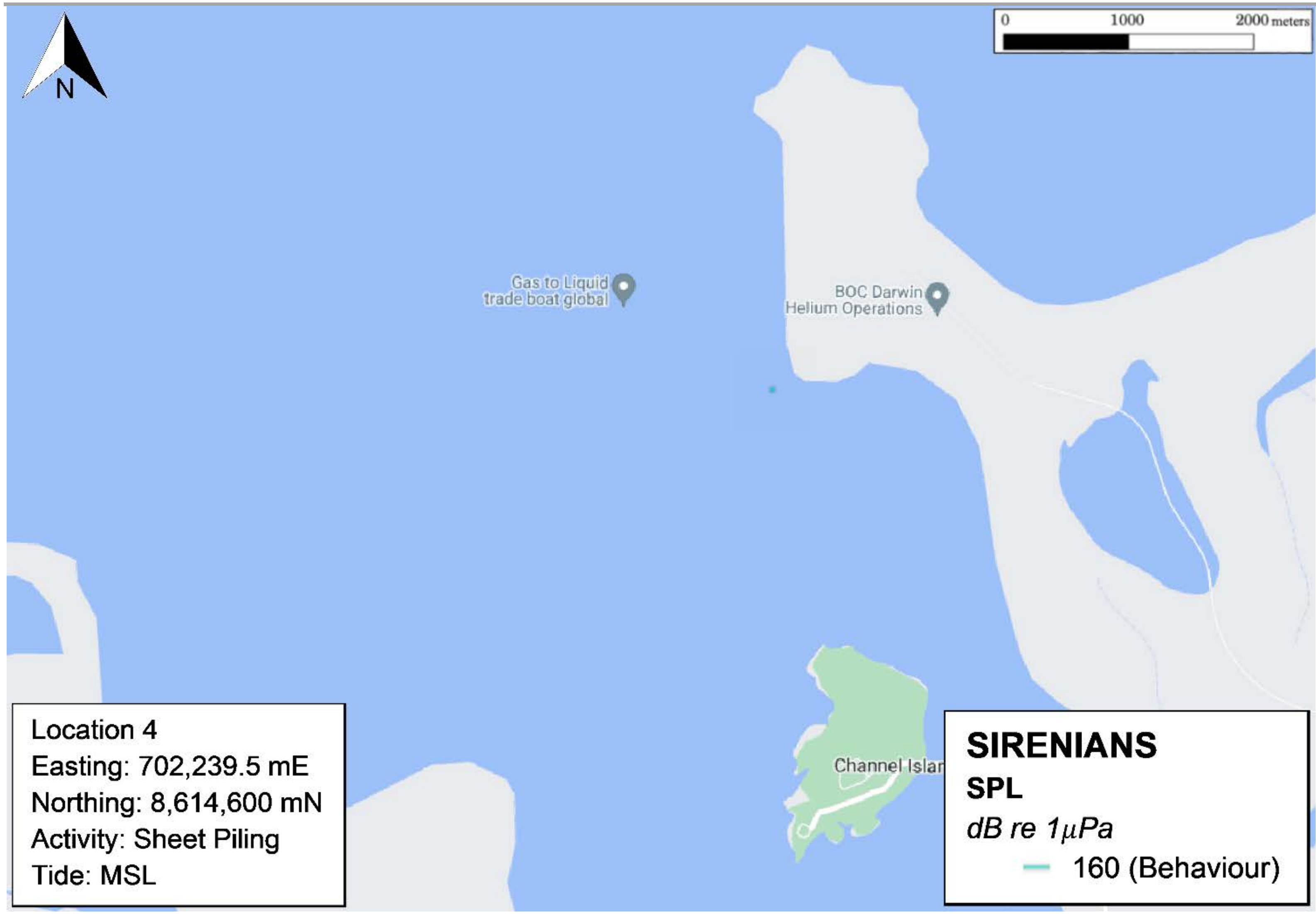

Figure 7-71 : Location 3 – Sheet Piling Behavioural Contours for Sirenians (MSL)

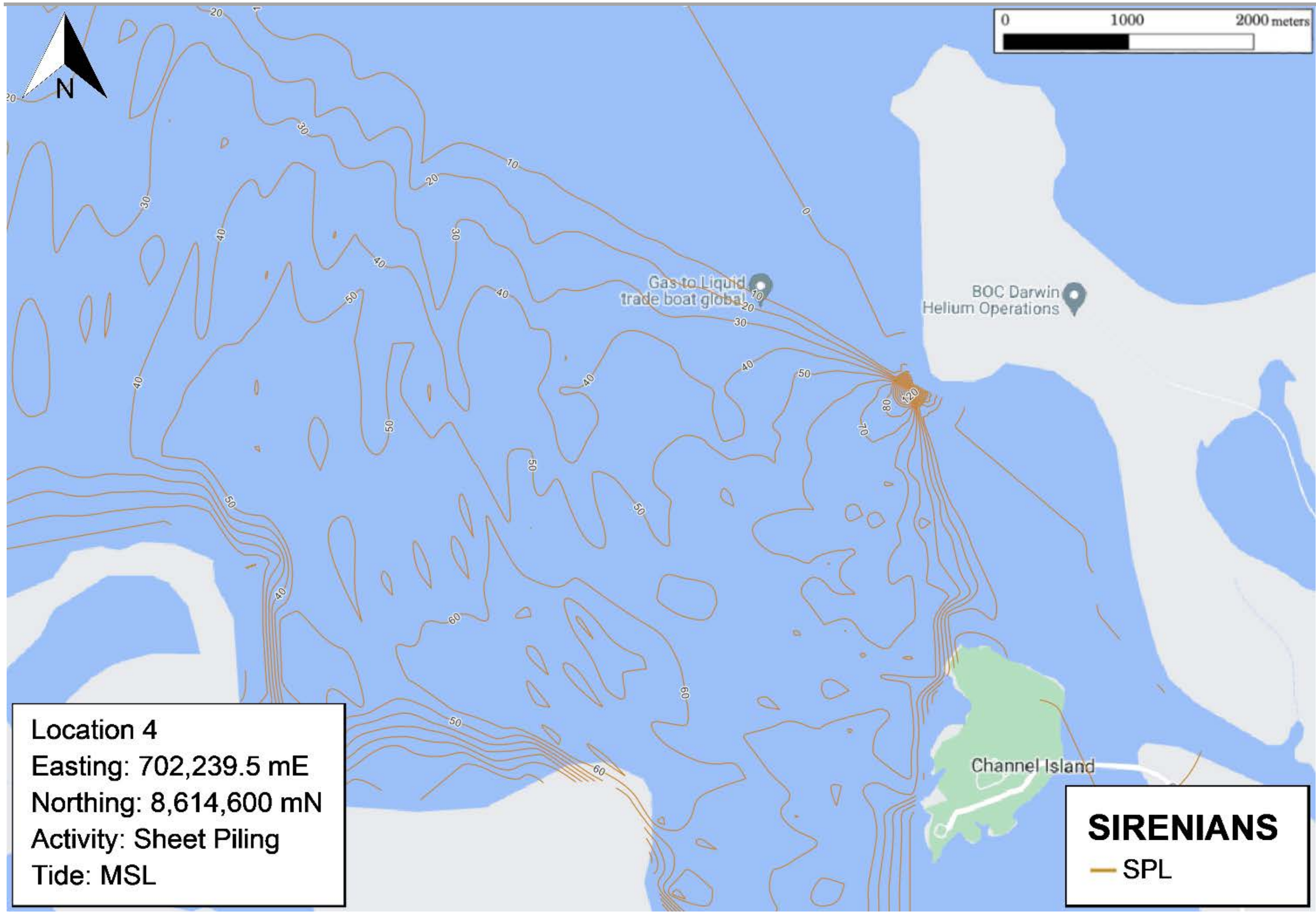

Figure 7-72 : Location 3 – Sheet Piling SPL Contours for Sirenians (MSL)

APPENDIX D
TTS and PTS Ranges

D.1 Location 1 – BHD (Digging)

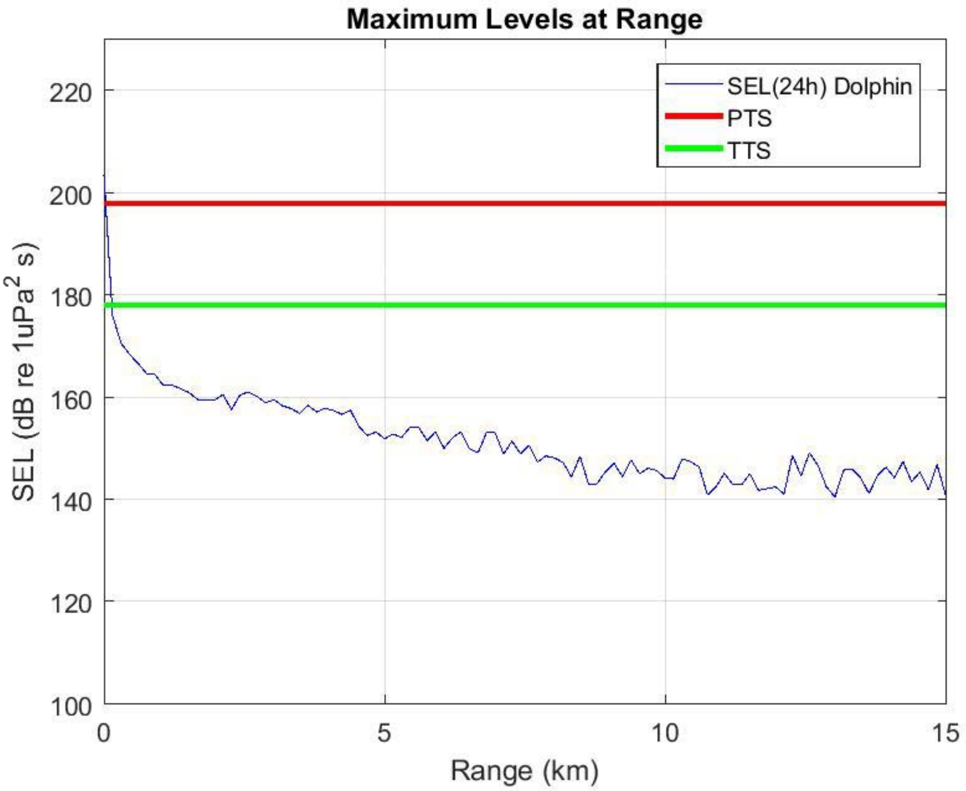

Figure 7-73 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Dolphin

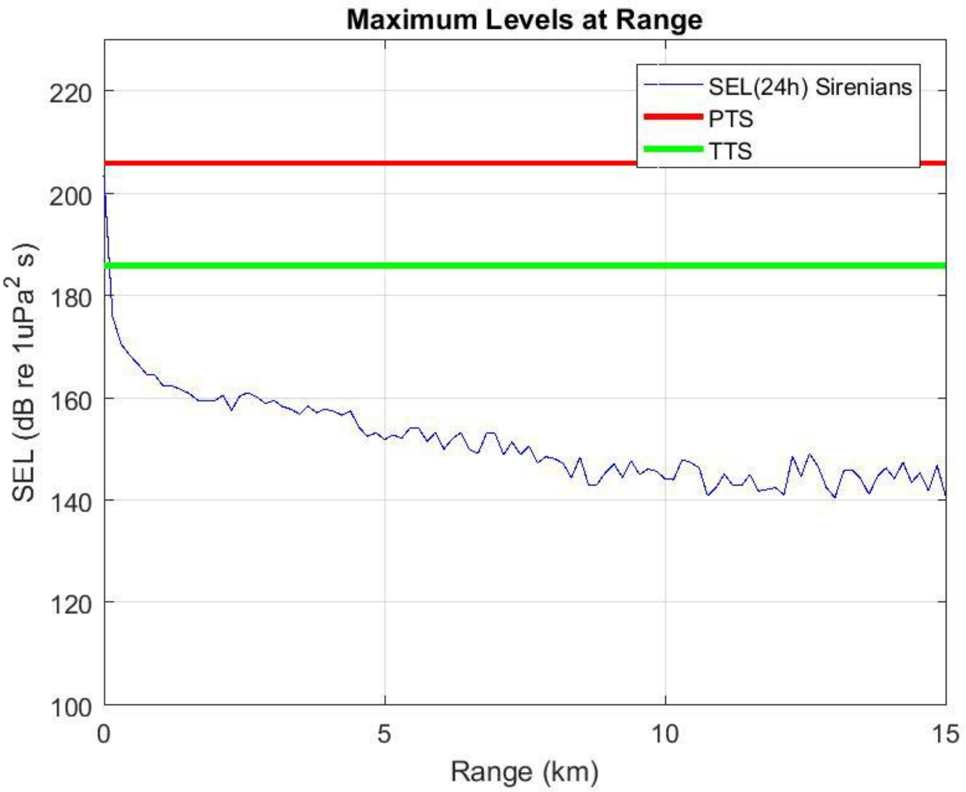

Figure 7-74 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Dugongs

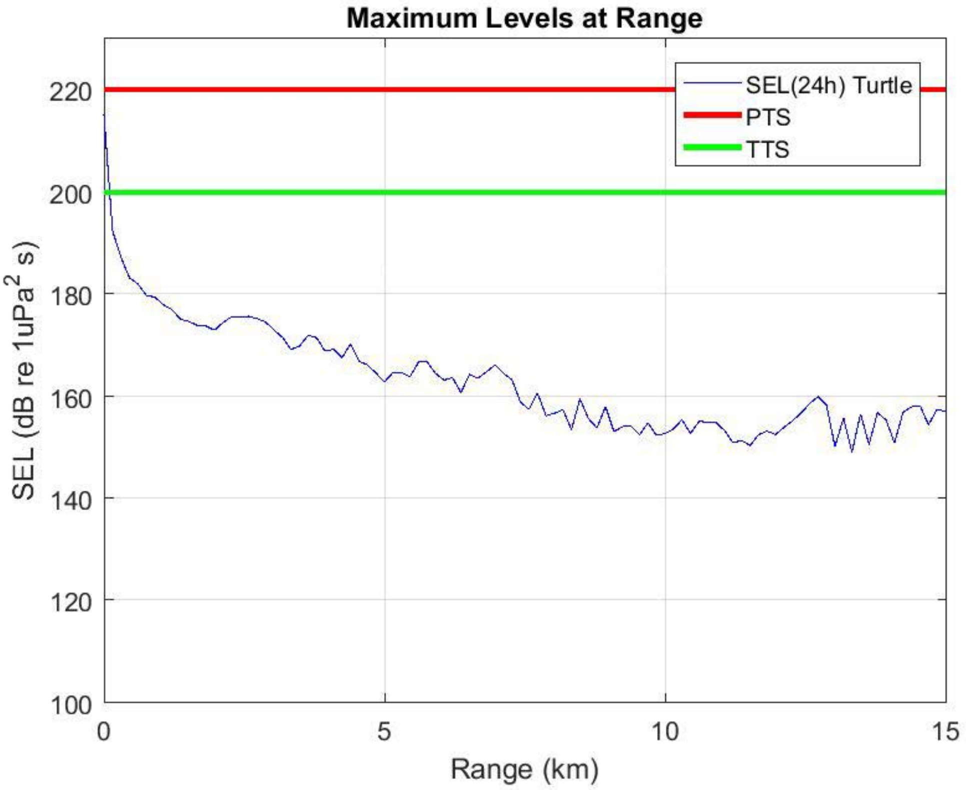

Figure 7-75 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Turtles

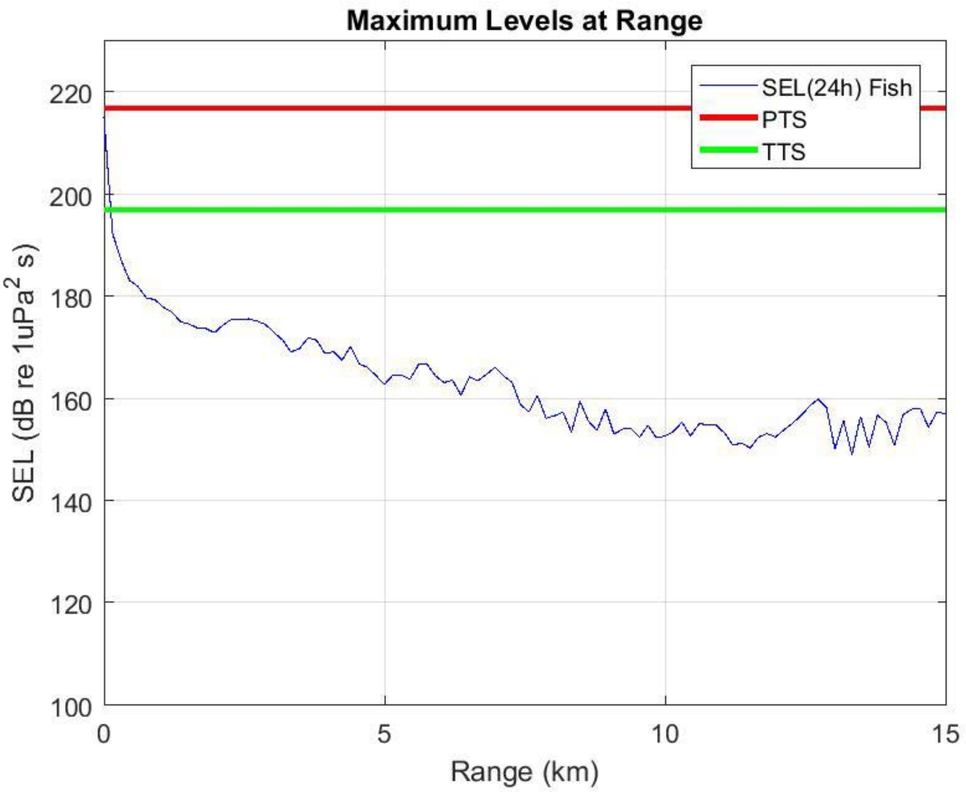

Figure 7-76 : MSL BHD (Digging) Location 1 maximum cumulative SEL with distance for Fish

D.2 Location 1 – BHD with Hydraulic Hammer

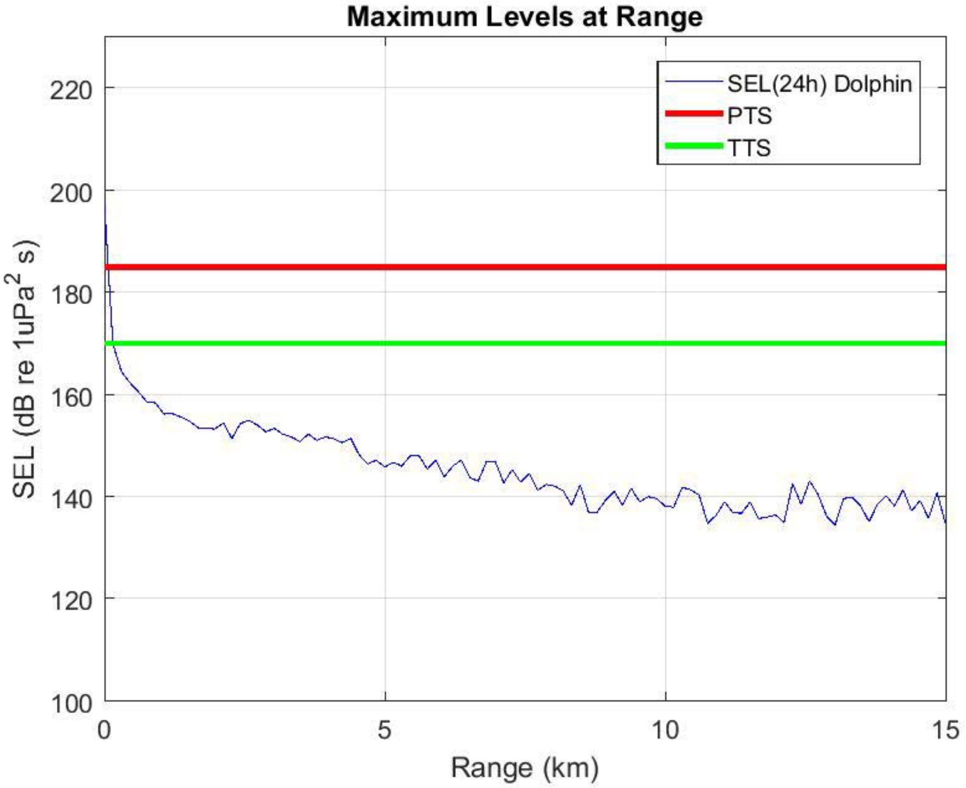

Figure 7-77 : MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Dolphin

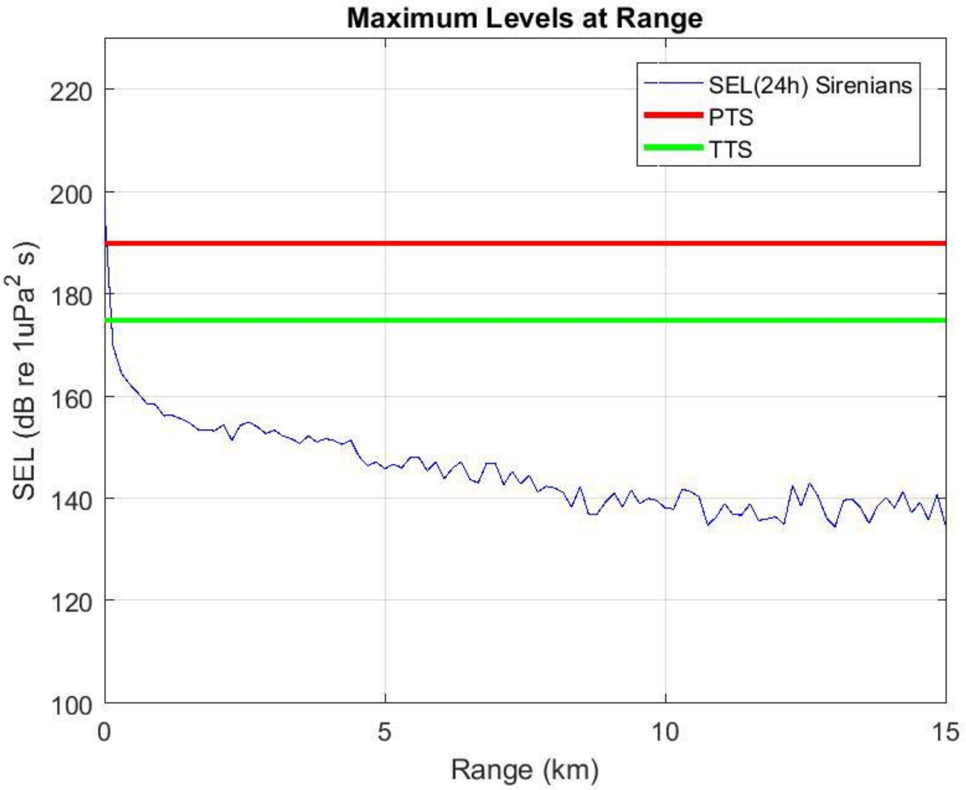

Figure 7-78 : MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Dugongs

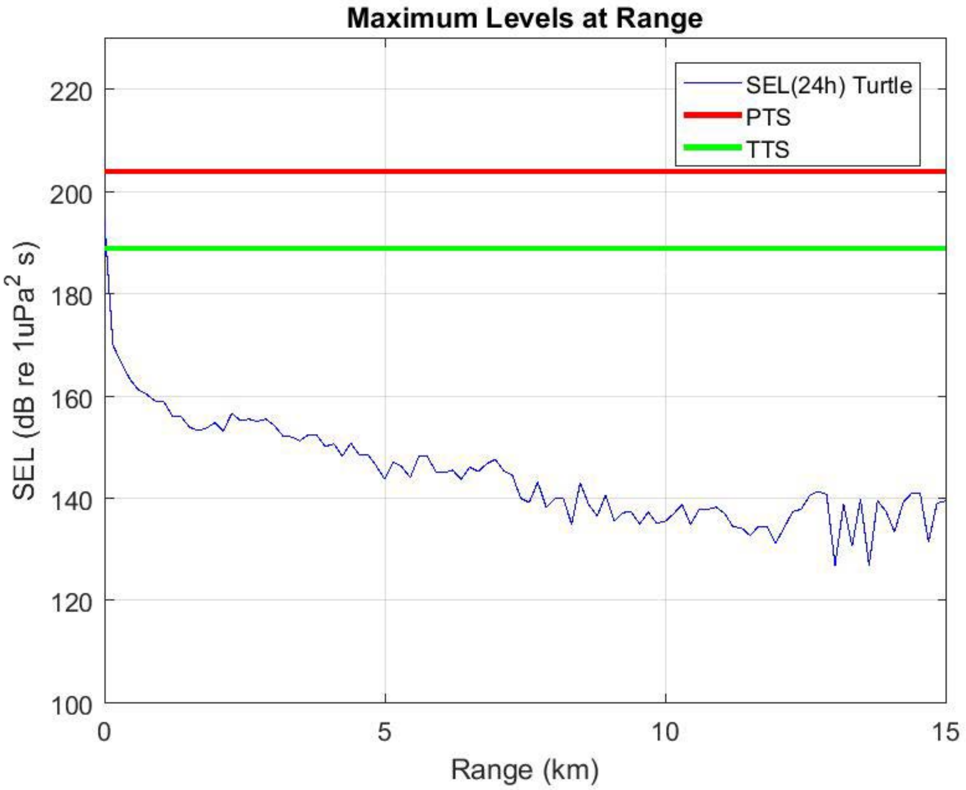

Figure 7-79 : MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Turtles

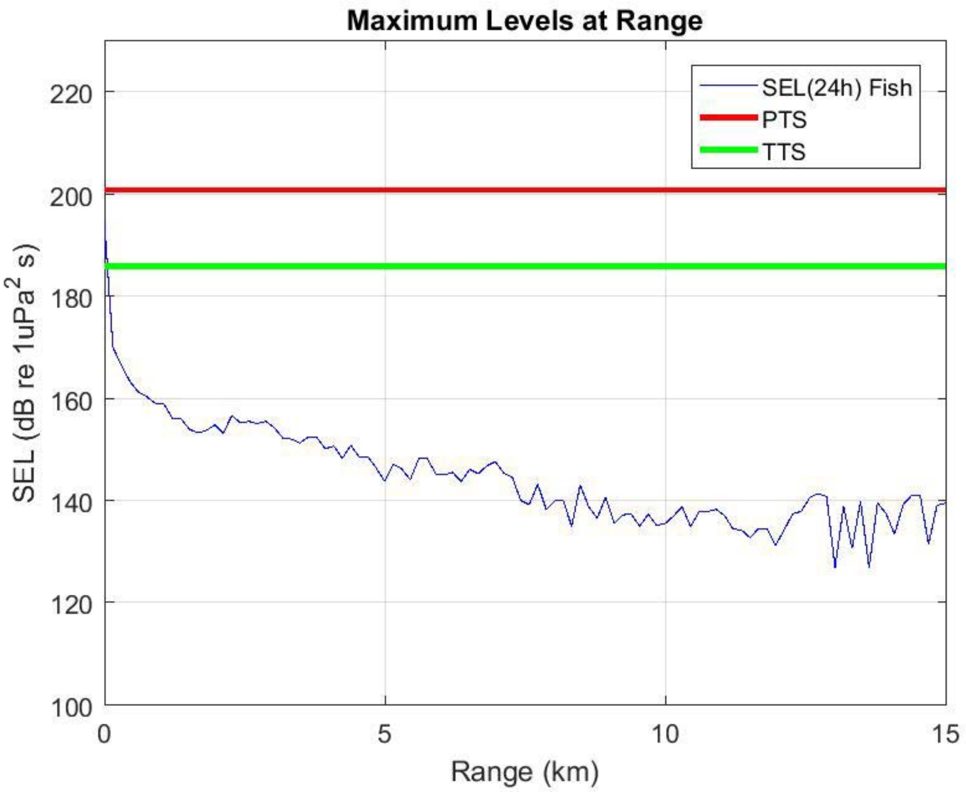

Figure 7-80 MSL BHD (Hydraulic Hammer) Location 1 maximum cumulative SEL with distance for Fish

D.3 Location 2 – TSHD

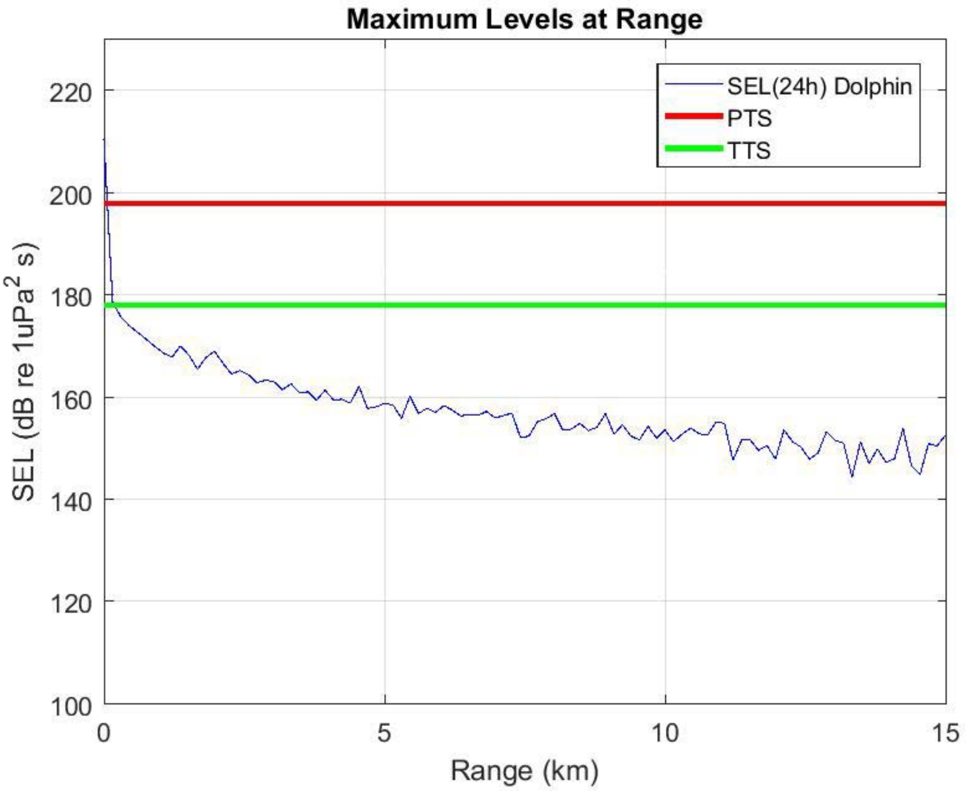

Figure 7-81 : MSL TSHD Location 2 maximum cumulative SEL with distance for Dolphin

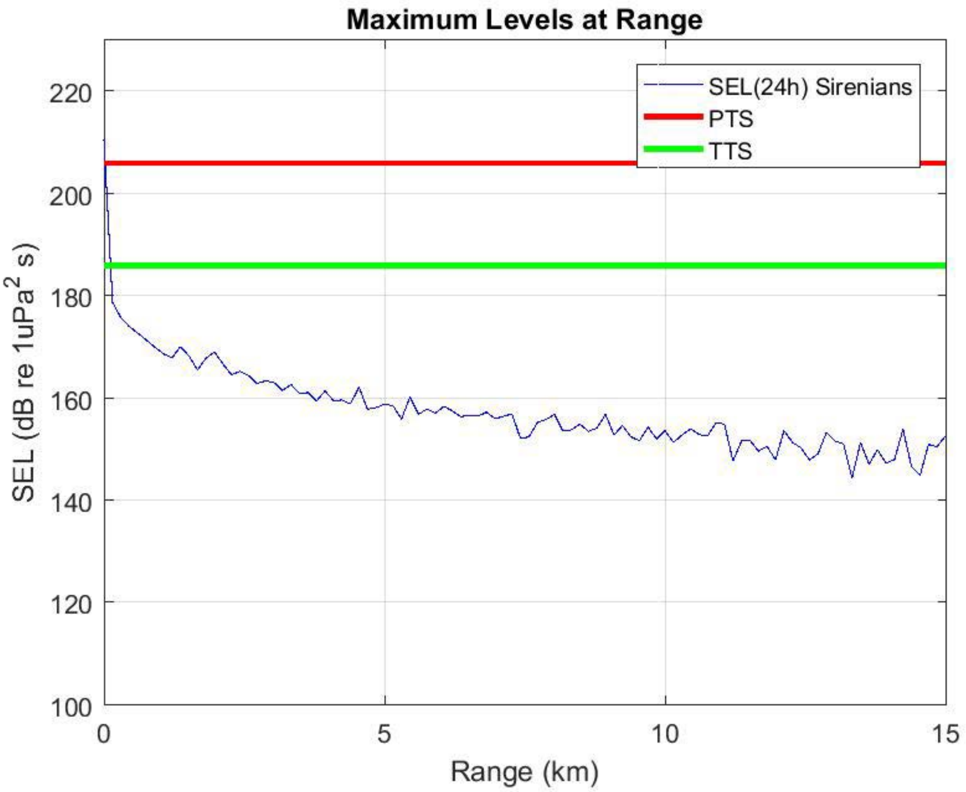

Figure 7-82 : MSL TSHD Location 2 maximum cumulative SEL with distance for Dugongs

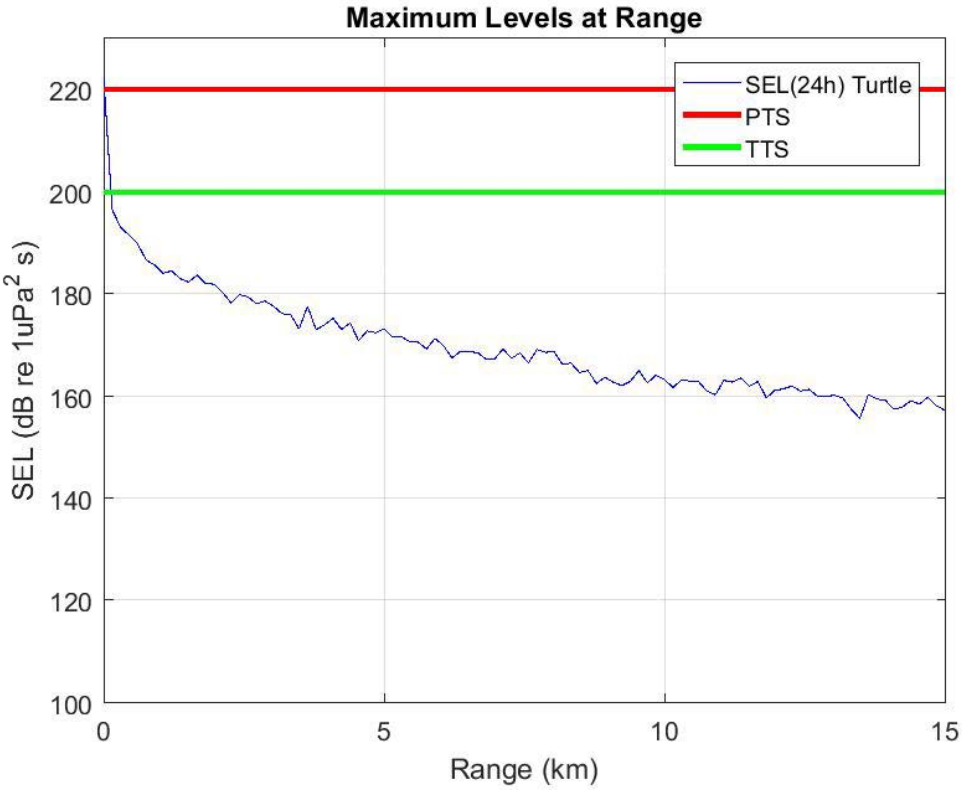

Figure 7-83 : MSL TSHD Location 2 maximum cumulative SEL with distance for Turtles

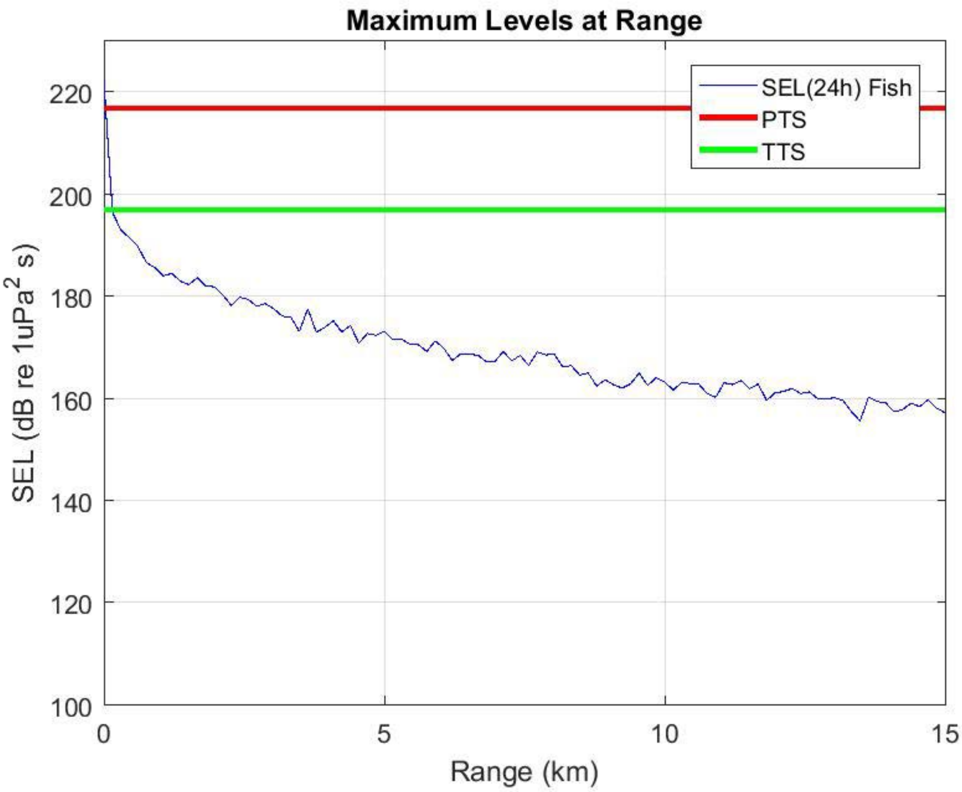

Figure 7-84 : MSL TSHD Location 2 maximum cumulative SEL with distance for Fish

D.4 Location 3 – TSHD

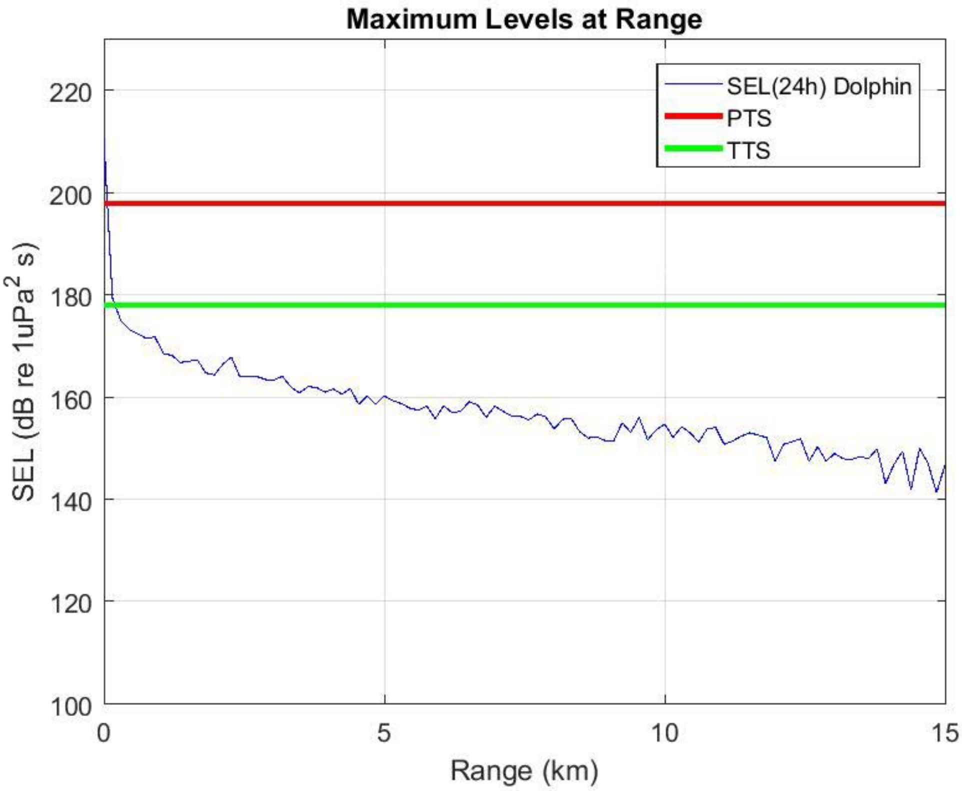

Figure 7-85 : MSL TSHD Location 3 maximum cumulative SEL with distance for Dolphin

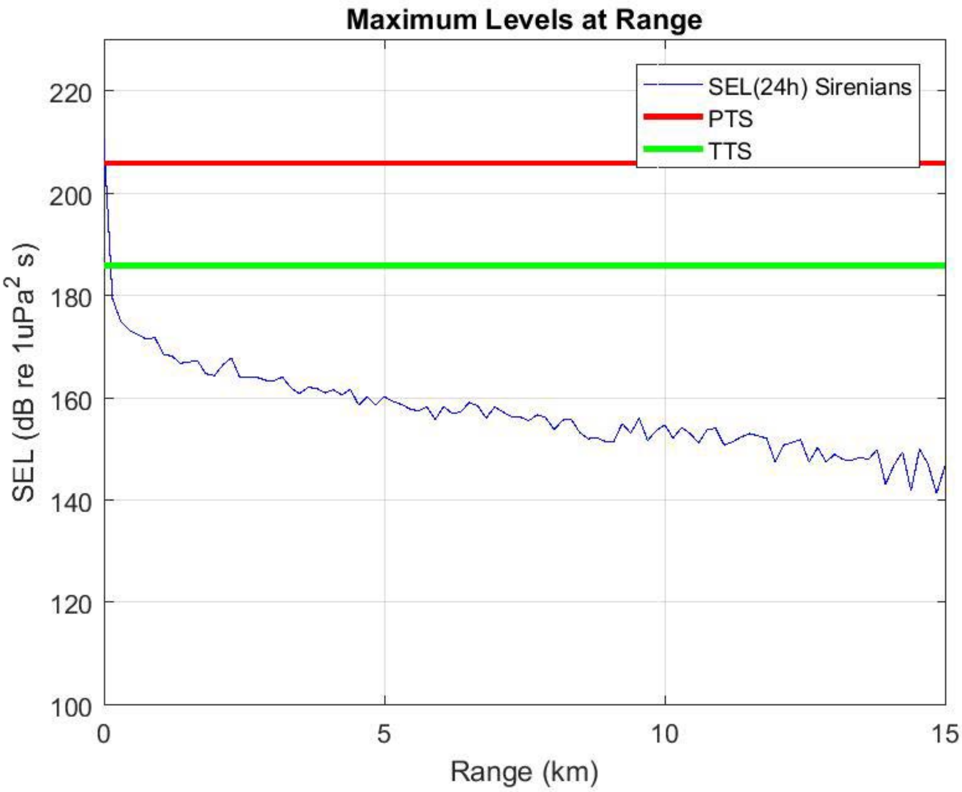

Figure 7-86 : MSL TSHD Location 3 maximum cumulative SEL with distance for Dugongs

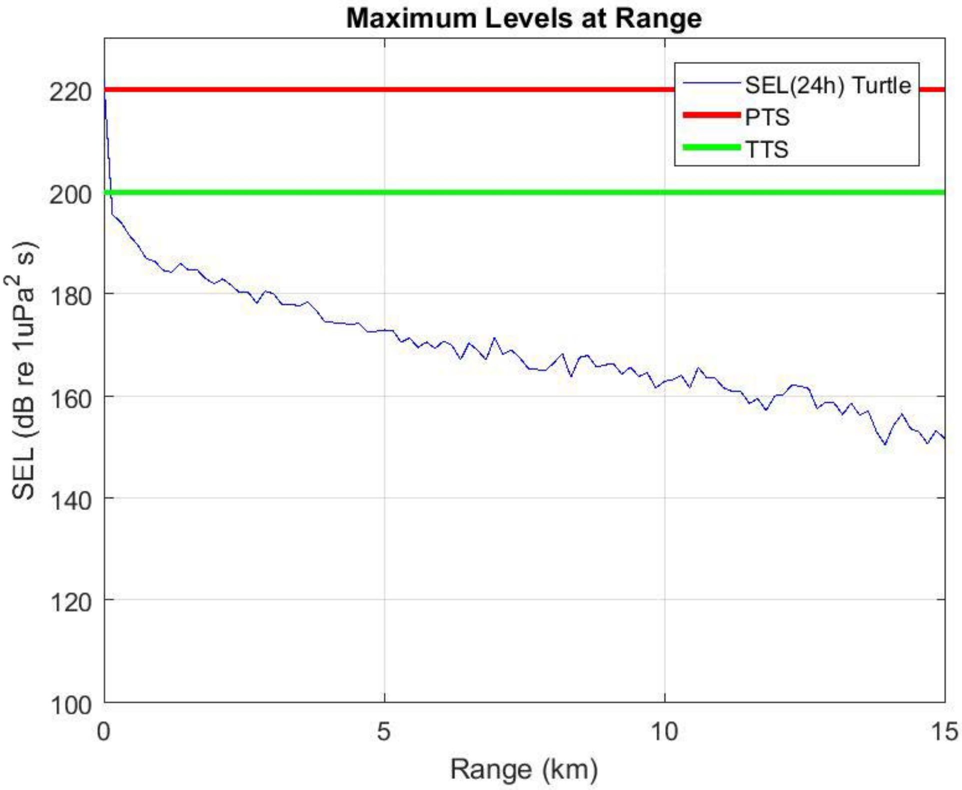

Figure 7-87 : MSL TSHD Location 3 maximum cumulative SEL with distance for Turtles

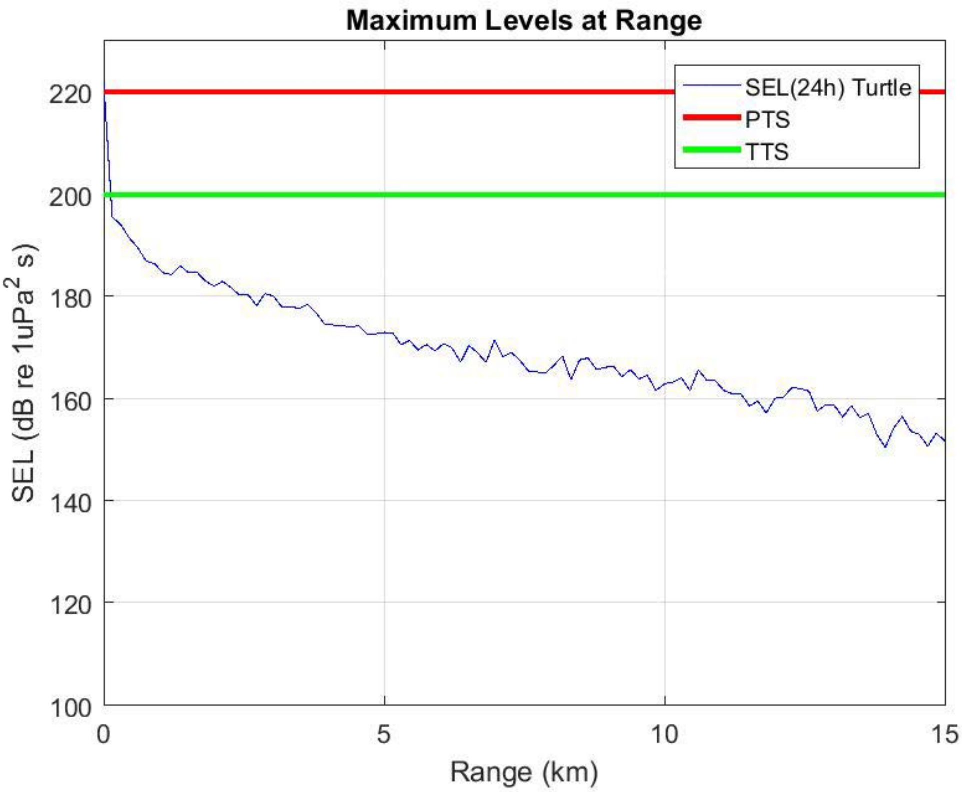

Figure 7-88 : MSL TSHD Location 3 maximum cumulative SEL with distance for Fish

D.5 Location 3 – Cumulative – TSHD and CSD

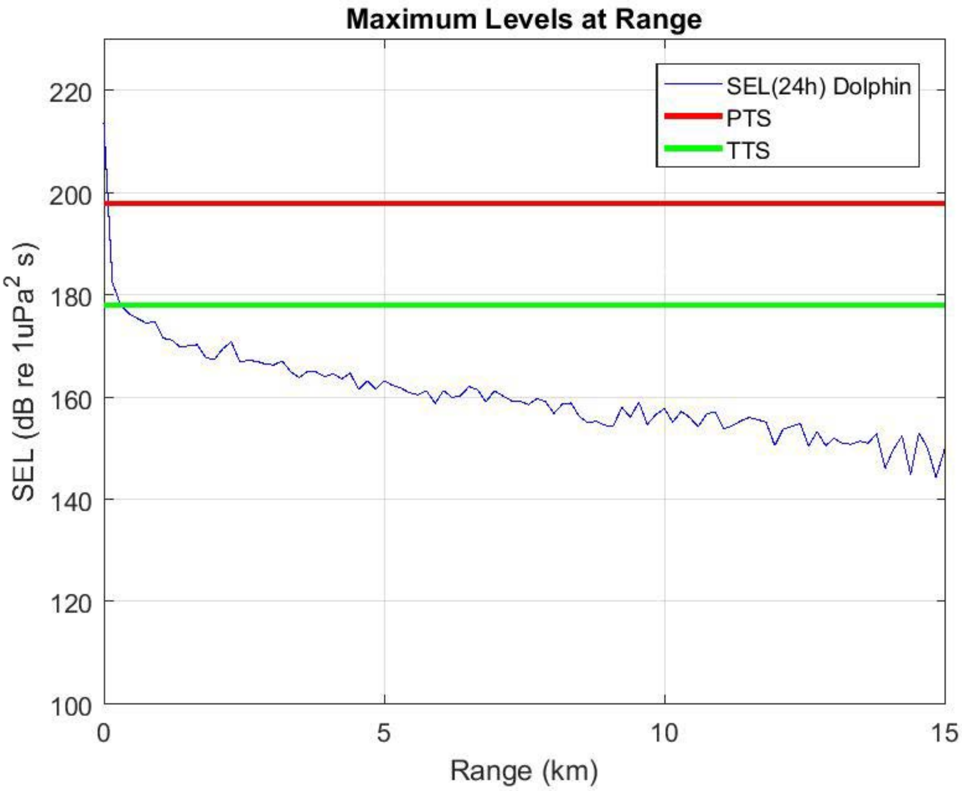

Figure 7-89 : MSL TSHD and CSD Location 3 maximum cumulative SEL with distance for Dolphin

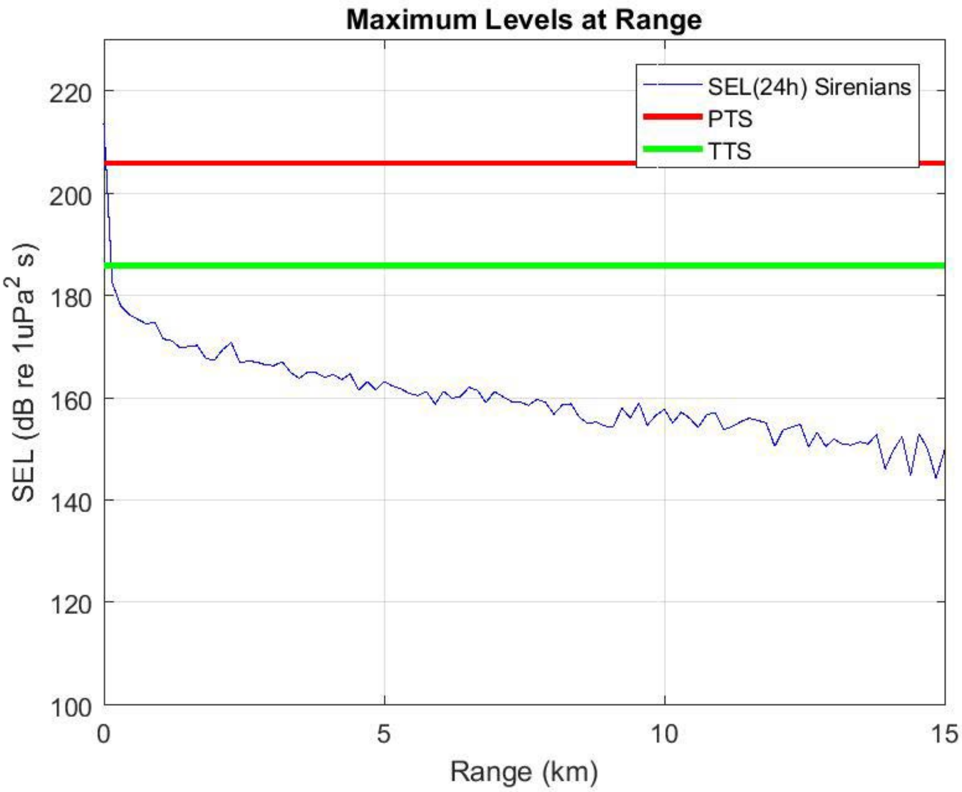

Figure 7-90 : MSL TSHD and CSD Location 3 maximum cumulative SEL with distance for Dugongs

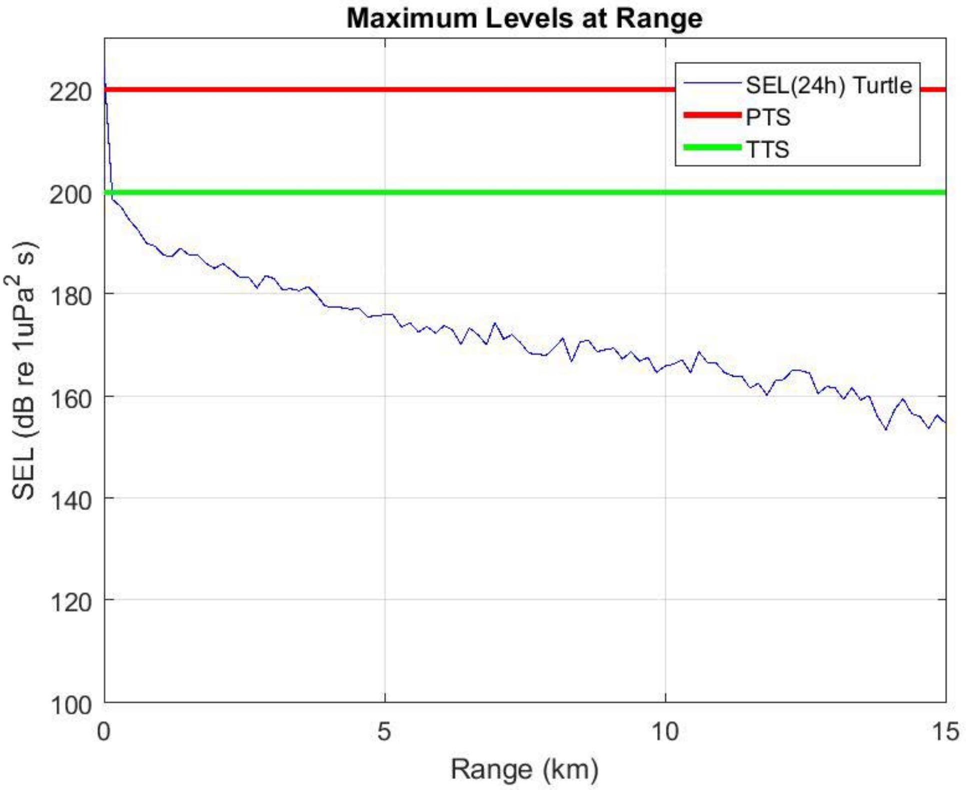

Figure 7-91 : MSL TSHD and CSD Location 3 cumulative SEL with distance for Turtles

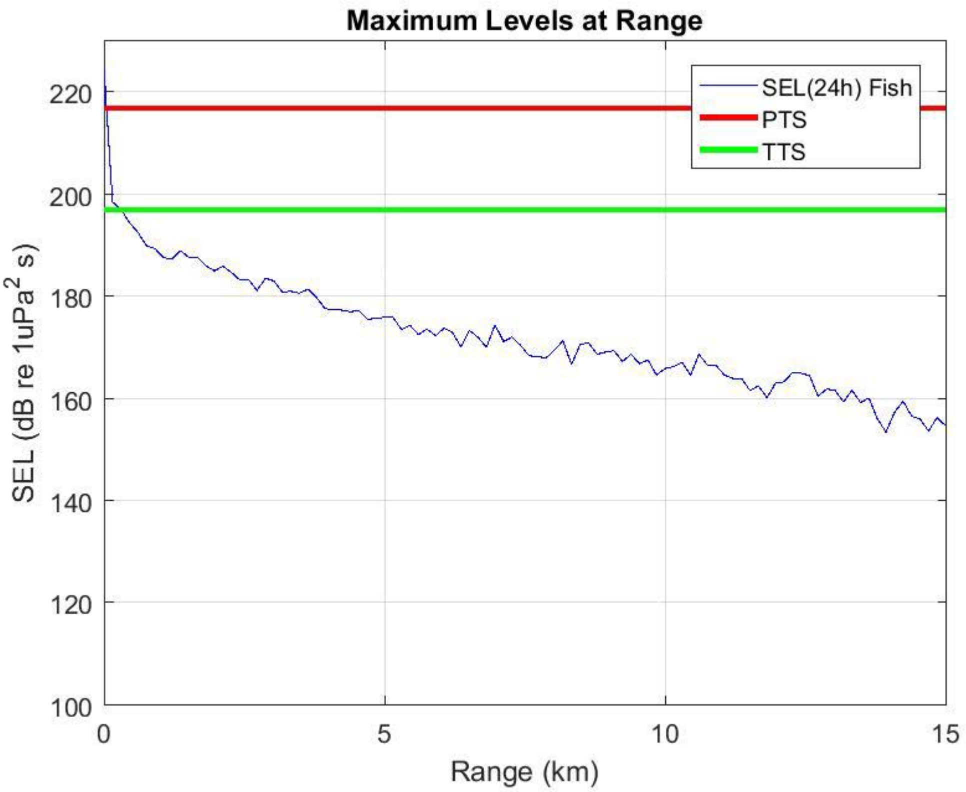

Figure 7-92 : MSL TSHD and CSD Location 3 maximum cumulative SEL with distance for Fish

D.6 Location 4 – Sheet Pile Driving (Mud Flat)

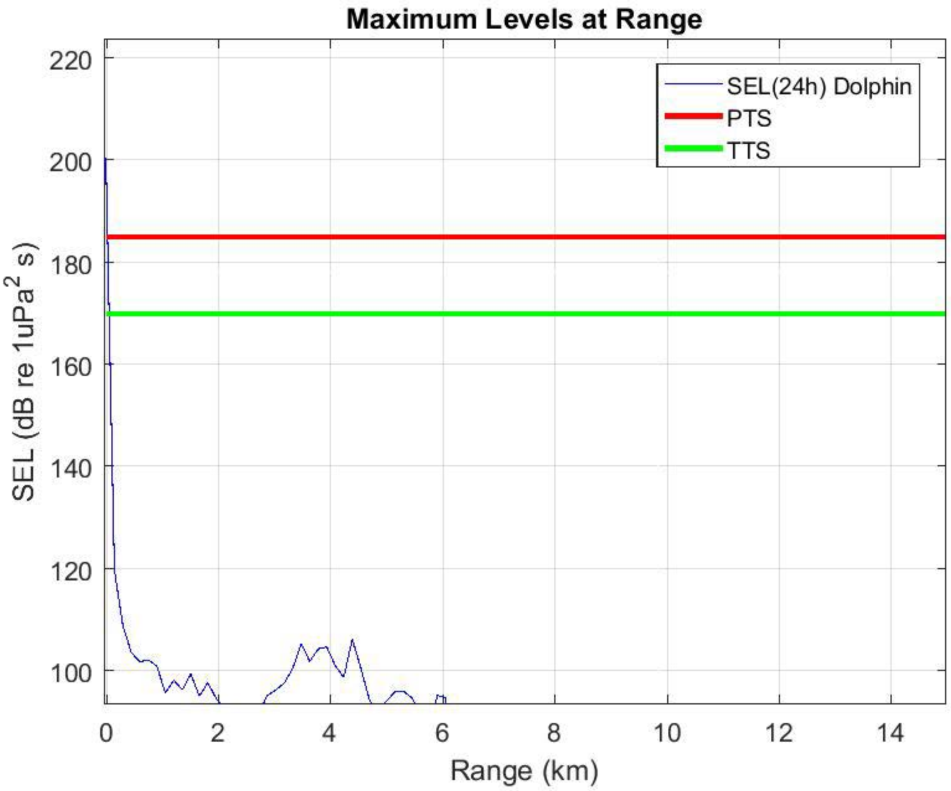

Figure 7-93 : Sheet Pile Driving maximum SEL with distance for Dolphins

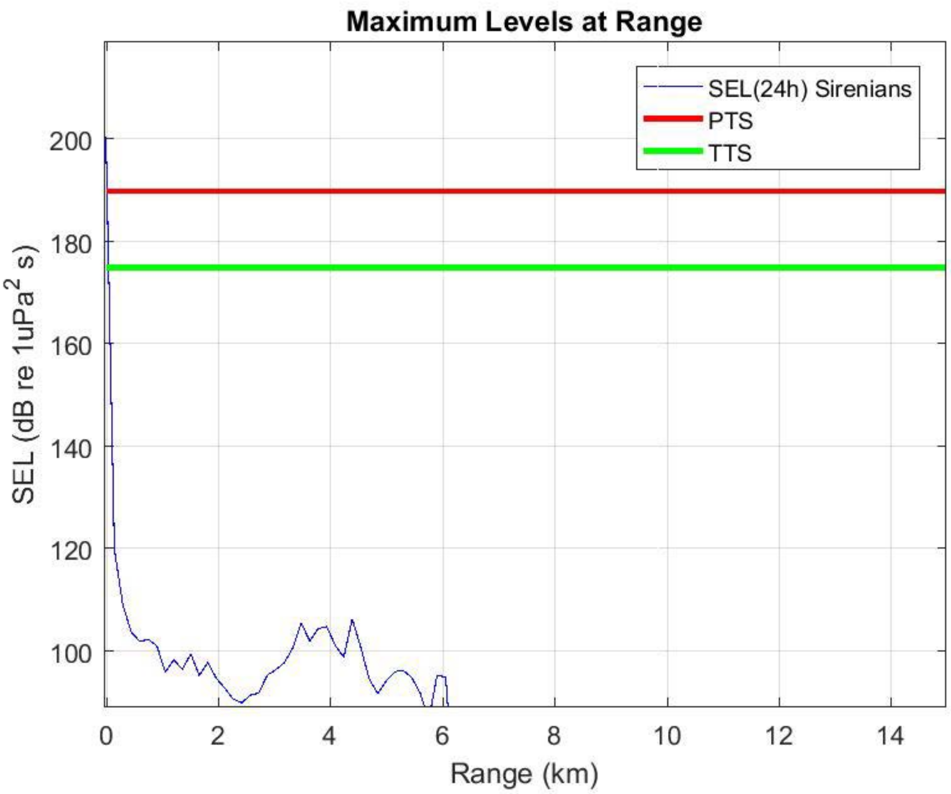

Figure 7-94 : Sheet Pile Driving maximum SEL with distance for Dugongs

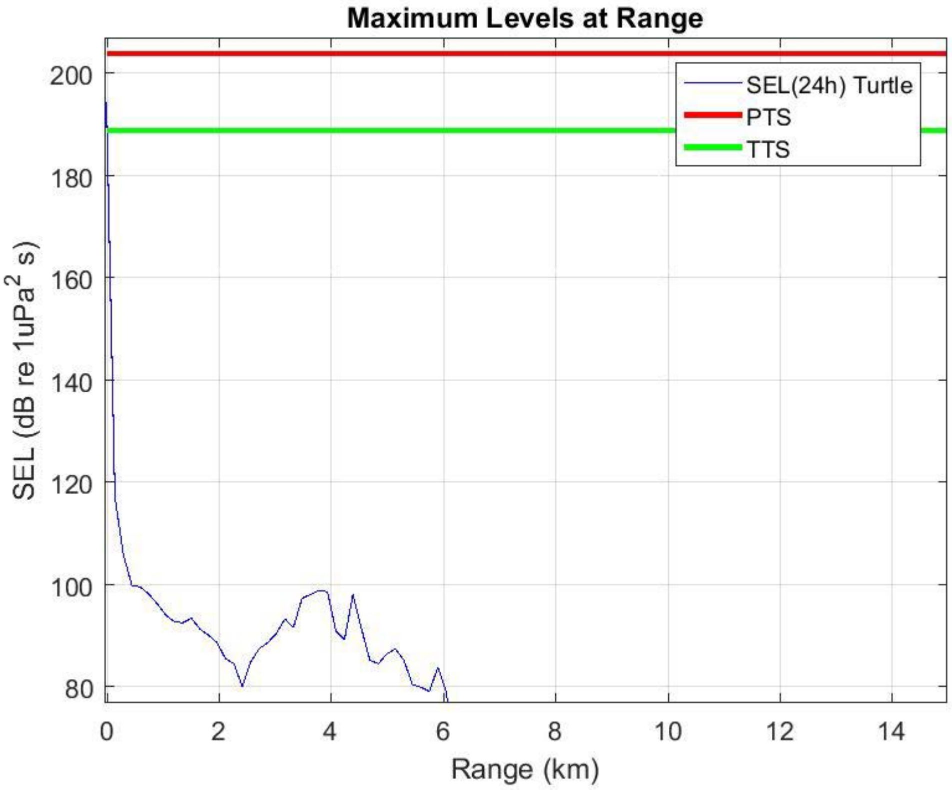

Figure 7-95 : Sheet Pile Driving maximum SEL with distance for Turtles

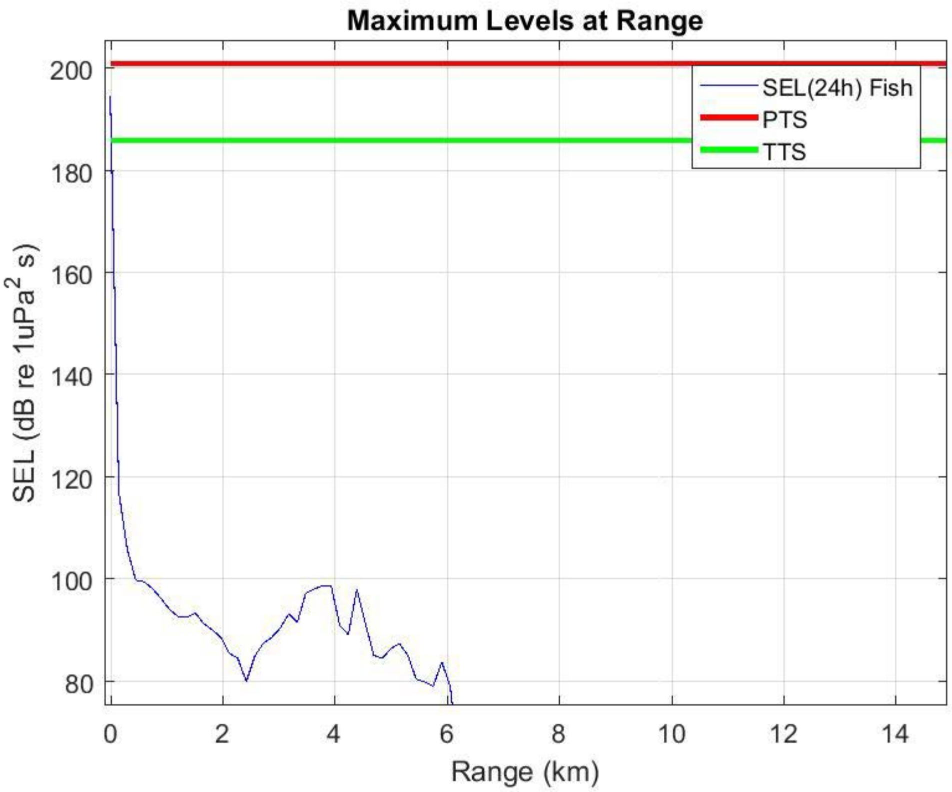

Figure 7-96 : Sheet Pile Driving maximum SEL with distance for Fish

APPENDIX E
Behavioural Ranges

E.1 Location 1 – BHD (Digging)

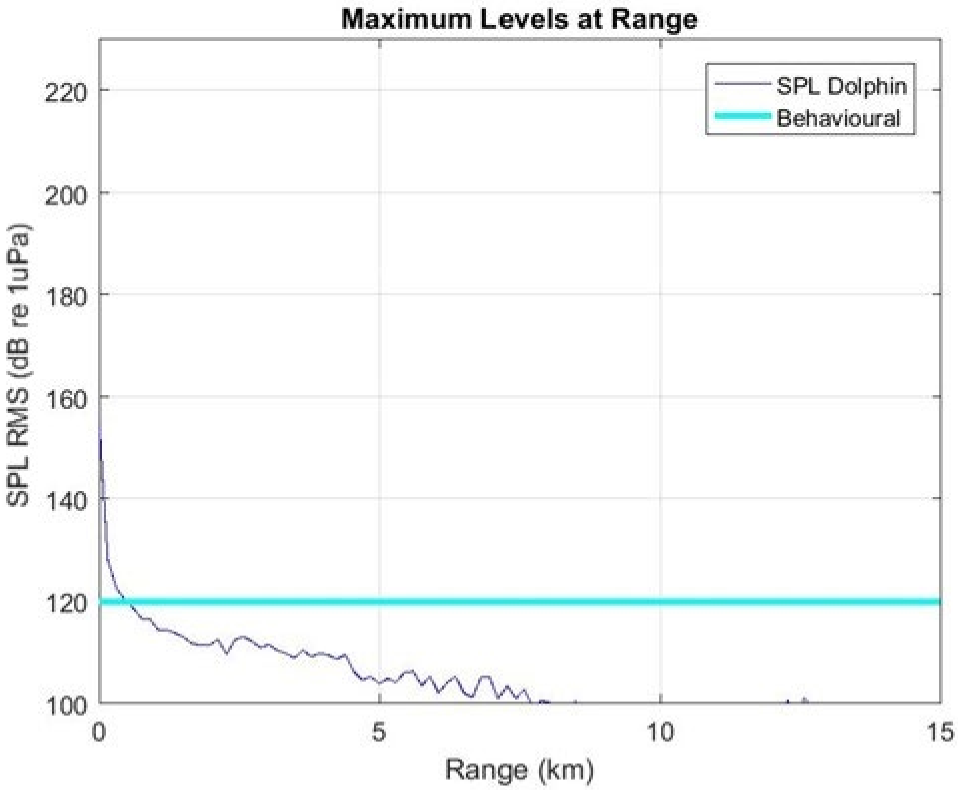

Figure 7-97 : MSL BHD (Digging) Location 1 maximum behavioural distance for Dolphin

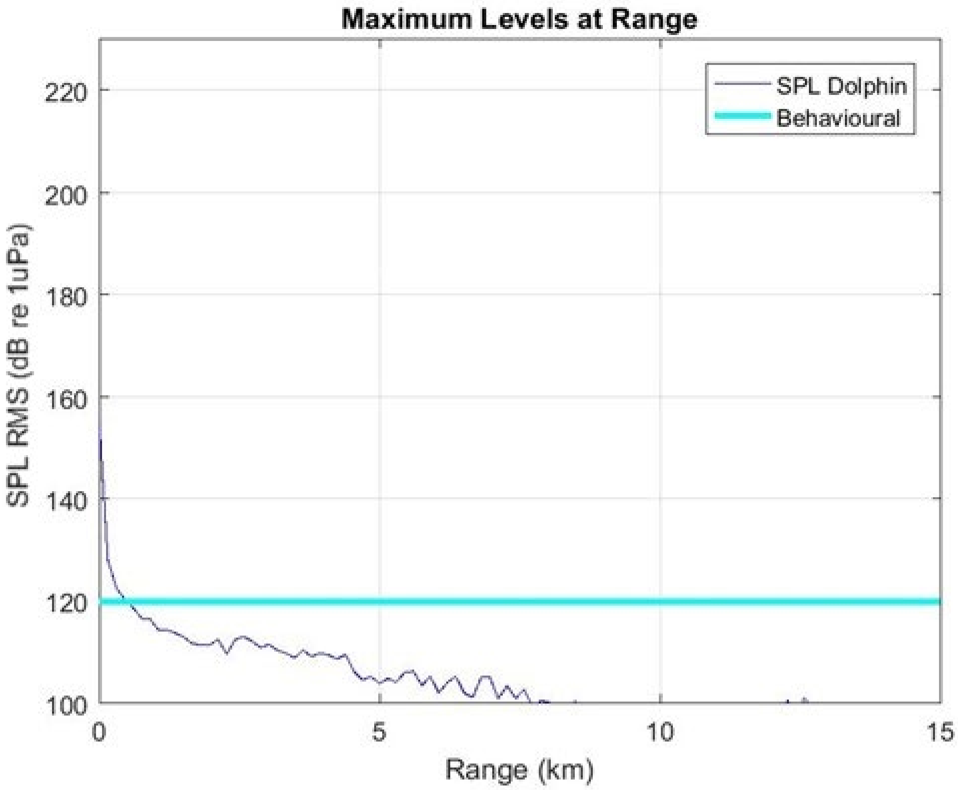

Figure 7-98 : MSL BHD (Digging) Location 1 maximum behavioural distance for Dugongs

E.2 Location 1 – BHD with Hydraulic Hammer

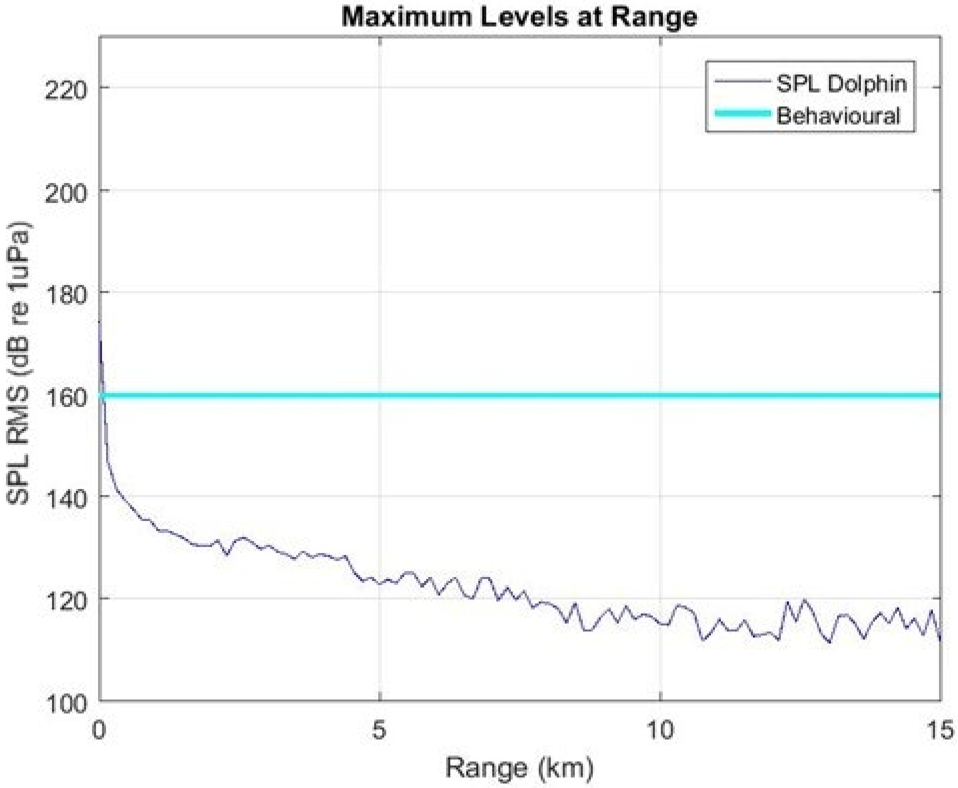

Figure 7-99 : MSL BHD (Hydraulic Hammer) Location 1 maximum behavioural distance for Dolphin

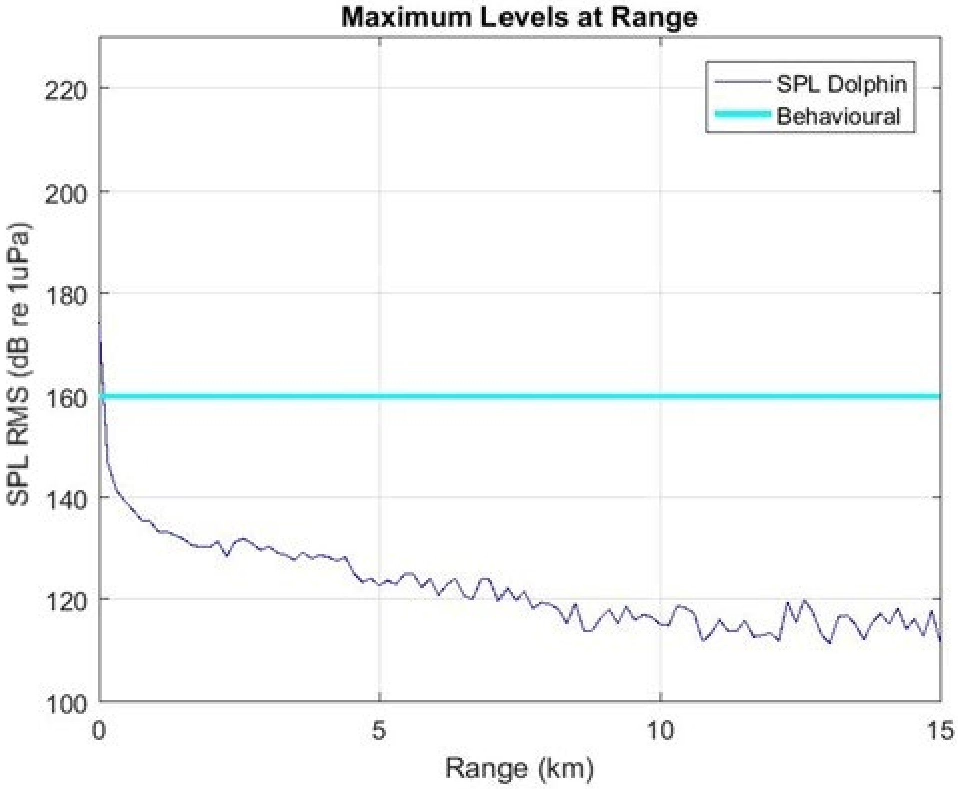

Figure 7-100 : MSL BHD (Hydraulic Hammer) Location 1 maximum behavioural distance for Dugongs

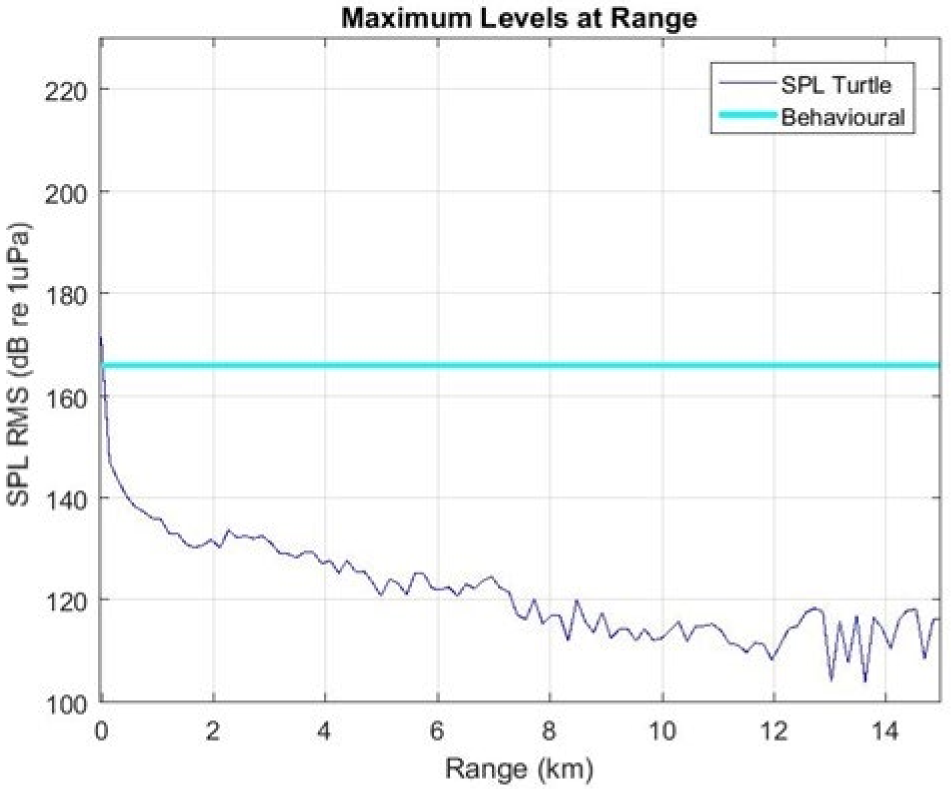

Figure 7-101 : MSL BHD (Hydraulic Hammer) Location 1 maximum behavioural distance Turtles

E.3 Location 2 – TSHD

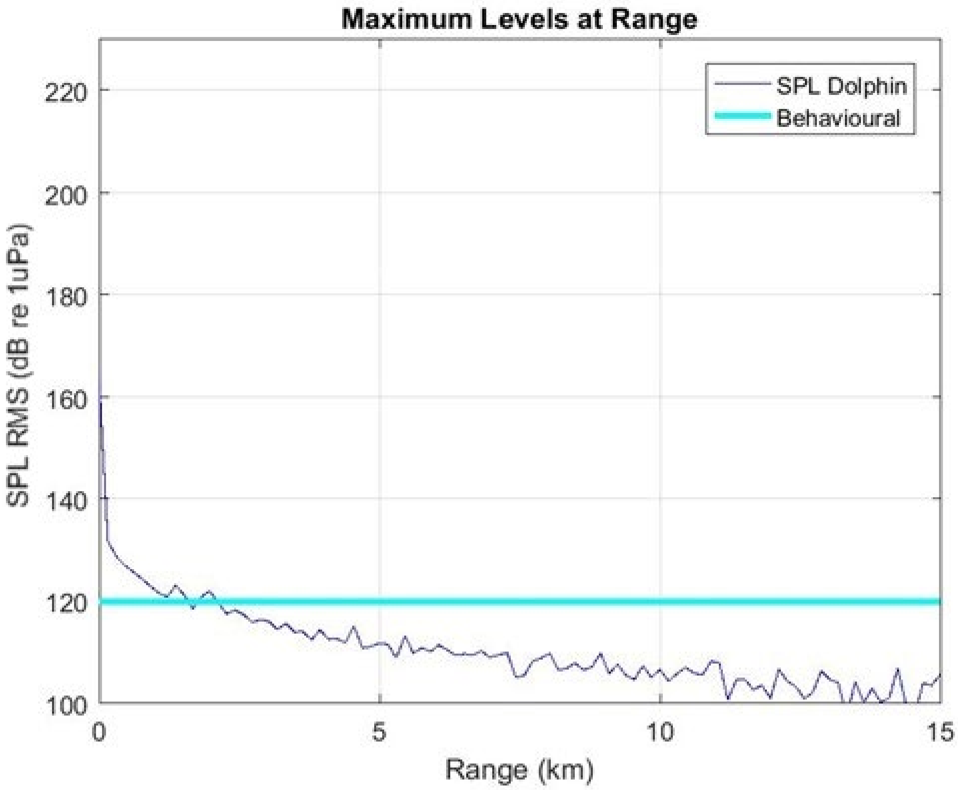

Figure 7-102 : MSL TSHD Location 2 maximum behavioural distance for Dolphin

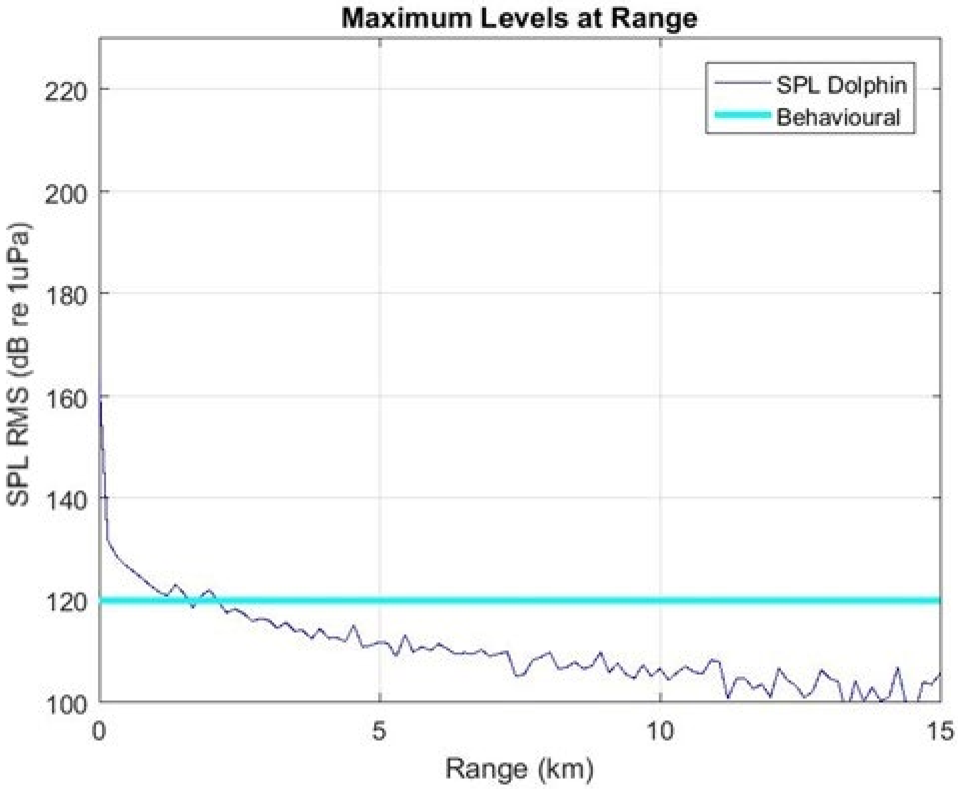

Figure 7-103 : MSL TSHD Location 2 maximum behavioural distance for Dugongs

E.4 Location 3 – TSHD

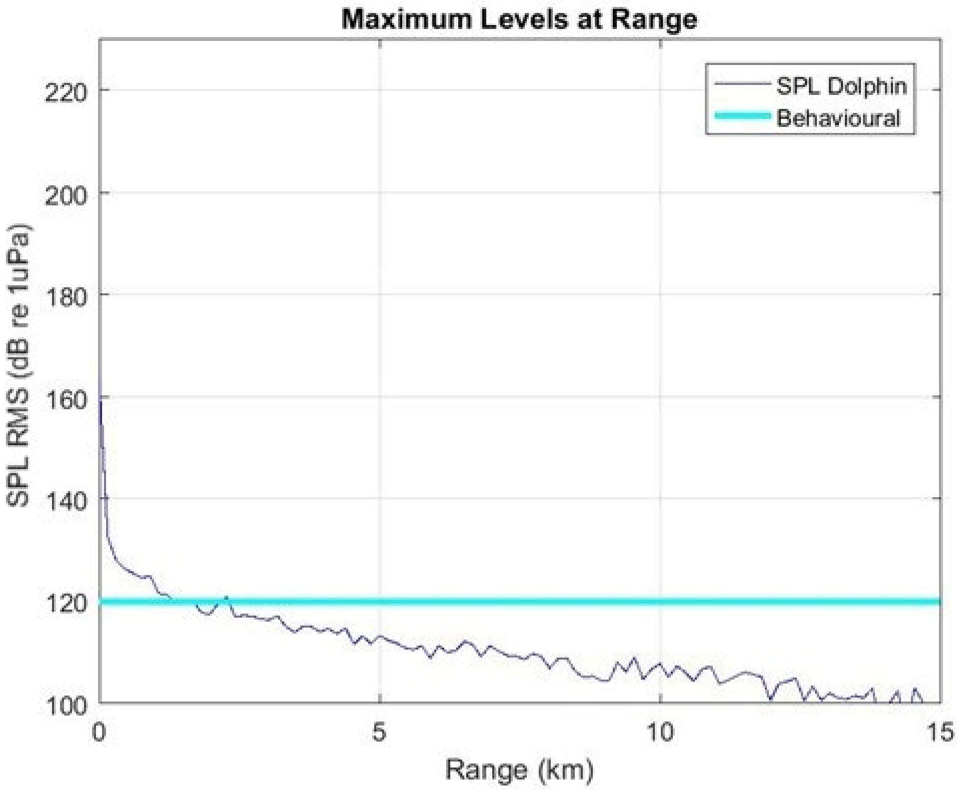

Figure 7-104 : MSL TSHD Location 3 maximum behavioural distance for Dolphin

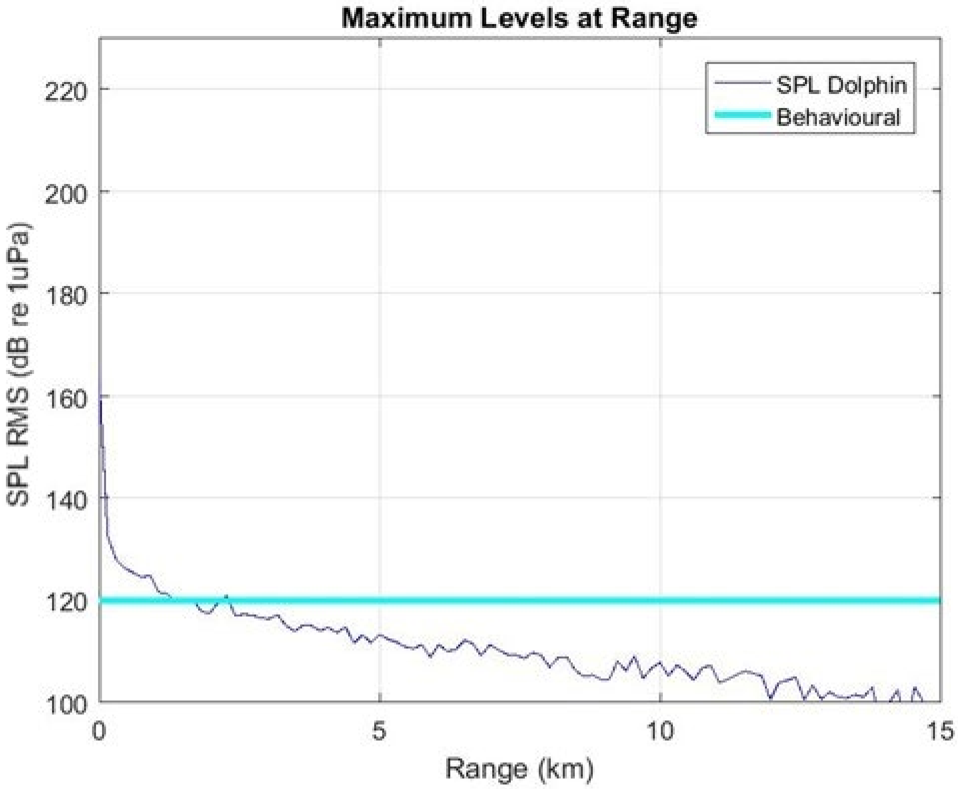

Figure 7-105 : MSL TSHD Location 3 maximum behavioural distance for Dugongs

E.5 Location 3 – Cumulative – TSHD and CSD

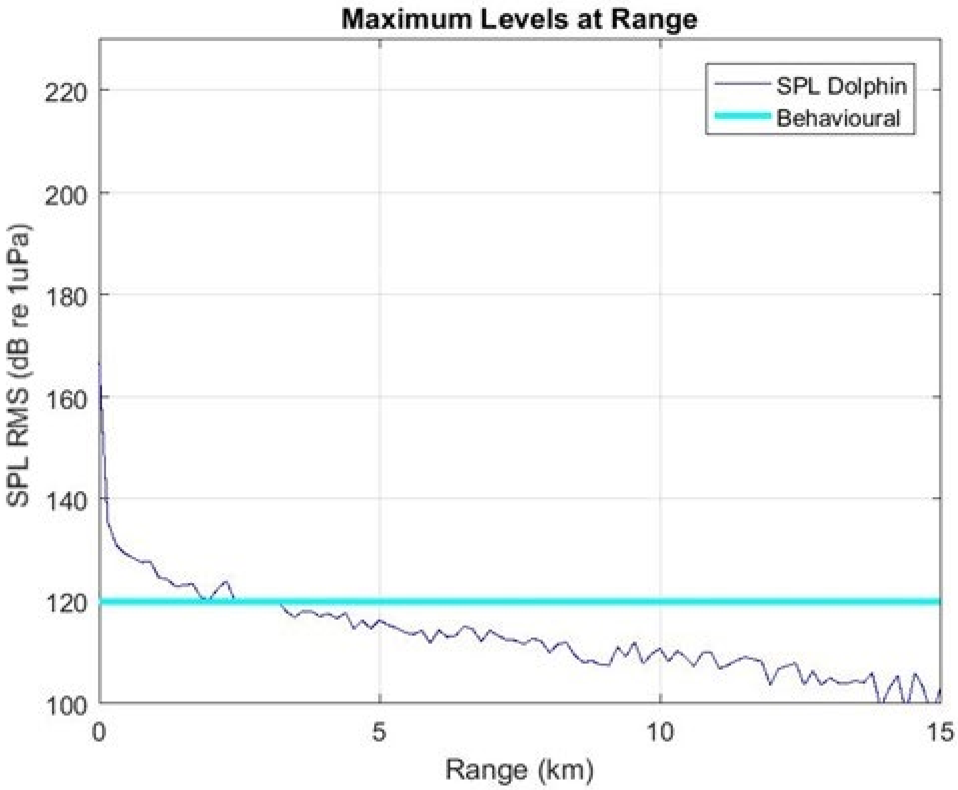

Figure 7-106 : MSL TSHD and CSD Location 3 maximum behavioural distance for Dolphin

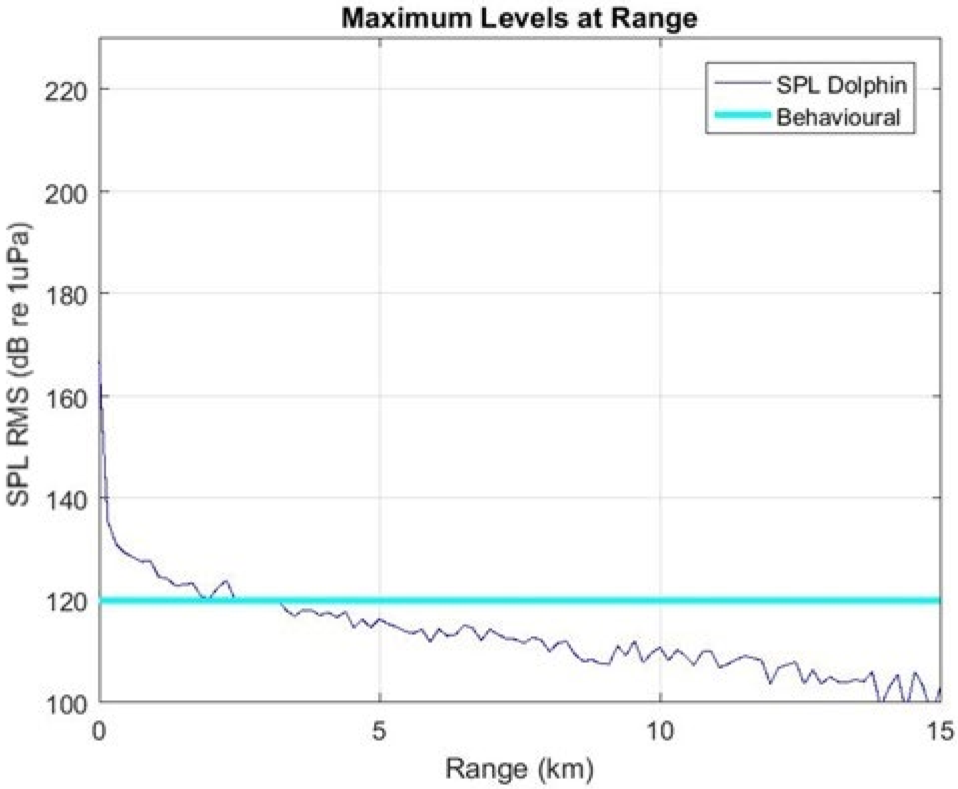

Figure 7-107 : MSL TSHD and CSD Location 3 maximum behavioural distance for Dugongs

E.6 Location 4 – Sheet Pile Driving (Mud Flats)

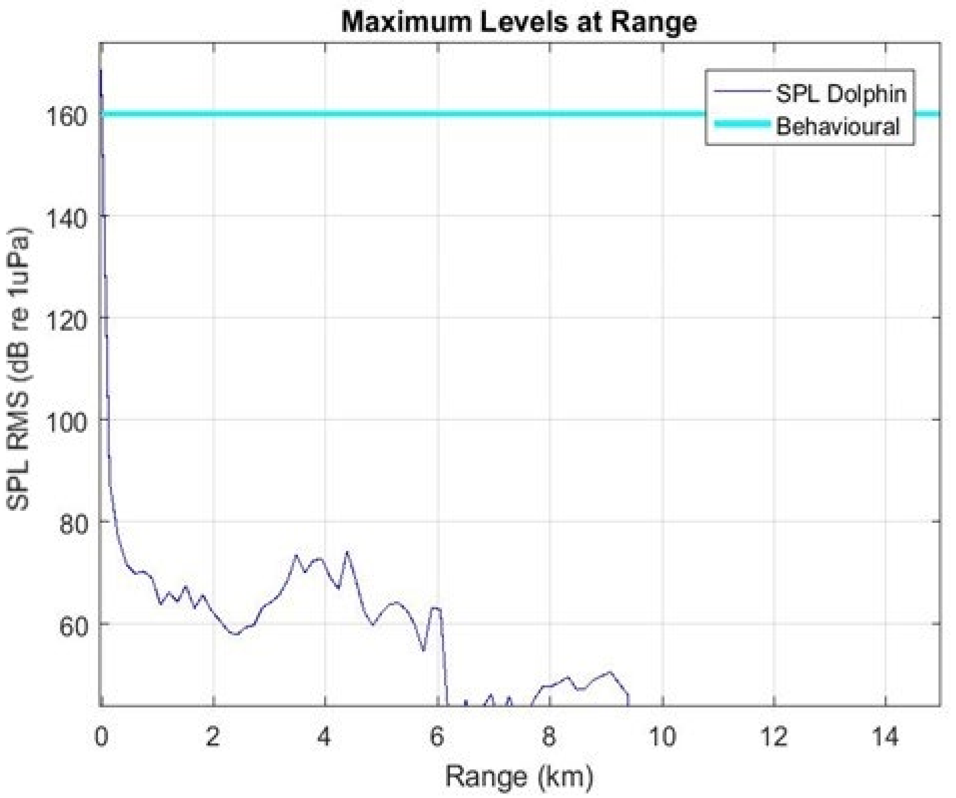

Figure 7-108 : Sheet Pile Driving behavioural distance for Dolphins

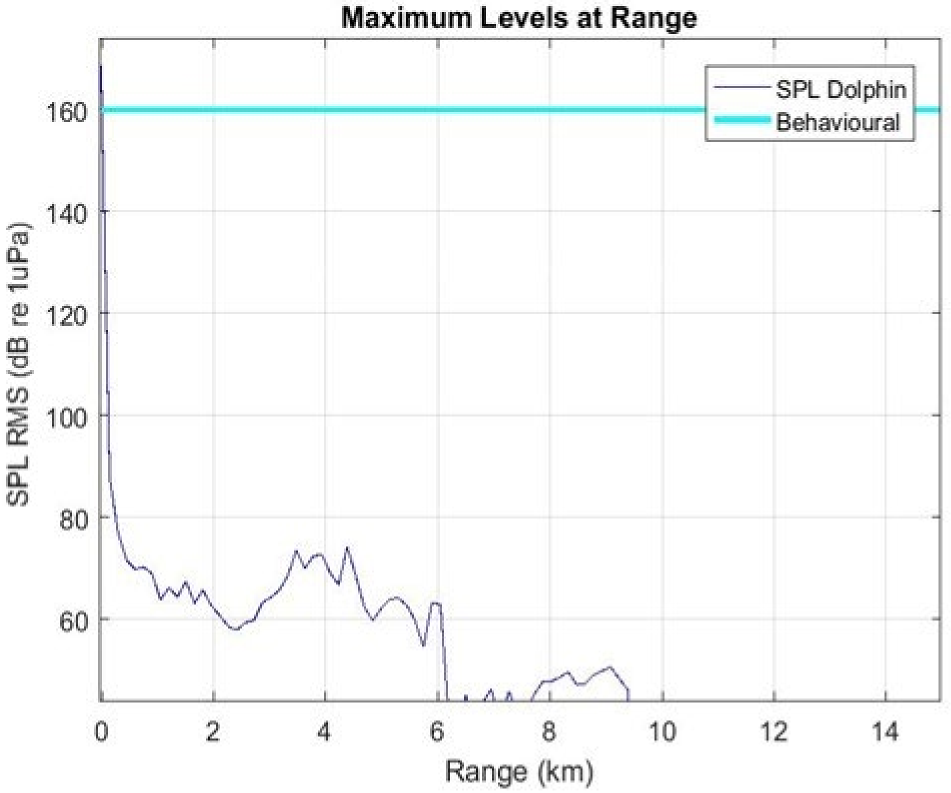

Figure 7-109 : Sheet Pile Driving behavioural distance for Dugongs

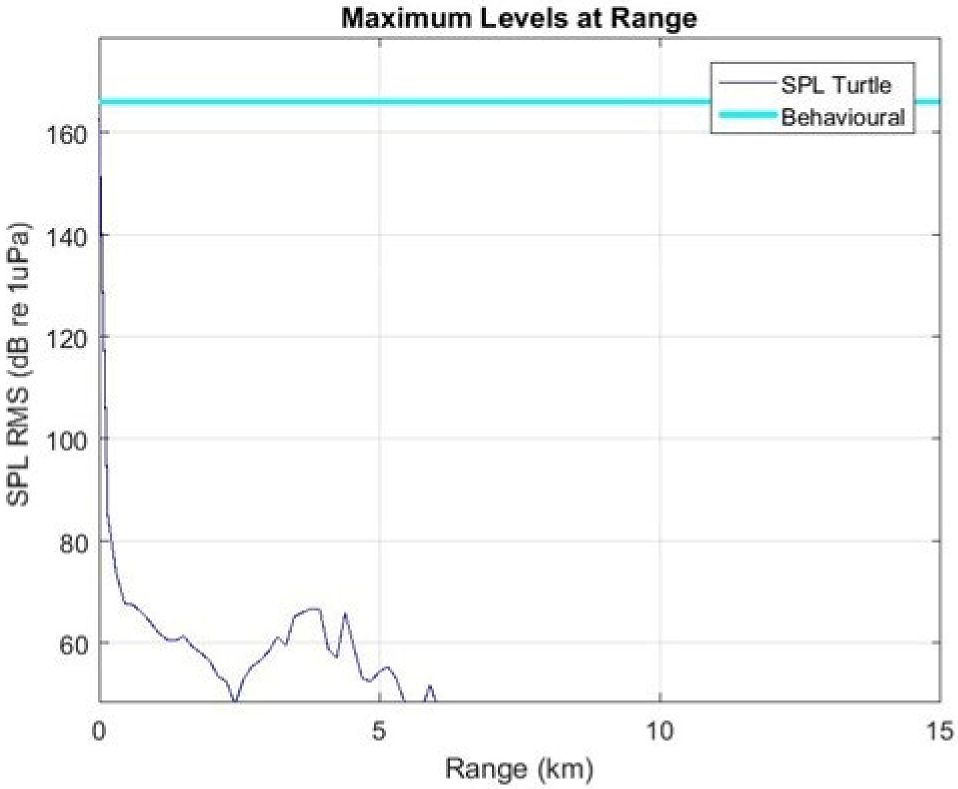

Figure 7-110 : Sheet Pile Driving behavioural distance for Turtles

APPENDIX F

Summary of Auditory Weighting and Exposure Function Parameters

Note: All of the following equations use SI units: Pascals, metres, seconds, and kilograms. For clarity, units are not included in every equation and constant.

Hearing Group	a	b	f_1 (kHz)	f_2 (kHz)	C (dB)	K (dB)
Low-frequency (LF) cetaceans	1.0	2	0.2	19	0.13	179
High-frequency (HF) cetaceans	1.6	2	8.8	110	1.20	177
Very High-frequency (HF) cetaceans	1.8	2	12	140	1.36	152

* Equations associated with Technical Guidance's auditory weighting ($W_{aud}(f)$) and exposure functions ($E_{aud}(f)$):

$$W_{aud}(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

$$E_{aud}(f) = K - 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

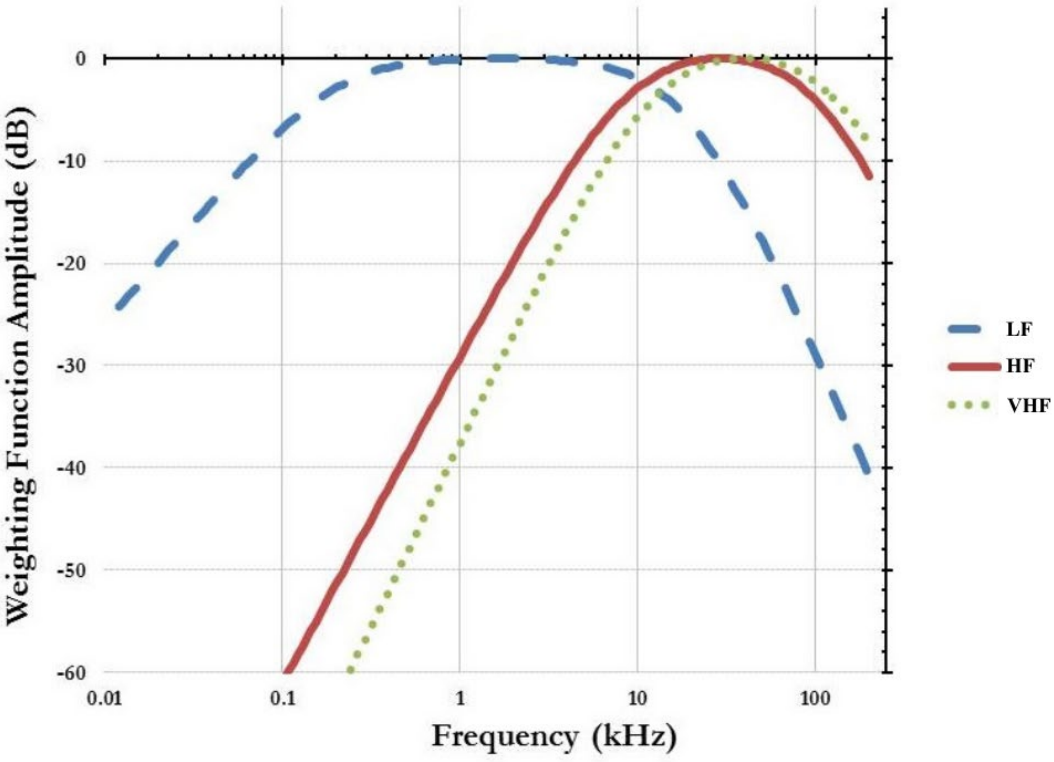

Figure 7-115: Hearing Sensitivity Curves for Cetaceans

Functional Hearing Group	K	a (Hz)	b (Hz)
Sea Turtles	0	10	2,000

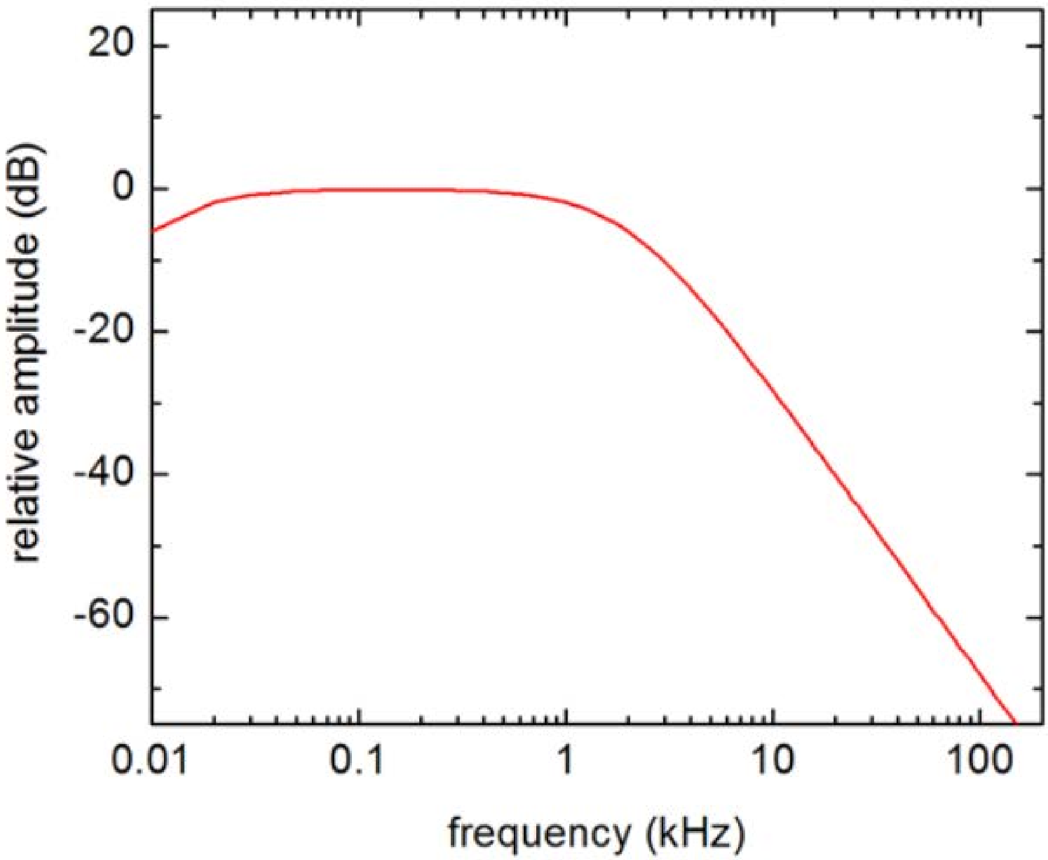

Figure 7-116: Hearing Sensitivity Curve for Turtles

Assets | Engineering | Environment | Noise | Spatial | Waste

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Santos

Appendix 9: Underwater Noise Modelling Report – Rock Breaking (JASCO)

Santos Barossa Darwin Pipeline Duplication

Acoustic Modelling for Assessing Marine Fauna Sound Exposure

JASCO Applied Sciences (Australia) Pty Ltd

28 March 2023

Submitted to:

Lachlan MacArthur
Santos
Contract 4800005952

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Contents

Table of Contents Contributors 6

Executive Summary 7

1. Introduction 10

1.1. Modelling Scenarios 10

2. Noise Effect Criteria 12

2.1. Impulsive Noise 13

2.1.1. Marine Mammals 13

2.1.2. Fish, Sea turtles, Fish Eggs, Fish Larvae 13

2.2. Non-impulsive Noise 2

2.2.1. Marine Mammals 2

2.2.2. Fish, Sea Turtles, Fish Eggs, and Fish Larvae 3

3. Methods 4

3.1. Sources 4

3.1.1. Xcentric Ripper 4

3.1.2. Hydraulic Hammer 5

3.2. Geometry and Modelled Regions 6

3.3. Accumulated Modelling 6

4. Results 7

4.1. Xcentric Ripper (non-impulsive sound source) 7

4.1.1. Tabulated Results 7

4.1.2. Sound Field Maps 8

4.2. Hydraulic Hammer (impulsive sound source) 14

4.2.1. Tabulated Results 14

4.2.2. Sound Field Maps 16

5. Discussion and Conclusion 23

Glossary 24

Literature Cited 32

Appendix A. Acoustic Metrics A-1

Appendix B. Sound Propagation Models B-1

Appendix C. Methods and Parameters C-1

Appendix D. Model Validation Information D-1

Appendix E. Additional Maps E-1

Appendix F. Hydraulic hammer operational time per day F-5

Figures

Figure 1. Overview of the modelled site and features associated with the Santos Barossa DPD. 11
Figure 2. Source level spectra (in decidecade frequency-band) for the Xcentric Ripper. 4
Figure 3. Source level spectra (in decidecade frequency-band) for the Hydraulic Hammer. 5
Figure 4. *Xcentric Ripper, LAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals. 9
Figure 5. *Xcentric Ripper, MSL, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals. 9
Figure 6. *Xcentric Ripper, HAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals. 10
Figure 7. *Xcentric Ripper, LAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect. 10
Figure 8. *Xcentric Ripper, MSL, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect. 11
Figure 9. *Xcentric Ripper, HAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect. 11
Figure 10. *Xcentric Ripper, LAT:* sound level contour map isopleths for HF cetaceans, sirenians and sea turtles. 12
Figure 11. *Xcentric Ripper, MSL:* sound level contour map isopleths for HF cetaceans, sirenians and sea turtles. 13
Figure 12. *Xcentric Ripper, HAT:* sound level contour map isopleths for HF cetaceans, sirenians and sea turtles. 13
Figure 13. *Hydraulic Hammer, LAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals and sea turtles. 17
Figure 14. *Hydraulic Hammer, MSL, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals and sea turtles. 17
Figure 15. *Hydraulic Hammer, HAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals and sea turtles. 18
Figure 16. *Hydraulic Hammer, LAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect. 18
Figure 17. *Hydraulic Hammer, MSL, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect. 19
Figure 18. *Hydraulic Hammer, HAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect. 19
Figure 19. *Hydraulic Hammer, LAT:* isopleths for HF cetaceans, sirenians, and sea turtles. 20
Figure 20. *Hydraulic Hammer, LAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for fish. 20
Figure 21. *Hydraulic Hammer, MSL:* isopleths for HF cetaceans, sirenians, and sea turtles. 21

Figure 22. *Hydraulic Hammer, MSL:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for fish. 21
Figure 23. *Hydraulic Hammer, HAT:* isopleths for HF cetaceans, sirenians, and sea turtles. 22
Figure 24. *Hydraulic Hammer, HAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for fish. 22

Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale. A-2
Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale. A-3
Figure A-3. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by Southall et al. (2019). A-7
Figure B-1. The N×2-D and maximum-over-depth modelling approach used by MONM. B-1
Figure C-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two scenarios. C-1
Figure C-2. Bathymetry in the modelled area. C-2
Figure C-3. The modelling sound speed profile corresponding to April is shown as the dotted line The profile is calculated from temperature and salinity profiles from Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). C-3
Figure E-1. *Xcentric Ripper, LAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. E-1
Figure E-2. *Xcentric Ripper, MSL:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. E-2
Figure E-3. *Xcentric Ripper, HAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. E-2
Figure E-4. *Hydraulic Hammer, LAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. E-3
Figure E-5. *Hydraulic Hammer, MSL:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. E-4
Figure E-6. *Hydraulic Hammer, HAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. E-4

Tables

Table 1. Summary of maximum (R_{max}) horizontal distances (in km) from the Xcentric Ripper at the modelled site to behavioural response thresholds, temporary threshold shift (TTS), and permanent threshold shift (PTS) for marine mammals. 8
Table 2. Summary of maximum (R_{max}) horizontal distances (in km) from the hydraulic hammer at the modelled site to behavioural response thresholds, temporary threshold shift (TTS), and permanent threshold shift (PTS) for marine mammals. 8
Table 3. *Xcentric Ripper*: summary of distances to sea turtle temporary threshold shift (TTS) and permanent threshold shift (PTS). 8
Table 4. *Hydraulic hammer*: summary of distances to sea turtle behavioural response criteria, temporary threshold shift (TTS), and permanent threshold shift (PTS). 9
Table 5. *Hydraulic Hammer*: Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for 24 h sound exposure level (SEL_{24h}) modelled scenarios. 9
Table 6. Modelled site locations and source information. 10
Table 7. Acoustic effects of impulsive noise on marine mammals: Unweighted SPL, SEL_{24h}, and PK thresholds. 13

Table 8. Criteria for pile driving noise exposure for fish 1
Table 9. Acoustic effects of impulsive noise on sea turtles: Unweighted sound pressure level (SPL), 24-hour sound exposure level (SEL_{24h}), and peak pressure (PK) thresholds 2
Table 10. Criteria for effects of non–impulsive noise exposure for marine mammals: Unweighted SPL and SEL_{24h} thresholds. 2
Table 11. Criteria for non–impulsive noise exposure for fish 3
Table 12. Acoustic effects of non–impulsive noise on sea turtles, weighted SEL_{24h}, Finneran et al. (2017). 3
Table 13. *Xcentric Ripper*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL). 7
Table 14. *Xcentric Ripper:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). 8
Table 15. *Hydraulic Hammer: modelled maximum–over–depth per–strike SPL isopleths*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km). 14
Table 16. *Hydraulic Hammer:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). 15
Table 17. *Hydraulic Hammer:* distances to 24 h sound exposure level (SEL_{24h}) based fish criteria in the water column. 16

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by Southall et al. (2019). A-7
Table C-1. Geoacoustic profile for Darwin Harbour. C-3
Table F-1. *Hydraulic Hammer*: Summary of maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} TTS for HF cetaceans, Sirenians, and Sea Turtles based on Southall et al. (2019) and Finneran et al. (2017) for different operation durations. F-5
Table F-2. *Hydraulic Hammer 2 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). F-6
Table F-3. *Hydraulic Hammer 4 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). F-7
Table F-4. *Hydraulic Hammer 6 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). F-8
Table F-5. *Hydraulic Hammer 8 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). F-9

Table of Contributors

SER Component	Key Roles	Organisation	Name	Qualifications	Experience
Underwater Noise Modelling Assessment – Rock Breaking Tools	Lead Author and Modeller	JASCO Applied Sciences	Steven C. Connell	Ph.D.	2 years
	Quality Control and report reviewer		Matthew W. Koessler	Ph.D.	>5 years
	Project Manager and report reviewer		Craig R. McPherson	BEng(Hons)	>15 years

Executive Summary

JASCO Applied Sciences (JASCO) performed a modelling study of underwater sound levels associated with the Santos Barossa Darwin Pipeline Duplication (DPD). The modelling study considers trenching activity using two sources – the Xcentric Ripper, considered to be a non-impulsive noise source, and a hydraulic hammer, considered to be an impulsive noise source.

The study predicted ranges to acoustic thresholds that may result in injury to or behavioural disturbance of marine fauna. The corresponding thresholds used in this study represented the best available science for behavioural response or disturbance, temporary threshold shift (TTS), and permanent threshold shift (PTS) or injury depending upon the fauna group. The fauna considered included marine mammals, sea turtles, and fish.

The modelling methodology was to characterise the sound sources and then determine how the sounds propagated at a specific location considering the environmental properties that influence the propagation of underwater sound. The models considered source levels of the trenching devices, and range-dependent environmental properties. It was assumed that any of the activities could be performed at any time during the year, therefore the most conservative season for the sound speed profile was considered.

Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p) and accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria and noise sources. In this report, the duration period for SEL accumulation is defined as an 8-hour period over which sound energy is integrated; the level is specified with the abbreviation SEL_{24h}.

SEL_{24h} is a cumulative metric that reflects the dosimetric effect of noise levels within 24 hours, based on the assumption that a receiver (e.g., an animal) is consistently exposed to such noise levels at a fixed position. More realistically, marine animals would not stay in the same location for 24 hours (especially in the absence of location-specific habitat) but rather a shorter period, depending on the animal's behaviour and the source's proximity and movements. Therefore, a reported radius for the SEL_{24h} criteria does not mean that marine fauna travelling within this radius of the source will be impaired, but rather that an animal could be exposed to the sound level associated with impairment (either PTS or TTS) if it remained at that location for 24 hours.

Marine Mammals

- The maximum distance where the NOAA (2019) marine behavioural response criterion of 120 dB 1 μPa for non-impulsive noise is shown in Table 1 and 160 dB 1 μPa for impulsive noise is shown in Table 2.
- The results for marine mammal injury considered the criteria from Southall et al. (2019). The metric used in this assessment is SEL_{24h}. The SEL_{24h} is a cumulative metric that reflects the dosimetric impact of noise levels within 24 hours based on the assumption that an animal is consistently exposed to such noise levels at a fixed position. More realistically, marine mammals (and fish) would not stay in the same location for 24 hours. Therefore, a reported radius of SEL24h criteria does not mean that marine fauna travelling within this radius of the source will be injured, but rather that an animal could be exposed to the source level associated with injury (either PTS or TTS) if it remained in that location for 24 hours.
- The distance to PTS and TTS was always farthest towards the offshore direction and is shown in Tables 1 and 2.

Table 1. Summary of maximum (R_{max}) horizontal distances (in km) from the Xcentric Ripper at the modelled site to behavioural response thresholds, temporary threshold shift (TTS), and permanent threshold shift (PTS) for marine mammals.

Hearing group	Modelled distance to effect threshold (R_{max})		
	Behavioural response[1]	Impairment: TTS[2]	Impairment: PTS[2]
LF cetaceans	14.7	3.83	0.18
HF cetaceans		0.16	–
Sirenians		0.11	–

Noise exposure criteria: [1] NOAA (2019) and [2] Southall et al. (2019)
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m)

Table 2. Summary of maximum (R_{max}) horizontal distances (in km) from the hydraulic hammer at the modelled site to behavioural response thresholds, temporary threshold shift (TTS), and permanent threshold shift (PTS) for marine mammals.

Hearing group	Modelled distance to effect threshold (R_{max})		
	Behavioural response[1]	Impairment: TTS[2]	Impairment: PTS[2]
LF cetaceans	0.27	20.1	5.78
HF cetaceans		2.44	0.20
Sirenians		2.78	0.23

Noise exposure criteria: [1] NOAA (2019) and [2] Southall et al. (2019)
A dash indicates the threshold was not reached within the limits of the modelling resolution (20 m)

Sea Turtles

- The maximum distance to the SEL_{24h} metrics from the modelled sites Finneran et al. (2017). As is the case with marine mammals, a reported radius fir SEL_{24h} criteria does not mean that sea turtles travelling within the radius of the source will be injured, but rather that an animal could be exposed to the sound level associated with either PTS or TTS if it remained in that location for 24 hours.
- Table 3 summarises the distances to where the criterion for behavioural response of sea turtles to 166 dB 1 µPa and the 175 dB 1 µPa threshold for behavioural disturbance could be exceed.

Table 3. *Xcentric Ripper*: summary of distances to sea turtle temporary threshold shift (TTS) and permanent threshold shift (PTS).

Hearing group	Modelled distance to effect threshold (R_{max})	
	Impairment: TTS[1]	Impairment: PTS[1]
Sea turtles	0.05	–

Noise exposure criteria: [1] Finneran et al. (2017)

Table 4. *Hydraulic hammer*: summary of distances to sea turtle behavioural response criteria, temporary threshold shift (TTS), and permanent threshold shift (PTS).

Hearing group	Modelled distance to effect threshold (R_{max})			
	Behavioural response[1]	Behavioural disturbance[1]	Impairment: TTS[2]	Impairment: PTS[2]
Sea turtles	0.09	0.27	1.18	0.12

Noise exposure criteria: [1] McCauley et al. (2000) and [2] Finneran et al. (2017)

NOTE: TTS and PTS for impulsive noise is considered as a dual metric with SEL_{24h} and peak thresholds and the longest range to threshold to be taken. Since the source levels were taken from measured data over 1 sec the time characteristics and hence peak could not be determined. Due to the noise source distance to thresholds is expected to be greater for SEL_{24h}

Fish, fish eggs, and fish larvae

- This modelling study assessed the ranges for qualitative criteria based on Popper et al. (2014) and considered SEL_{24h} metrics associated with mortality and potential mortal injury as well as impairment in the following groups:
  - Fish without a swim bladder (also appropriate for sharks in the absence of other information),
  - Fish with a swim bladder that do not use it for hearing,
  - Fish that use their swim bladders for hearing,
  - Fish eggs and fish larvae.
- Table 5 summarises distances to effect criteria for fish, fish eggs, and fish larvae.

Table 5. *Hydraulic Hammer*: Summary of maximum fish, fish eggs, and larvae injury and temporary threshold shift (TTS) onset distances for 24 h sound exposure level (SEL_{24h}) modelled scenarios.

Relevant hearing group	Effect Criteria	Modelled distance to effect threshold (R_{max})
Fish: No swim bladder	Recoverable injury	0.03
	TTS	4.27
Fish: swim bladder not involved in hearing and Swim bladder involved in hearing	Recoverable injury	0.34
	TTS	4.27
Fish eggs and larvae	Injury	0.09

1. Introduction

Jasco Applied Sciences (JASCO) performed a numerical estimation study of underwater sound levels associated with the planned trenching activities in relation to the Santos Barossa Darwin Pipeline Duplication (DPD) to assist in understanding the potential acoustic effect on receptors including marine mammals, sea turtles, and fish.

The modelling study predicted the distances at which underwater sound levels from operations reached noise effect thresholds and criteria. Due to the variety of species considered, there are several different thresholds for evaluating effects, including: mortality, injury, temporary reduction in hearing sensitivity, and behavioural disturbance.

The modelling methodology considered underwater acoustic propagation models used in conjunction with the parametrisation specific to modelled sources (source level, frequency content, and source directivity) and range-dependent environmental properties that effect the propagation of underwater sound. Estimated underwater acoustic levels are presented as sound pressure levels (SPL, L_p) and accumulated sound exposure levels (SEL, L_E) as appropriate for different noise effect criteria for either non-impulsive (Xcentric Ripper) or impulsive (hydraulic hammer) noise sources.

Section 1.1 outlines the specific details of modelling study. Section 2 details the metrics used to represent underwater acoustic fields and the associated effect criteria considered. Section 3 details the methodology for predicting the source levels and modelling the sound propagation, including source levels and environmental parameters required by the propagation models. Section 4 presents the results, which are then discussed in Section 5.

1.1. Modelling Scenarios

The acoustic modelling study for trenching activities for the Santos Barossa DPD considers sites within Darwin Harbour with a water depth approximately 10 m deep. The project components considered two sources for trenching at three different tide datums for consistency with previous work – Lowest Astronomical Tide (LAT), Mean Sea Level (MSL), and Highest Astronomical Tide (HAT). The modelled site and scenarios considered are detailed in Table 6 with an overview map of the area shown in Figure 1.

Table 6. Modelled site locations and source information.

Site	Source	Latitude (S)	Longitude (E)	MGA[1] Zone 52 (GDA94)		Datum	Water Depth (m)	Duration (h)
				X (m)	Y (m)			
1	Xcentric Ripper XR-60	12° 31' 39.87"	130° 51' 11.43"	701366	8614382	LAT	5.0	2 x 4 h
						MSL	9.2	
						HAT	13.1	
	Hydraulic Hammer					LAT	5.0	2 x 4 h
						MSL	9.2	
						HAT	13.1	

[1] Map Grid of Australia (MGA)
LAT: Lowest Astronomical Tide
MSL: Mean Sea Level
HAT: Highest Astronomical Tide

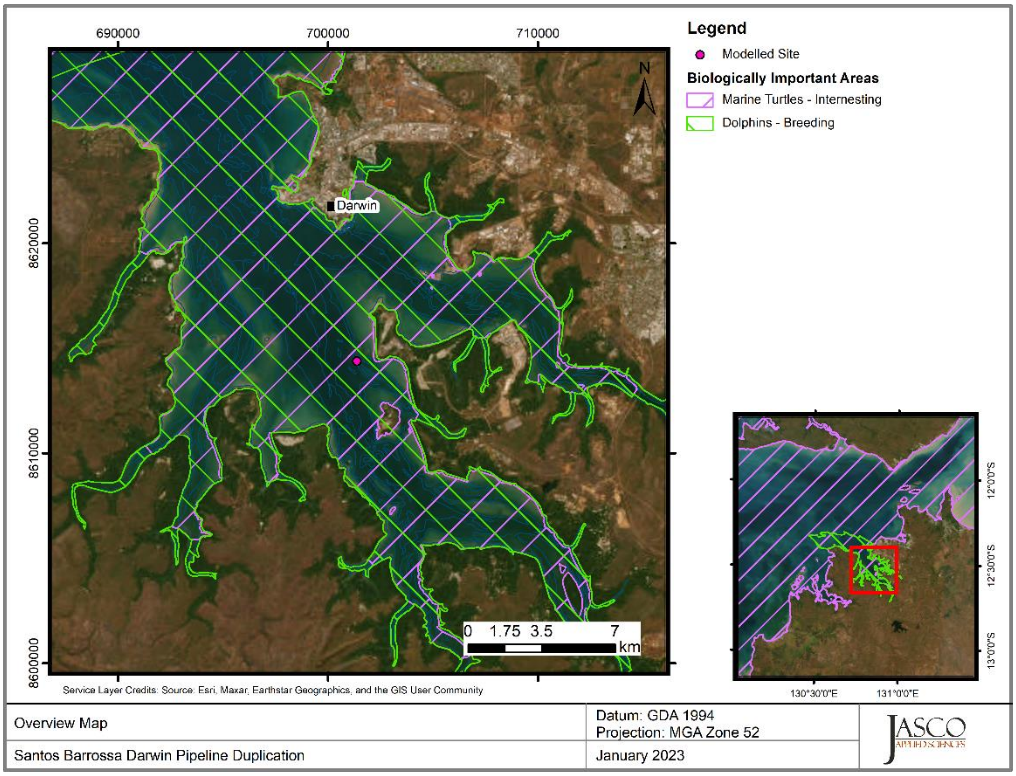

Figure 1. Overview of the modelled site and features associated with the Santos Barossa DPD.

2. Noise Effect Criteria

To assess the potential effects of a sound–producing activity, it is necessary to first establish exposure criteria (thresholds) for which sound levels may be expected to have a negative effect on animals. Whether acoustic exposure levels might injure or disturb marine fauna is an active research topic. Since 2007, several expert groups have developed SEL–based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), United States National Marine Fisheries Service (NMFS 2018) and Southall et al. (2019). The number of studies that investigate the level of behavioural disturbance to marine fauna by anthropogenic sound has also increased substantially.

Several impulsive metrics have been suggested to discern between impulsive and non-impulsive sounds for aerial and underwater sounds. Southall et al. (2007) proposed that regulations should use the Harris (1998) definition that says an impulse is present if there is more than a 3 dB difference between the impulse time weighted SPL and the slow-time weighted SPL (referred to here as the Harris impulse factor). Erdreich (1986) presented as an indicator of impulsiveness and demonstrated that kurtosis was a sensitive discriminator of the impulsiveness of noise. Kurtosis (β) (ISO 18405, 2017, Müller et al. 2020) is a statistical measure describing the distribution of acoustic energy across the frequency spectrum of a sound. It is a measure of the outliers in a given distribution (or time-series) relative to their occurrence in a normal distribution. Popper and Hawkins (2019) proposed kurtosis as a metric to distinguish impulsive sounds in the studies of fish and invertebrates. Martin et al. (2020) compared various types of impulsive and non-impulsive sounds in terms of their kurtosis, and the results strongly support using kurtosis for quantifying impulsiveness for future assessments and revised underwater noise regulations. The results also show that by applying this metric, it becomes irrelevant for assessing hearing impairment if impulsive signals seemingly merge into non-impulsive signals over distance due to dispersion as their kurtosis remains high (i.e., an indicator for impulsiveness). Guan et al. (2022) findings suggest that a simple dichotomy of classifying sounds as impulsive or non-impulsive may be overly simplistic for assessing auditory impacts (in marine mammals) and studies investigating the impacts from complex sound fields are needed.

The conclusions drawn in Guan et al. (2022) support the characterisation of the hydraulic hammer as an impulsive source while the Xcentric Ripper is used as a non-impulsive source. For these sound sources SPL and SEL are the relevant metrics. The period of accumulation associated with SEL is defined, with this report referencing either a “strikes in 1 sec” assessment or over 24 h. The acoustic metrics in this report reflect the ISO standard for acoustic terminology, ISO/DIS 18405:2017 (2017).

The following thresholds and guidelines for this study were chosen because they represent the best available science, and sound levels presented in literature for fauna with no defined thresholds:

1. Marine mammals:
   a. Marine mammal behavioural thresholds based on the current interim U.S. National Oceanic and Atmospheric Administration (NOAA) (2019) unweighted criterion for marine mammals of 120 dB re 1 µPa (SPL; L_p) and 160 dB re 1 µPa (SPL; L_p) for non–impulsive and impulsive sound sources, respectively.
1. Fish, fish eggs, and larvae:
   a. Sound exposure guidelines for fish, fish eggs, and larvae (Popper et al. 2014).
2. Sea turtles (also applied to other marine reptiles including crocodiles):
   a. Frequency–weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of PTS and TTS in turtles for non–impulsive and impulsive sound sources.
   b. Sea turtle behavioural response threshold of 166 dB re 1 µPa (SPL; L_p) for impulsive noise, along with a sound level associated with behavioural disturbance 175 dB re 1 µPa (SPL; L_p) (McCauley et al. 2000).

The following sections (Sections 2.1 and 2.2, along with Appendix A.4 and A.5), expand on the thresholds, guidelines and sound levels for all marine fauna.

2.1. Impulsive Noise

Hydraulic hammering activities have been assessed as impulsive noise source as consistent with the considered thresholds and guidelines.

2.1.1. Marine Mammals

The criteria applied in this study to assess possible effects of impulsive noise sources on marine mammals are summarised Table 7; cetaceans were identified as the hearing group requiring assessment. Details on thresholds related to auditory threshold shifts or hearing loss and behavioural response are provided in Appendix A.4, with frequency weighting explained in detail in Appendix A.5. Whilst the newly published Southall et al. (2021) provides recommendations and discusses the nuances of assessing behavioural response, the authors do not recommend new numerical thresholds for onset of behavioural responses for marine mammals. The criteria from the current interim U.S. National Oceanic and Atmospheric Administration (NOAA) (2019) has been applied.

Table 7. Acoustic effects of impulsive noise on marine mammals: Unweighted SPL, SEL_{24h}, and PK thresholds.

Hearing group	NOAA (2019)	Southall et al. (2019)			
	Behaviour	PTS onset thresholds* (received level)		TTS onset thresholds* (received level)	
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	PK (L_{pk}; dB re 1 µPa)
Low–Frequency (LF) cetaceans	160	183	219	168	213
High–frequency (HF) cetaceans		185	230	170	224
Sirenians		190	226	175	220

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non–impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted.
L_E denotes cumulative sound exposure over a 24 h period.

2.1.2. Fish, Sea turtles, Fish Eggs, Fish Larvae

In 2006, the Working Group on the Effects of Sound on Fish and Sea Turtles was formed to continue developing noise exposure criteria for fish and sea turtles, work begun by a NOAA panel two years earlier. The Working Group developed guidelines with specific thresholds for different levels of effects for several species groups (Popper et al. 2014). The guidelines define quantitative thresholds for three types of immediate effects:

- Mortality, including injury leading to death,
- Recoverable injury, including injuries unlikely to result in mortality, such as hair cell damage and minor haematoma, and

- TTS.

Masking and behavioural effects can be assessed qualitatively, by assessing relative risk rather than by specific sound level thresholds. However, as these depend upon activity–based subjective ranges, these effects are not addressed in this report and are included in Tables 8 for completeness only. Because the presence or absence of a swim bladder has a role in hearing, fish's susceptibility to injury from noise exposure depends on the species and the presence and possible role of a swim bladder in hearing. Thus, different thresholds were proposed for fish without a swim bladder (also appropriate for sharks and applied to whale sharks in the absence of other information), fish with a swim bladder not used for hearing, and fish that use their swim bladders for hearing. Sea turtles, fish eggs, and fish larvae are considered separately.

Impulsive noise from hydraulic hammering is assessed in this study based on the relevant effects thresholds from Popper et al. (2014) listed in Table 8. In general, whether an impulsive sound adversely effects fish behaviour depends on the species, the state of the individual exposed, and other factors.

The SEL metric integrates noise intensity over some period of exposure. Because the period of integration for regulatory assessments is not well defined for sounds that do not have a clear start or end time, or for very long–lasting exposures, an exposure evaluation time must be defined. Southall et al. (2007) defines the exposure evaluation time as the greater of 24 h or the duration of the activity. Popper et al. (2014) recommend a standard period of the duration of the activity; however, the publication also includes caveats about considering the actual exposure times if fish move. Integration times in this study for hammering have been applied as 24 h even though the operational time is less than a day (2x4 h) following Southall et al. (2007).

Table 8. Criteria for pile driving noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	> 219 dB SEL_{24h} or > 213 dB PK	> 216 dB SEL_{24h} or > 213 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	>> 186 dB SEL_{24h}	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24h} or > 207 dB PK	203 dB SEL_{24h} or > 207 dB PK	186 dB SEL_{24h}	Pile driving: (N, I) High (F) Moderate Seismic: (N, I) Low (F) Moderate	(N, I) High (F) Moderate
Fish eggs and fish larvae	> 210 dB SEL_{24h} or > 207 dB PK	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	Pile driving: (N) Moderate (I, F) Low Seismic: (N, I, F) Low	(N) Moderate (I, F) Low

Peak sound pressure level dB re 1 µPa; SEL_{24h} dB re 1µPa^2·s.
All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F). Where near might be considered in the 10's of m, intermediate in the 100's of m and far in the 1000's of m.

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon–specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles). Finneran et al. (2017) in turn presented revised thresholds for sea turtle injury and hearing impairment (TTS and PTS). Their rationale is that sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Bartol and Ketten 2006, Dow Piniak et al. 2012). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

McCauley et al. (2000) observed the behavioural response of caged sea turtles—green (*Chelonia mydas*) and loggerhead (*Caretta caretta*)—to an approaching seismic airgun. For received levels above 166 dB re 1 µPa (SPL), the sea turtles increased their swimming activity, and above 175 dB re 1 µPa they began to behave erratically, which was interpreted as an agitated state. The Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy et al. 2017) acknowledges the 166 dB re 1 µPa SPL reported (McCauley et al. 2000) as the level that may result in a behavioural response to marine turtles. The 175 dB re 1 µPa level from McCauley et al. (2000) is recommended as a criterion for behavioural disturbance.; these thresholds are shown in Table 9.

Table 9. Acoustic effects of impulsive noise on sea turtles: Unweighted sound pressure level (SPL), 24-hour sound exposure level (SEL_{24h}), and peak pressure (PK) thresholds

Effect type	Criterion	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	PK (L_{pk}; dB re 1 µPa)
Behavioural response	McCauley et al. (2000)	166	NA	
Behavioural disturbance		175		
PTS onset thresholds[1] (received level)	Finneran et al. (2017)	NA	204	232
TTS onset thresholds[1] (received level)			189	226

[1] Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS and TTS onset. If a non–impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
L_p denotes sound pressure level period and has a reference value of 1 µPa.
$L_{pk,flat}$ denotes peak sound pressure is flat weighted or unweighted and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^{2}s.

2.2. Non-impulsive Noise

Xcentric Ripper operations have been assessed as non-impulsive noise source as consistent with the considered thresholds and guidelines.

2.2.1. Marine Mammals

The criteria applied in this study to assess possible effects of non-impulsive noise sources on marine mammals are summarised in Table 10.

Table 10. Criteria for effects of non–impulsive noise exposure for marine mammals: Unweighted SPL and SEL_{24h} thresholds.

Hearing group	NOAA (2019)	Southall et al. (2019)	
	Behaviour	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
Low–Frequency (LF) cetaceans	120	199	179
High–frequency (HF) cetaceans		198	178
Sirenians		206	186

L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^2·s.

2.2.2. Fish, Sea Turtles, Fish Eggs, and Fish Larvae

Non-impulsive noise from the Xcentric Ripper is assessed in this study based on the relevant effects thresholds from Popper et al. (2014). Table 11 lists the relevant effects thresholds from Popper et al. (2014) for Xcentric Ripper operational noise. Some evidence suggests that fish sensitive to acoustic pressure show a recoverable loss in hearing sensitivity, or injury when exposed to high levels of noise (Scholik and Yan 2002, Amoser and Ladich 2003, Smith et al. 2006); this is reflected in the SPL thresholds for fish with a swim bladder involved in hearing. Finneran et al. (2017) presented revised thresholds for turtle injury, considering frequency weighted SEL, which have been applied in this study for non-impulsive sound sources (Table 12).

Table 11. Criteria for non–impulsive noise exposure for fish, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	170 dB SPL for 48 h	158 dB SPL for 12 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Sound pressure level dB re 1 µPa.
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F). Where near might be considered in the 10's of m, intermediate in the 100's of m and far in the 1000's of m.

Table 12. Acoustic effects of non–impulsive noise on sea turtles, weighted SEL_{24h}, Finneran et al. (2017).

PTS onset thresholds (received level)	TTS onset thresholds (received level)
220	200

3. Methods

This section describes the methods used to characterise acoustic sources considered in this study, the Xcentric Ripper and the Hydraulic Hammer; as well as the acoustic propagation models and associated inputs used to make numerical predictions of acoustic fields.

3.1. Sources

3.1.1. Xcentric Ripper

The Xcentric Ripper is a hydraulic rock breaking tool which can be attached to an excavator. Underwater measurements of an Xcentric Ripper XR-60 were performed at Acheron Head in Otago Lawrence (2016) by Marshall Day Acoustics. The measurement consisted of three hydrophones at approximate measurement distances of 430, 950, and 2000 m. From Barham and East (2018) a fit equation of $N\log_{10}(r) - \alpha r$ curve was fit to the data, giving values of $N = 14.8$ and $\alpha = -0.0075$.

To determine source level the received levels from Lawrence (2016) were backpropagated using the following method. Using the spectral data from Lawrence (2016), the closest hydrophone (430 m away from source) was backpropagated using the fit curve above. At a range approximately equal to 1 water depth levels were further backpropagated using a $20\log_{10}(r)$ spreading loss. A broadband source level was then calculated as 184.8 dB re 1 µPa^{2}m^{2}s with the associated spectra shown in Figure 2.

The additional backpropagation step was applied since the fit curve may not be appropriate in the near-field region close to the source. In this region, there is little interaction with the seabed with loss almost entirely ascribed to spherical spreading loss thus we have used $20\log_{10}(r)$. More accurate source levels could be determined through backpropagation using a propagation model, however this isn't possible with the information available.

Most acoustic energy from the Xcentric Ripper is output at frequencies in the hundreds to thousands of hertz. The sound produced was considered to be isotropic with the main source of noise a nominal 1 m above the seafloor.

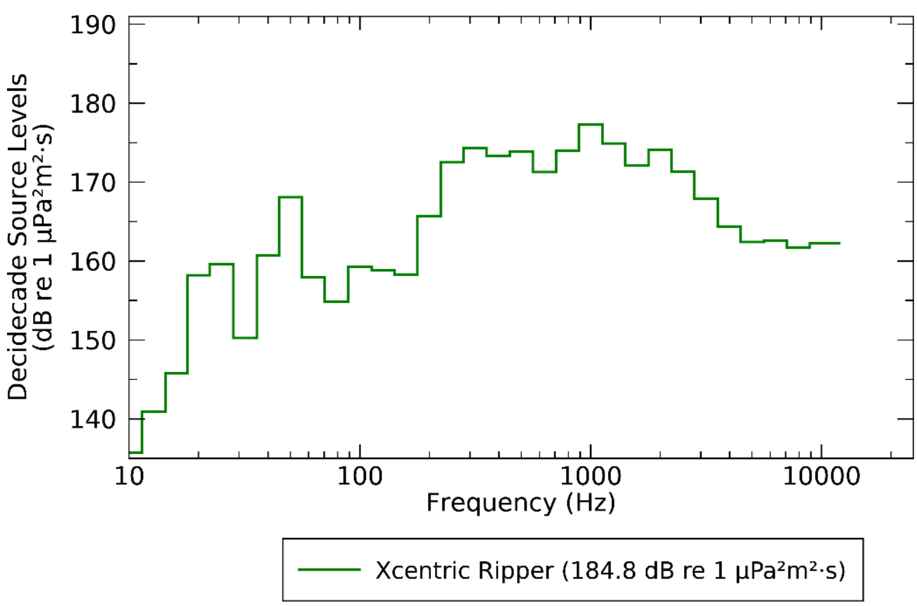

Figure 2. Source level spectra (in decidecade frequency-band) for the Xcentric Ripper.

3.1.2. Hydraulic Hammer

The Epiroc HB 10000 is a hydraulic rock breaking hammer tool, which can be attached to an excavator. Detailed measurements of the underwater source level were not available at the time of the study, therefore the source level spectra corresponding to Down-The-Hole (DTH) hydro-hammering were used as a proxy of the proposed hydraulic rock breaking hammer tool. DTH hydro-hammering is a percussive rotating drilling technique appropriate for hard rock formations. The proxy DTH levels correspond to a Numa Patriot 180 hammer, used to drive 24 inch (0.6 m) diameter piles at a ferry terminal at Kodiak, AK, USA (Denes et al. 2016). The acoustic signature for this activity was recorded at 10 to 30 m from the pile. The measured sound levels (in decidecade frequency bands) were adjusted to determine the levels at the pile, (i.e., backpropagated using spherical spreading) and averaged to provide the representative decidecade frequency-band energy source level (ESL) seen in Figure 3. This source level spectrum yields a broadband ESL of 192 dB 1 $\mu Pa^2 \cdot s\ m^2$.

Depending on several factors, mainly the repetition rate, hydraulic hammer tool could be impulsive or non-impulsive. Since the hydraulic rock breaking hammer tool operates at a repetition rate between 250-380 strikes/min we consider it an impulsive source, in a similar fashion to the DTH tool presented in Guan et al. (2022). However, it is close to the threshold where it may be considered quasi-continuous. While the hydraulic hammer tool is considered as impulsive, the measurements from Denes et al. (2016) give only a source level and spectra over 1 sec. The report does not provide enough temporal information needed to determine peak levels. The noise effect criteria for TTS and PTS (Section 2.1) are dual metrics which require the longest distance to threshold between peak and SEL_{24h}; however, based on JASCO's experience it is expected that SEL_{24h} will produce greater distances to threshold than peak pressure level for this source. It is unlikely that PK thresholds will be exceeded except within the close vicinity of the source.

Most acoustic energy from the hydraulic hammer tool is output at frequencies in the hundreds to thousands of hertz. The sound produced was considered to be isotropic with the main source of noise a nominal 1 m above the seafloor.

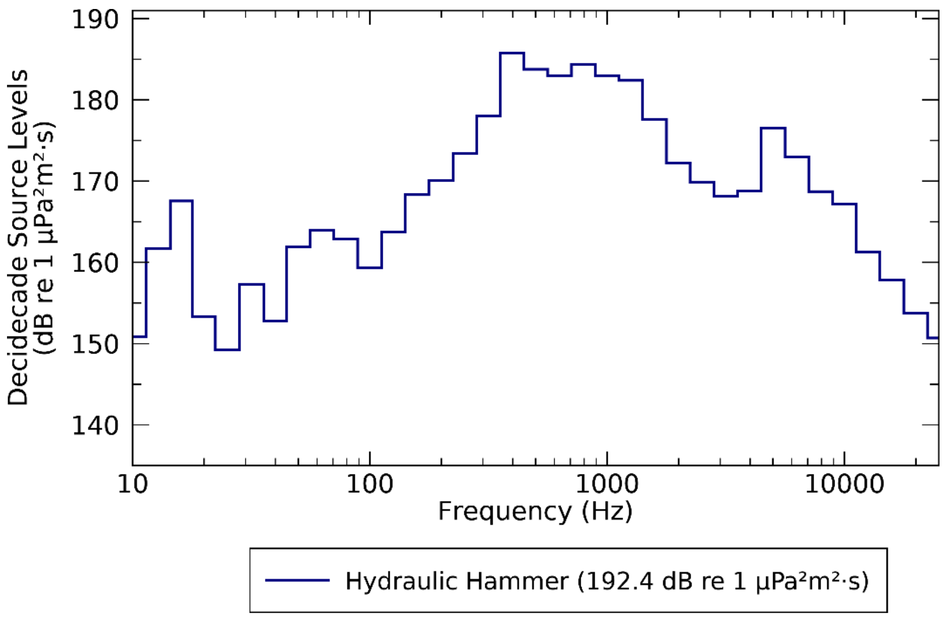

Figure 3. Source level spectra (in decidecade frequency-band) for the Hydraulic Hammer.

3.2. Geometry and Modelled Regions

To predict sound levels with MONM-BELLHOP was used to calculate propagation losses up to distances of 40 km from the source, with a horizontal separation of 20 m between receiver points along all modelled radials. The sound fields were modelled with a horizontal angular resolution of $\Delta\theta$ = 2.5° for a total of *N* = 144 radial planes. Receiver depths were chosen to span the entire water column over the modelled area, from 2 m to a maximum of 100 m, with step sizes that increased with depth. To supplement the MONM results, high-frequency results for propagation loss were modelled using BELLHOP for frequencies from 1.25 to 25 kHz. The MONM and Bellhop results were combined to produce results for the full frequency range of interest.

3.3. Accumulated Modelling

For both sources, the source levels were measured over a 1 sec period. As such SPL is equivalent to the SEL over the same duration. Modelling results were converted to SEL_{24h} by the duration of the measurement. As SEL was assessed over 8 h, the conversion from SEL over 1 second was obtained by increasing the levels by $10*\log_{10}(T)$, where T is 28,800 (the number of seconds in 8 h). Additional modelling times of 2, 4, and 6 h for the hydraulic hammer are presented in Appendix F.

4. Results

The results below are split into two sections Xcentric Ripper and hydraulic hammer. For the results and tables presented below where a dash is used in place of a horizontal distance, these thresholds may or may not be reached due to the discreetly sampled radial increments of the modelled sound fields. A dash therefore is an indication that effect levels for the associated metric may only be reached within a very close proximity to a given source.

4.1. Xcentric Ripper (non-impulsive sound source)

Table 13 presents the maximum and 95% distances to SPL. The SPL sound footprints presented represent the instantaneous sound field and do not depend on the accumulation time. Table 14 presents the maximum distances to frequency-weighted SEL_{24h} thresholds, as well as total ensonified area.

4.1.1. Tabulated Results

Table 13. *Xcentric Ripper*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km) to sound pressure level (SPL). A dash indicates the threshold is not reached within the limits of the modelled resolution (20 m).

SPL (L_p; dB re 1 µPa)	LAT		MSL		HAT	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–
170[a]	–	–	–	–	–	–
160	0.06	0.06	0.05	0.05	0.03	0.03
158[b]	0.09	0.08	0.06	0.06	0.05	0.05
150	0.35	0.31	0.28	0.25	0.23	0.21
140	1.52	1.33	1.30	1.15	1.20	1.04
130	6.86	4.99	4.97	4.19	4.71	3.91
120[c]	14.7	11.5	14.0	11.0	13.1	11.1

[a] 48 h threshold for recoverable injury for fish with a swim bladder involved in hearing (Popper et al. 2014).
[b] 12 h threshold for TTS for fish with a swim bladder involved in hearing (Popper et al. 2014).
[c] Threshold for marine mammal behavioural response to non-impulsive noise (NOAA 2019).

Table 14. *Xcentric Ripper:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 6.

Hearing group	Frequency-weighted SEL_{24h} threshold (LE,24h; dB re 1 µPa²·s)	LAT		MSL		HAT	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS							
LF cetaceans	199	0.18	0.06	0.10	0.03	0.09	0.02
HF cetaceans	198	–	–	–	–	–	–
Sirenians	206	–	–	–	–	–	–
Sea Turtles	220	–	–	–	–	–	–
TTS							
LF cetaceans	179	3.83	12.27	3.02	11.59	2.68	10.8
HF cetaceans	178	0.16	0.06	0.10	0.03	0.09	0.02
Sirenians	186	0.11	0.03	0.07	0.02	0.06	0.01
Sea Turtles	200	0.05	0.01	0.04	0.01	0.03	\

4.1.2. Sound Field Maps

SPL maps are presented as maximum-over-depth sound level contour in Figures 4-6 and as vertical slice plots shown in Figures 7-9 for selected azimuths. SEL_{24h} maps are shown in Figures 10-12 with LF cetacean contour maps shown for context in Appendix E.1.

4.1.2.1. SPL Sound level contour maps

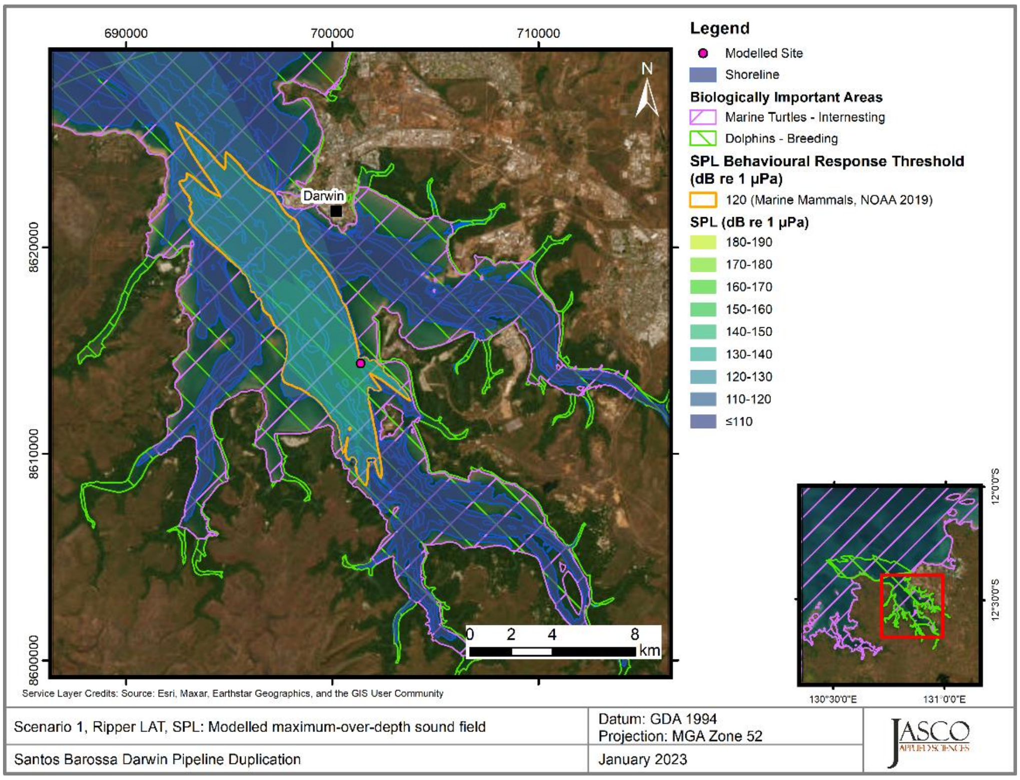

Figure 4. *Xcentric Ripper, LAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals.

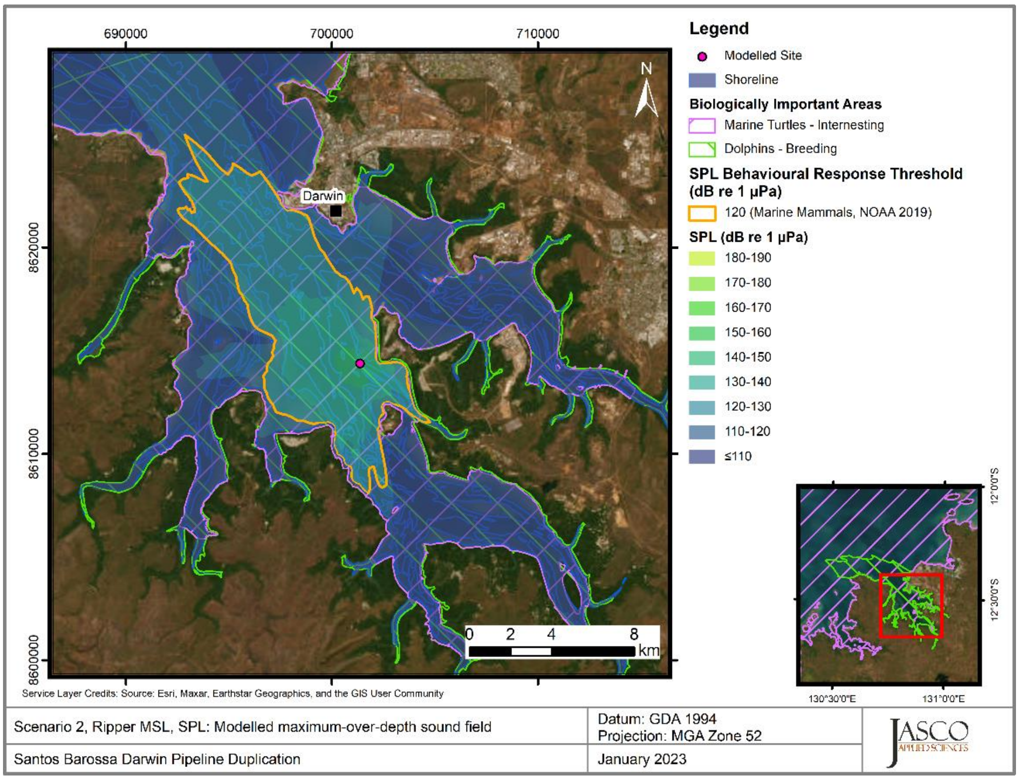

Figure 5. *Xcentric Ripper, MSL, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals.

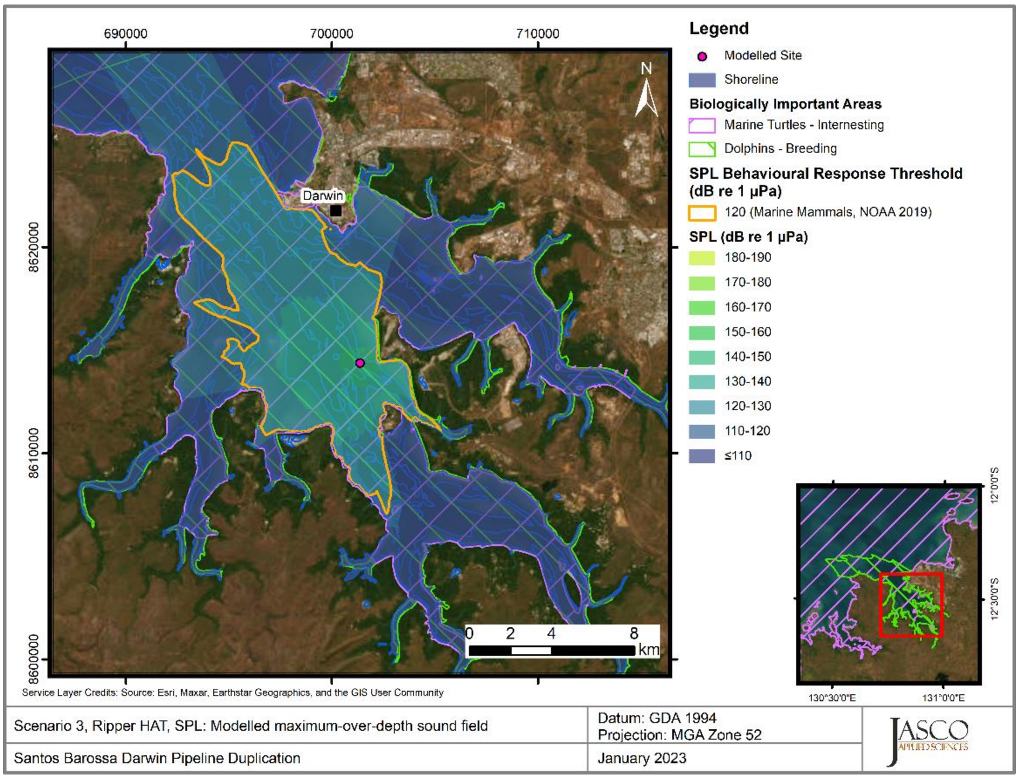

Figure 6. *Xcentric Ripper, HAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals.

4.1.2.2. SPL Vertical slice plots

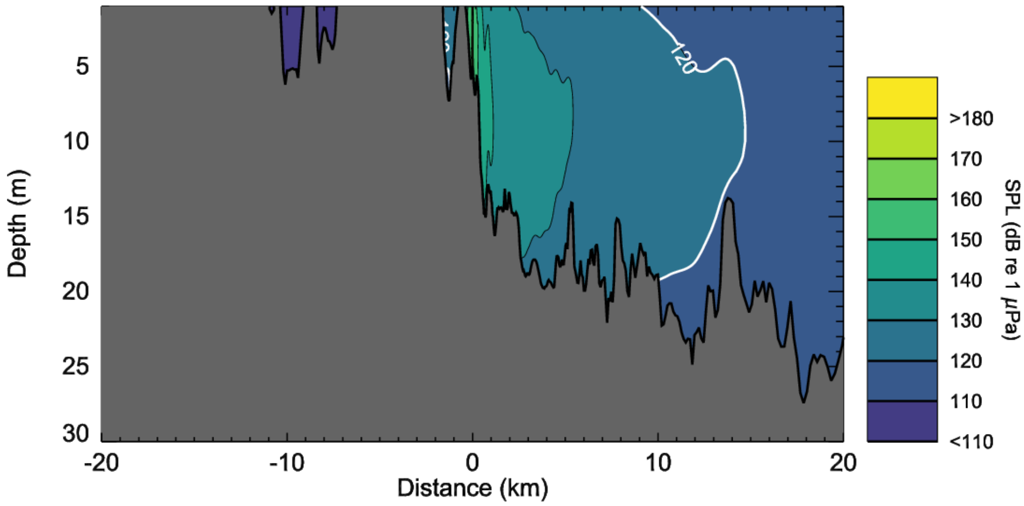

Figure 7. *Xcentric Ripper, LAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect.

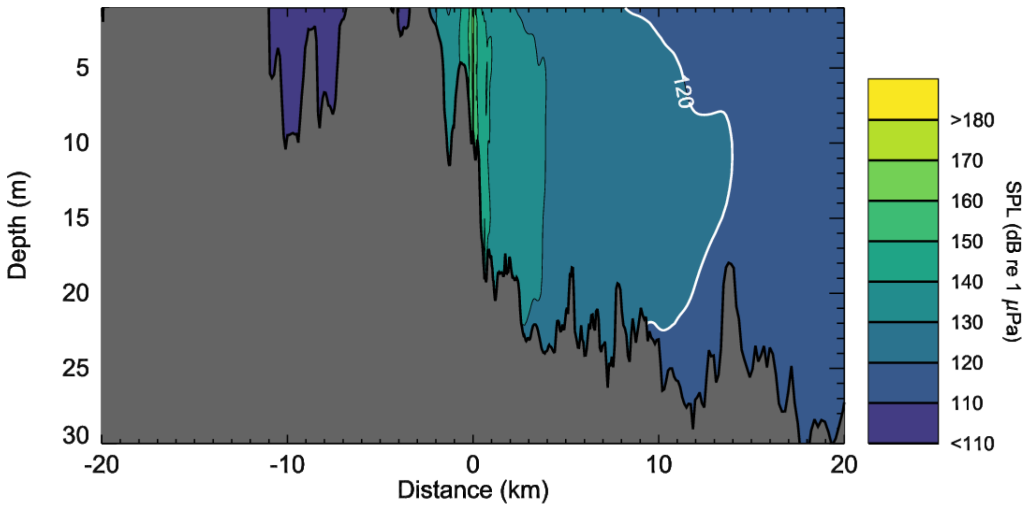

Figure 8. *Xcentric Ripper, MSL, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect.

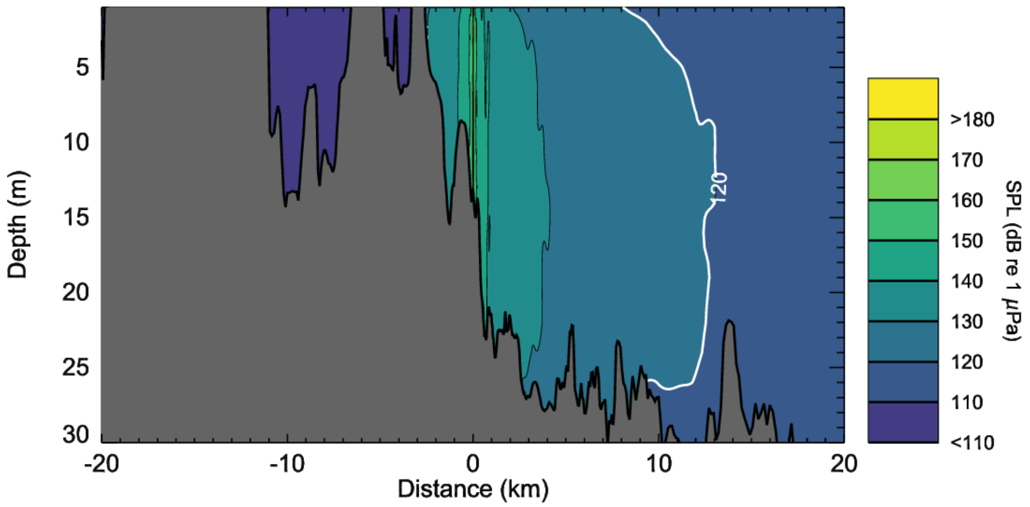

Figure 9. *Xcentric Ripper, HAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect.

4.1.2.3. Accumulated SEL_{24h} sound level contour maps

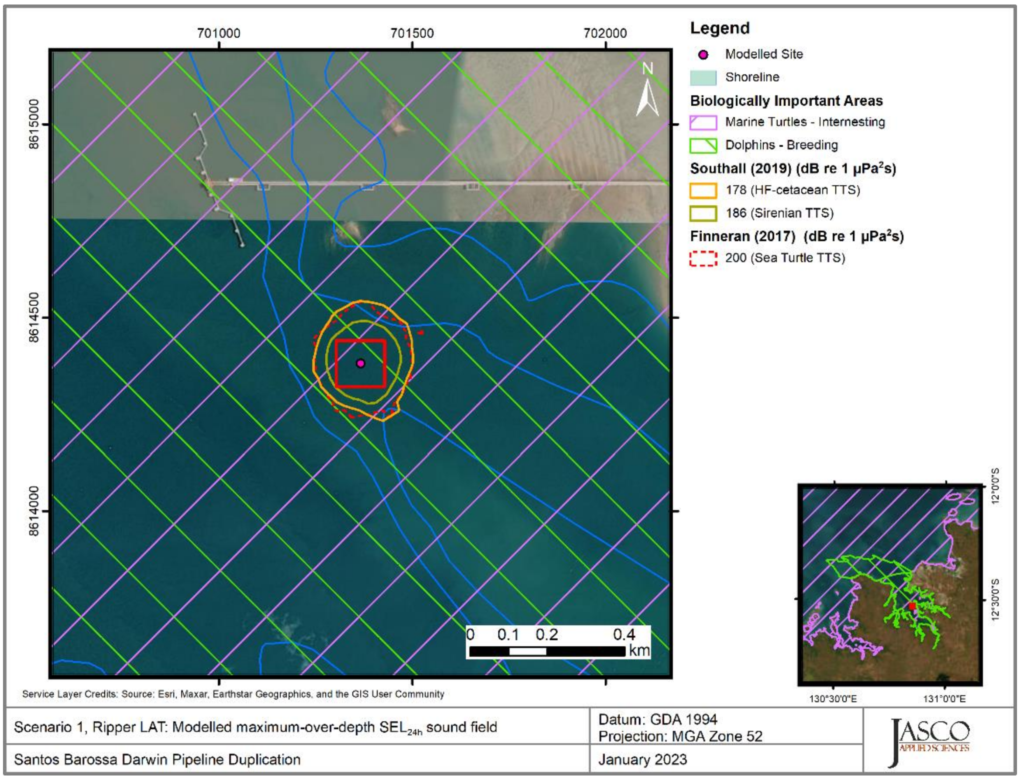

Figure 10. *Xcentric Ripper, LAT:* sound level contour map isopleths for HF cetaceans, sirenians and sea turtles. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

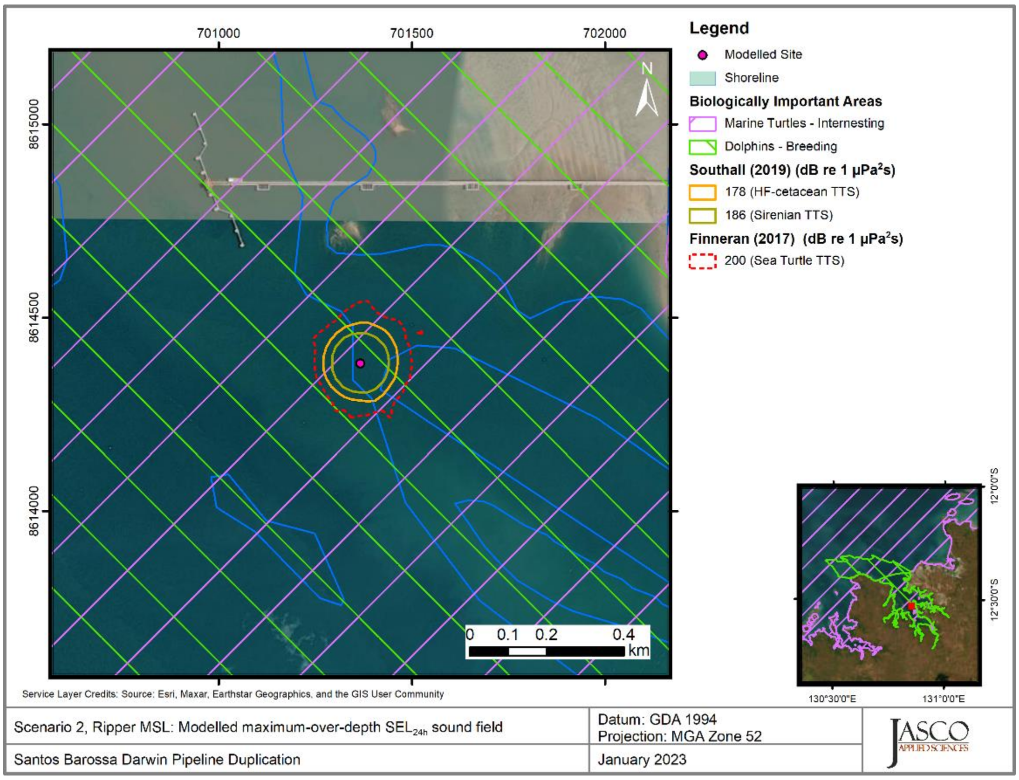

Figure 11. *Xcentric Ripper, MSL:* sound level contour map isopleths for HF cetaceans, sirenians and sea turtles.

Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

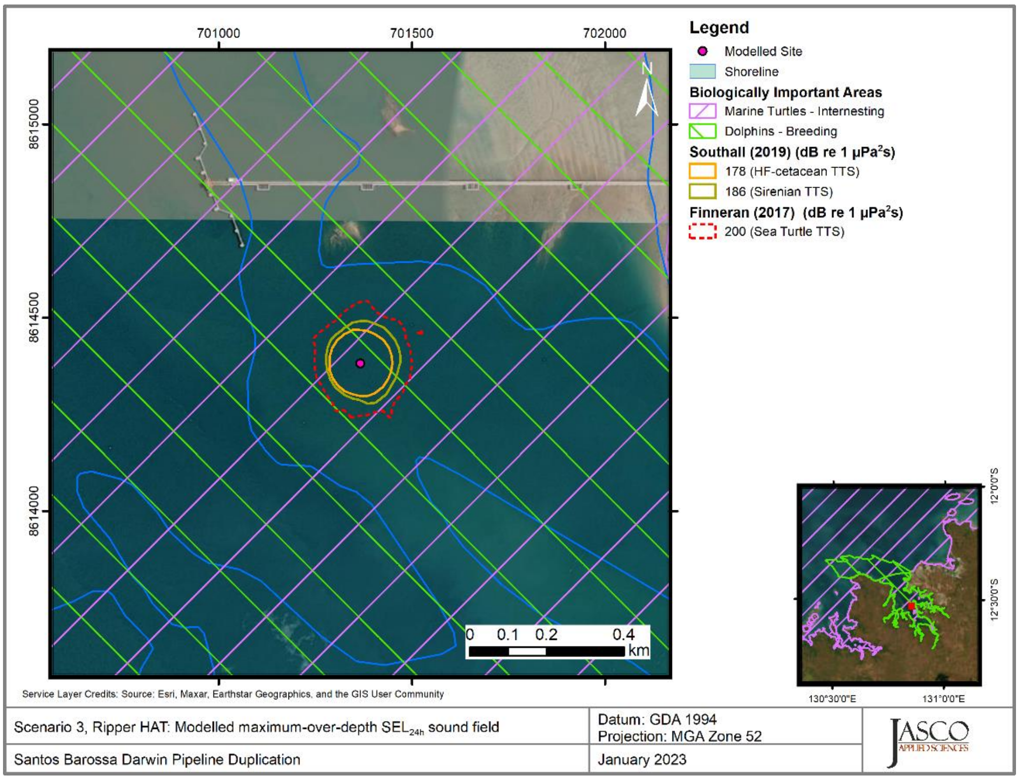

Figure 12. *Xcentric Ripper, HAT:* sound level contour map isopleths for HF cetaceans, sirenians and sea turtles.

Thresholds omitted here not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

4.2. Hydraulic Hammer (impulsive sound source)

Table 15 presents the maximum and 95% distances to SPL. The SPL sound footprints presented represent the instantaneous sound field and do not depend on the accumulation time. Table 16 presents the maximum distances to frequency-weighted SEL_{24h} thresholds, as well as total ensonified area. Additional modelling times of 2, 4, and 6 h for the hydraulic hammer are presented in Appendix F.

4.2.1. Tabulated Results

Table 15. *Hydraulic Hammer: modelled maximum–over–depth per–strike SPL isopleths*: Maximum (R_{max}) and 95% ($R_{95\%}$) horizontal distances (in km).

SPL (L_p; dB re 1 µPa)	Hydraulic Hammer					
	LAT		MSL		HAT	
	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)	R_{max} (km)	$R_{95\%}$ (km)
180	–	–	–	–	–	–
175[1]	–	–	–	–	–	–
170	0.04	0.04	0.03	0.03	0.02	0.02
166[2]	0.09	0.08	0.06	0.06	0.06	0.06
160[3]	0.27	0.24	0.22	0.20	0.17	0.15
150	1.21	1.07	0.96	0.84	0.90	0.75
140	4.83	3.80	4.25	3.39	3.82	3.12
130	11.3	8.48	11.1	8.62	12.6	8.75
120	26.6	22.7	29.3	24.3	29.3	25.0

[1] Threshold for turtle behavioural disturbance from impulsive noise (McCauley et al. 2000).
[2] Threshold for turtle behavioural response to impulsive noise (McCauley et al. 2000).
[3] Marine mammal behavioural threshold for impulsive sound sources (NOAA 2019).
A slash indicates that $R_{95\%}$ radius to threshold is not reported when the R_{max} was greater than the modelling extent (40 km).

Table 16. *Hydraulic Hammer:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 6.

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	LAT		MSL		HAT	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS							
LF cetaceans	183	5.78	19.0	4.71	22.56	4.39	24.14
HF cetaceans	185	0.20	0.08	0.13	0.04	0.10	0.03
Sirenians	190	0.23	0.11	0.16	0.06	0.12	0.04
Sea Turtles	204	0.12	0.03	0.10	0.02	0.06	0.01
TTS							
LF cetaceans	168	20.1	69.75	24.2	102.9	19.9	133.2
HF cetaceans	170	2.44	4.81	1.83	5.36	1.63	5.04
Sirenians	175	2.78	8.33	2.50	7.06	1.94	6.62
Sea Turtles	189	1.18	1.90	0.95	1.68	0.90	1.61

Table 17. *Hydraulic Hammer:* distances to 24 h sound exposure level (SEL_{24h}) based fish criteria in the water column. A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2). Scenario descriptions are given in Table 6.

Marine fauna group	Threshold SEL_{24h} ($L_{E,24h}$; dB re 1 µPa²·s)	Maximum-over-depth					
		LAT		MSL		HAT	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
Mortality and potential mortal injury							
I	219	–	–	–	–	–	–
II, fish eggs and fish larvae	210	0.09	0.03	0.06	0.01	0.06	0.01
III	207	0.20	0.07	0.16	0.04	0.09	0.03
Fish recoverable injury							
I	216	0.03	\	0.02	\	–	–
II, III	203	0.34	0.24	0.28	0.17	0.24	0.12
Fish temporary threshold shift (TTS)							
I, II, III	186	4.27	14.43	3.44	14.67	3.13	13.75

Fish I–No swim bladder; Fish II–Swim bladder not involved with hearing; Fish III–Swim bladder involved with hearing.

4.2.2. Sound Field Maps

Maps for SPL are presented as maximum-over-depth sound level contours in Figures 13-15 and as vertical slice plots shown in Figures 16-18 for selected azimuths. SEL_{24h} contour maps are shown in Figures 19–24 for HF cetaceans, sirenians, sea turtles, and fish. While the LF cetacean contours are shown for context in Appendix E.1.

4.2.2.1. SPL Sound level contour maps

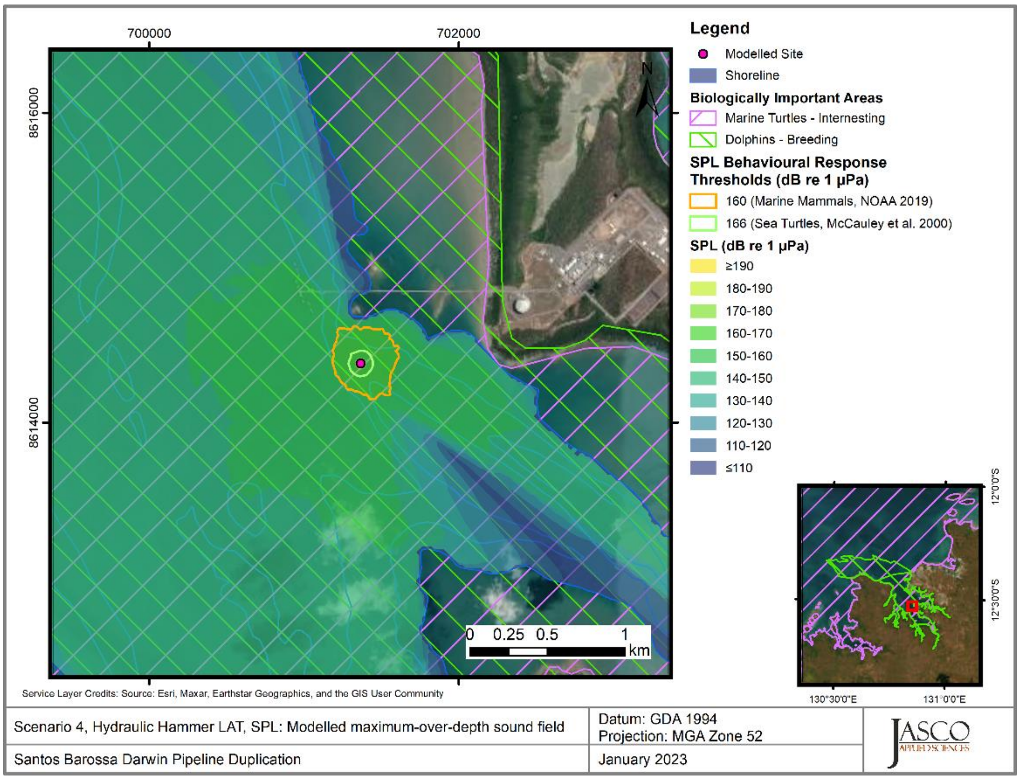

Figure 13. *Hydraulic Hammer, LAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals and sea turtles.

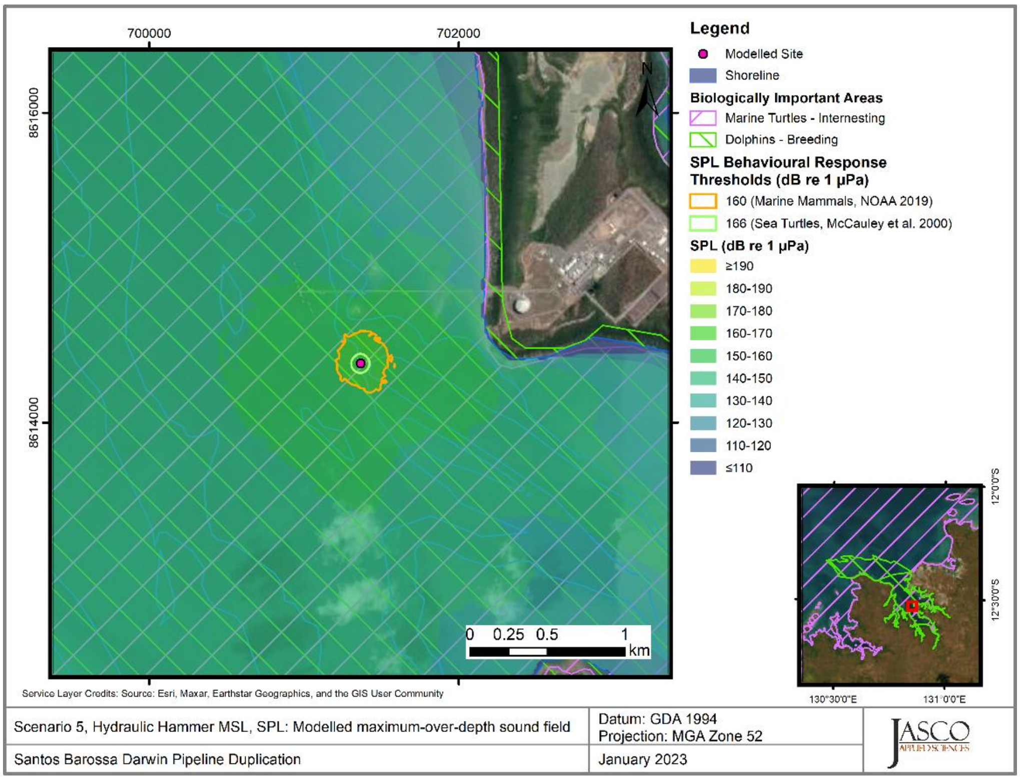

Figure 14. *Hydraulic Hammer, MSL, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals and sea turtles.

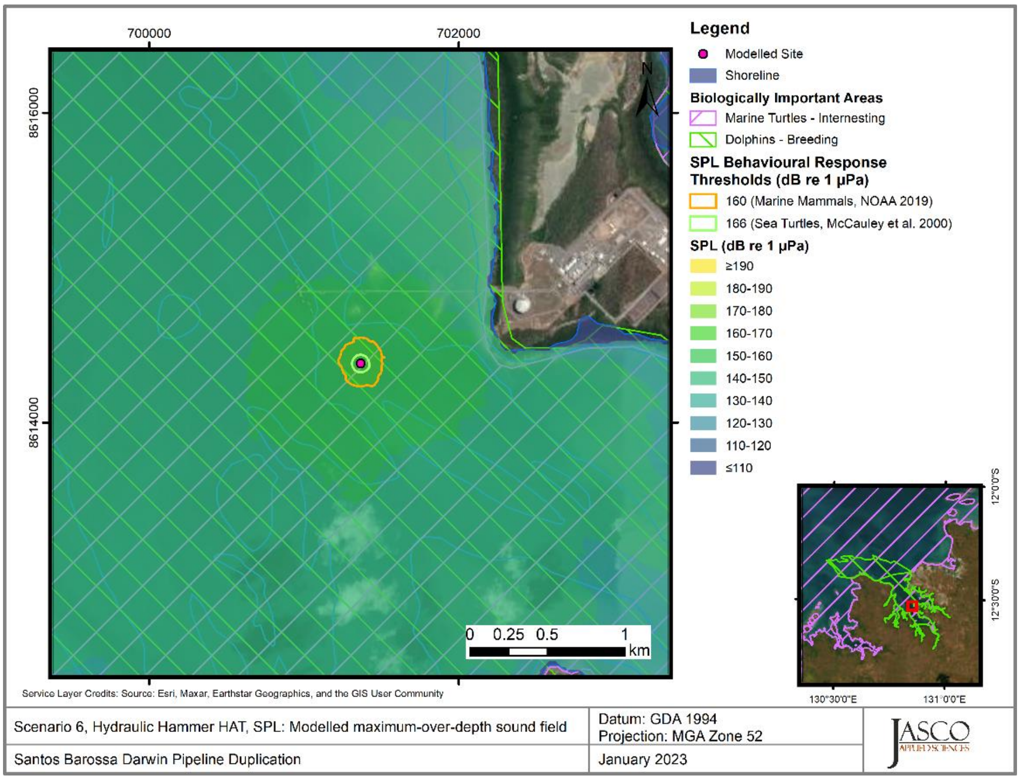

Figure 15. *Hydraulic Hammer, HAT, SPL*: Sound level contour map showing the unweighted maximum-over-depth sound field in 10 dB steps, and the isopleths for behavioural thresholds for marine mammals and sea turtles.

4.2.2.2. SPL Vertical slice plots

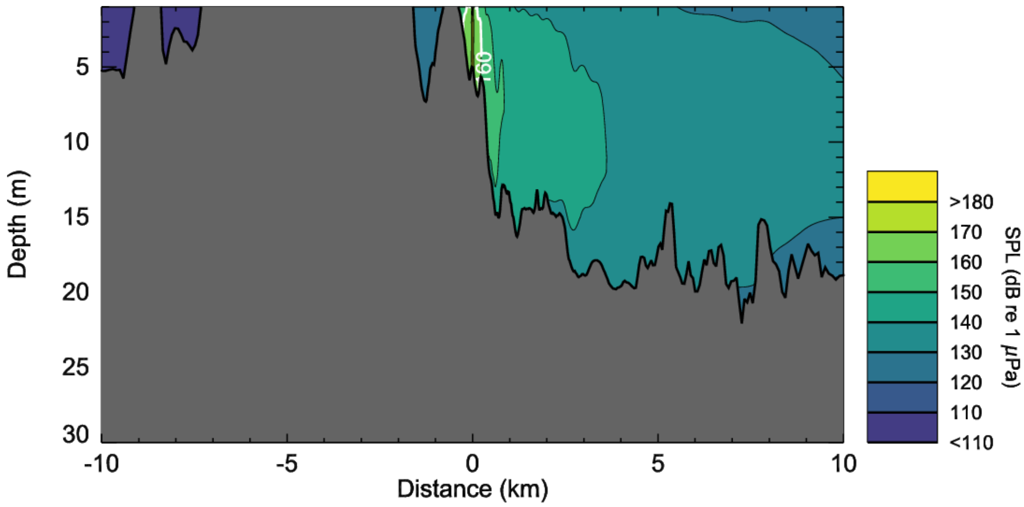

Figure 16. *Hydraulic Hammer, LAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect.

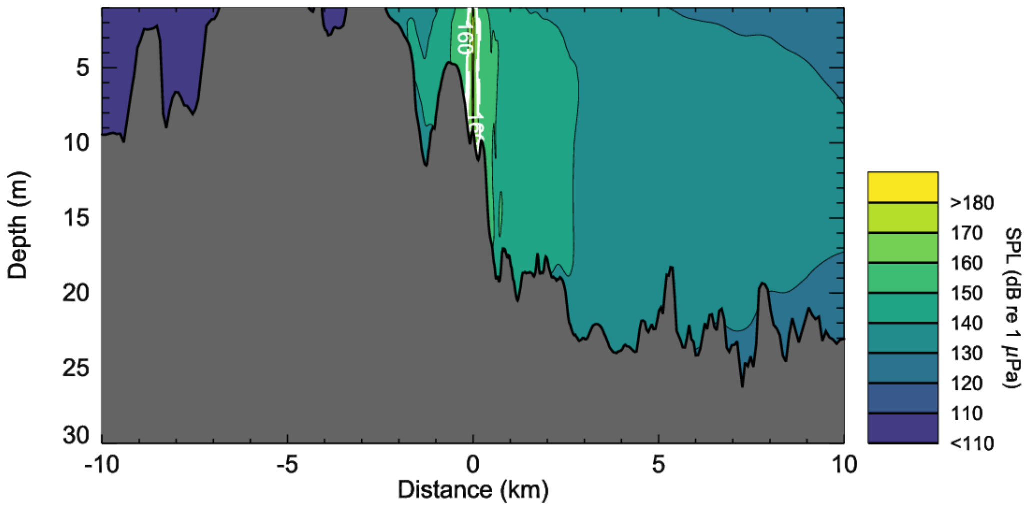

Figure 17. *Hydraulic Hammer, MSL, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect.

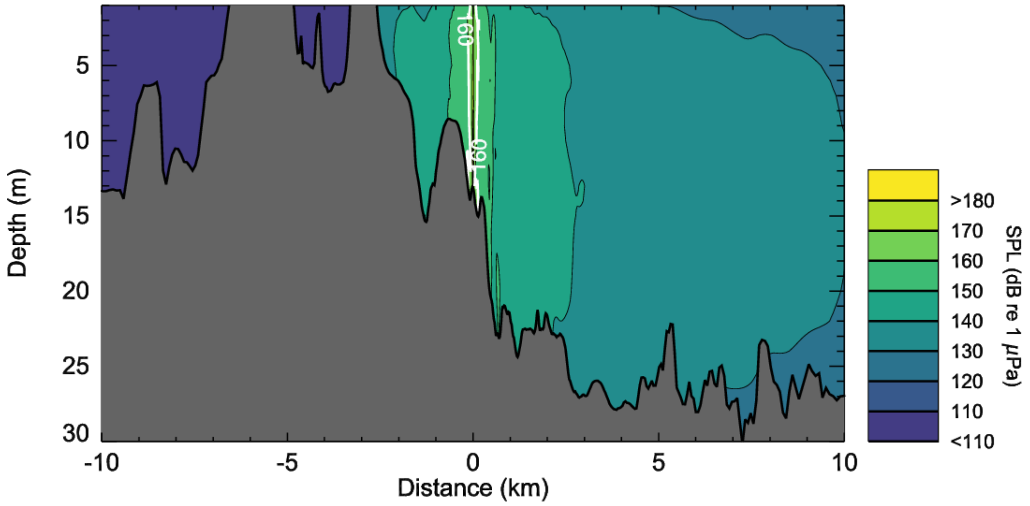

Figure 18. *Hydraulic Hammer, HAT, SPL*: Vertical slice plot showing variations with depth and distance from the source with the isopleth for behavioural threshold for marine mammals. The seabed is shown in dark grey. Cross sections are along the 142/322° transect.

4.2.2.3. Accumulated SEL_{24h} sound level contour maps

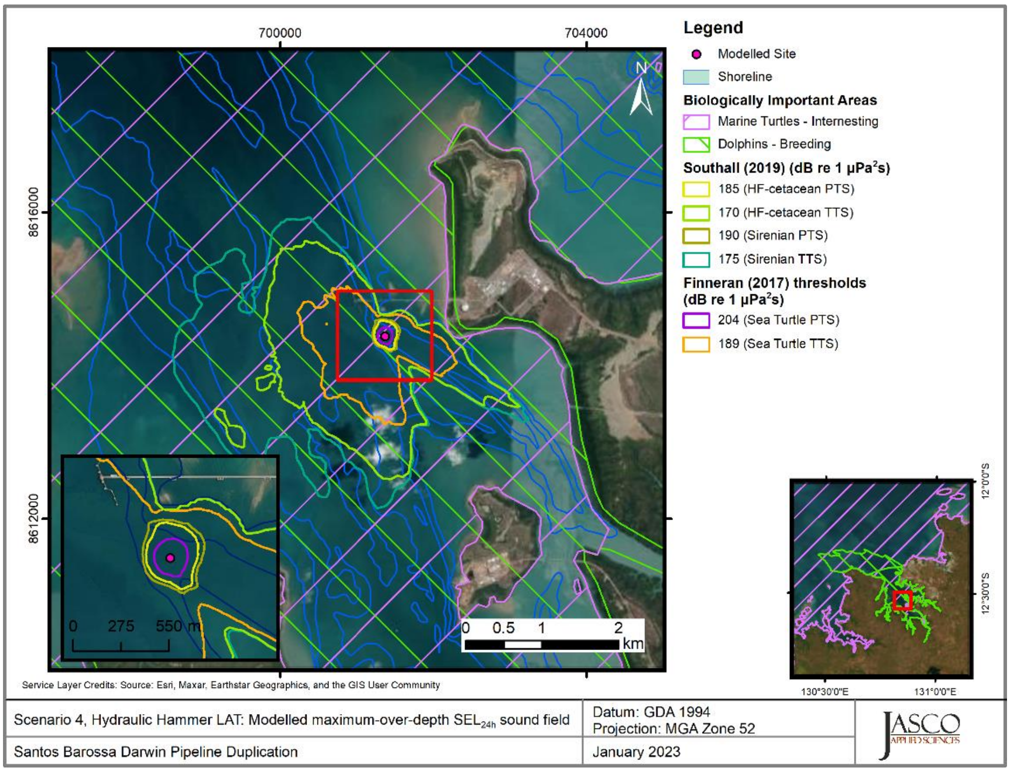

Figure 19. *Hydraulic Hammer, LAT:* isopleths for HF cetaceans, sirenians, and sea turtles. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

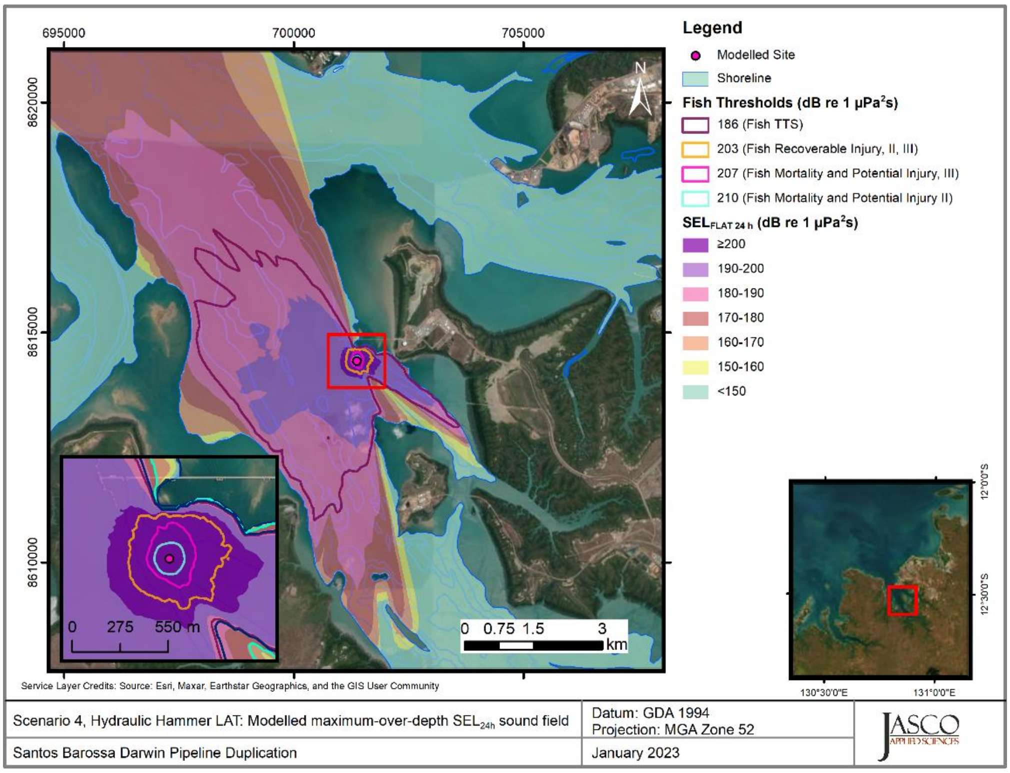

Figure 20. *Hydraulic Hammer, LAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

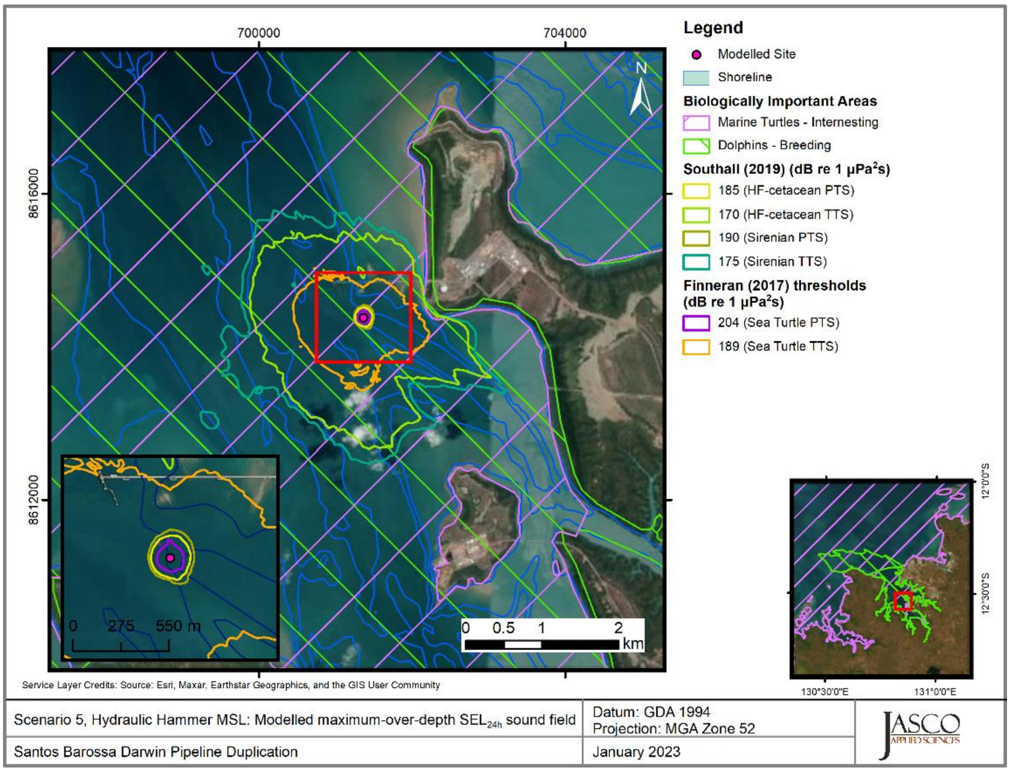

Figure 21. *Hydraulic Hammer, MSL:* isopleths for HF cetaceans, sirenians, and sea turtles. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

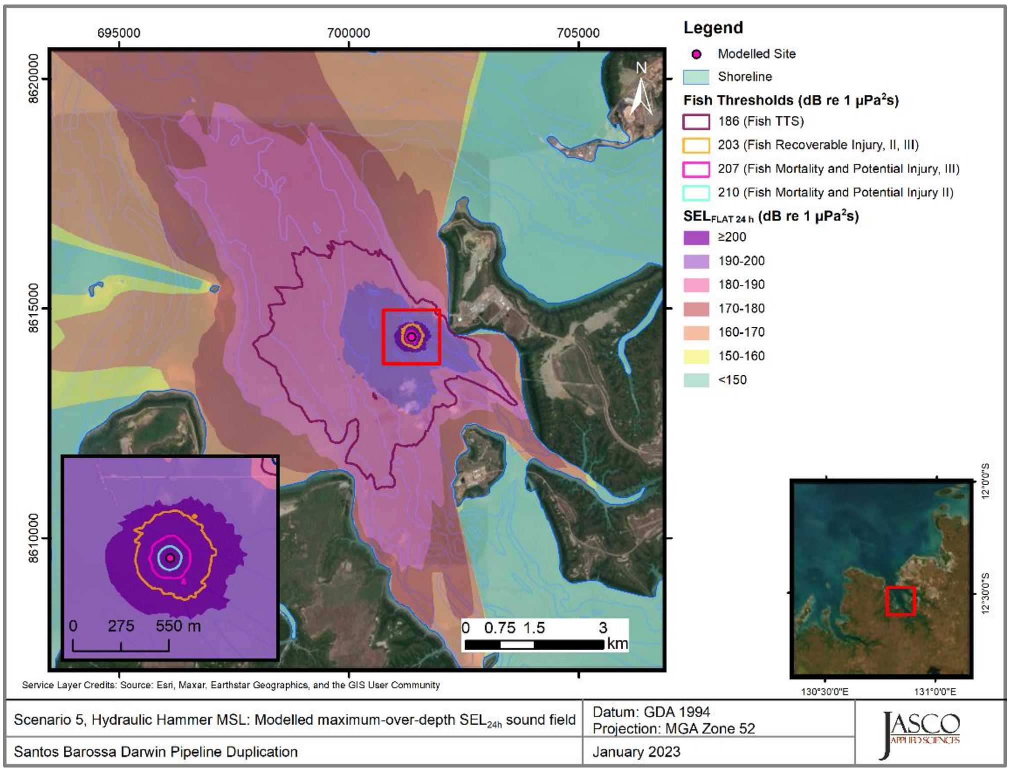

Figure 22. *Hydraulic Hammer, MSL:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

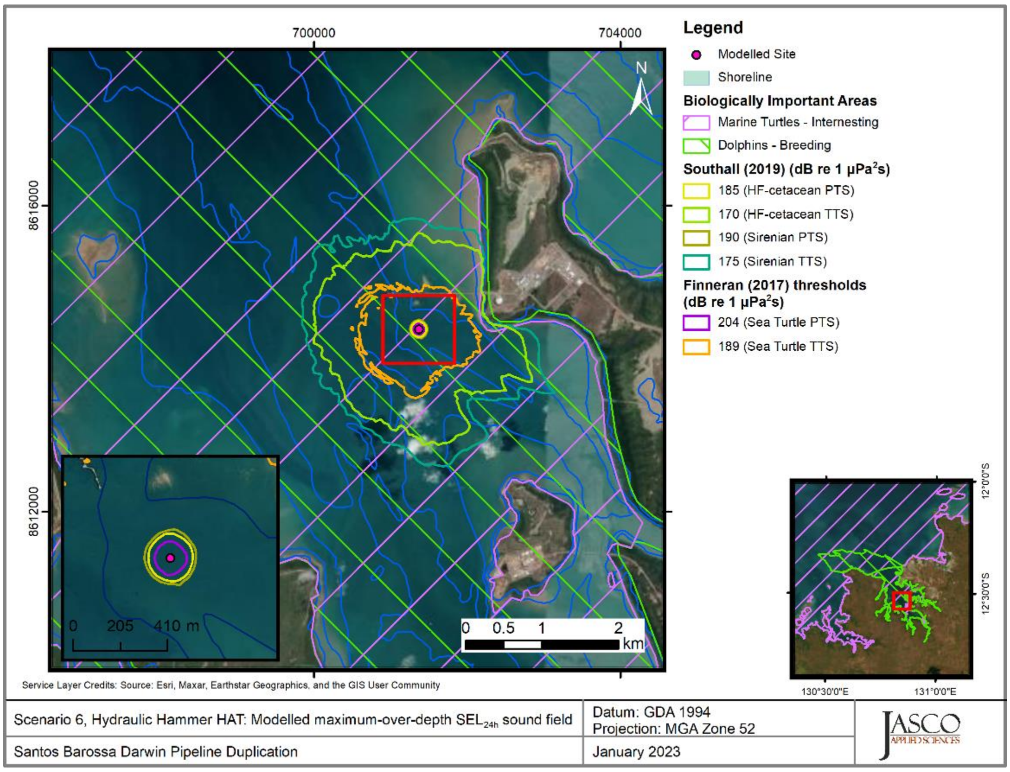

Figure 23. *Hydraulic Hammer, HAT:* isopleths for HF cetaceans, sirenians, and sea turtles. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

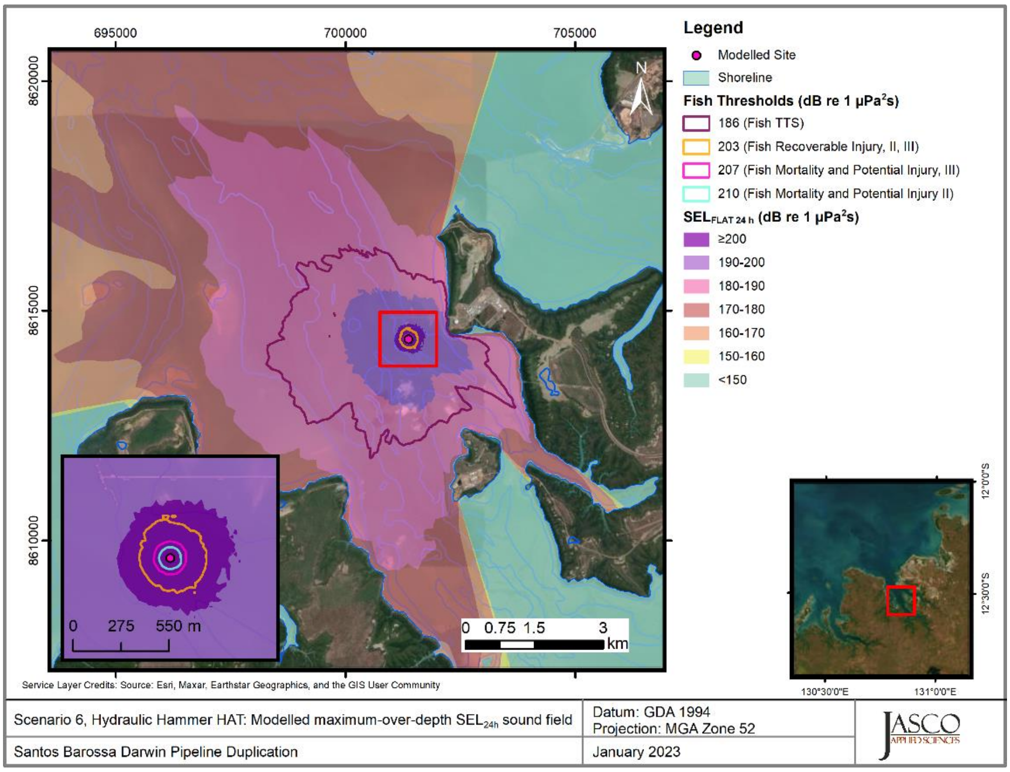

Figure 24. *Hydraulic Hammer, HAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for fish. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

5. Discussion and Conclusion

The modelling study predicted underwater sound levels associated with rock breaking activities for the Santos Darwin DPD. The underwater sound field was modelled for two types of rock breakers, the Xcentric Ripper and a hydraulic hammer. The source levels for each of these rock breakers were selected from measurement studies. However, a surrogate source (see Section 3.1.2) has been proposed to represent the potential spectral characteristics for the hydraulic hammer. No reliable information could be found on the underwater noise levels of this tool at the time of this study. The measurement of the hydraulic hammer source and subsequent use in re-modelling would increase accuracy of the estimates of distances to thresholds presented above.

An analysis of seasonal sound speed profiles indicates that April is the month most conducive to sound propagation; as such it was selected to ensure a conservative estimation of distances to received sound level thresholds (Appendix C.2.2). Modelling also accounted for site-specific bathymetric variations at three vertical height datums, LAT, MSL, and HAT (Appendix C.2.1) and local geoacoustic properties (Appendix C.2.3).The April sound speed profile was primarily slightly upward refracting between the sea surface and the sea floor due to the shallow water depth and the high surface temperature. The profile had a minimum sound speed at approximately 1532 m/s at the sea surface. The seafloor and sea surface create a waveguide which only allows energy of certain frequencies to be trapped.

Considering the activity location in shallow water within Darwin Harbour the bathymetry was used at three different vertical datums, LAT, MSL, and HAT, which results in a difference in water depth between LAT and HAT of ~8.1 m. These different datums also changed the water depth at the source location from 5.0 m to 8.2, and 13.1 m and these changes can influence the waveguide physics of propagating sound. For successive reflections between the sea surface and the seafloor energy is stripped from the water column mainly due to multiple interactions with the seabed. For shallow water environments, underwater sound propagation is generally better than free-field propagation at short and intermediate ranges but worse at longer ranges due to the increased number of interaction with the seabed at long range (see result for the hydraulic hammer tool, Section 4.2.1). However, this is not the case for the Xcentric Ripper (see Section 4.1.1). These can be understood by considering optimum propagation. Shallow water environment tend to have a high optimum propagation frequency than a deeper counter parts (Jensen et al. 2011), and if the source spectra overlaps with the optimum propagation frequencies then shallower water depths may lead to slightly higher levels at distance. The radii associated with sound level contours for LAT datum were marginally longer and persisted to longer ranges compared to the HAT scenario.

The vertical slice plots assist in demonstrating the propagation characteristics of the different water depths (Sections 4.1.2.2 and 4.2.2.2).

Glossary

Unless otherwise stated in an entry, these definitions are consistent with ISO 18405 (2017).

1/3-octave

One third of an octave. *Note*: A 1/3-octave is approximately equal to one decidecade (1/3 oct ≈ 1.003 ddec).

1/3-octave-band

Frequency band whose bandwidth is one 1/3-octave. *Note*: The bandwidth of a 1/3-octave-band increases with increasing centre frequency.

90 % energy time window

The time interval over which the cumulative energy rises from 5 to 95 % of the total pulse energy. This interval contains 90 % of the total pulse energy. Used to compute the 90 % sound pressure level. Unit: second (s). Symbol: T_{90}.

90 % sound pressure level (90 % SPL)

The sound pressure level calculated over the 90 % energy time window of a pulse. Unit: decibel (dB).

absorption

The conversion of sound energy to heat energy. Specifically, the reduction of sound pressure amplitude due to particle motion energy converting to heat in the propagation medium.

acoustic impedance

The ratio of the sound pressure in a medium to the volume flow rate of the medium through a specified surface due to the sound wave. It is a measure of how well sound propagates through a particular medium.

acoustic noise

Sound that interferes with an acoustic process.

ambient sound

Sound that would be present in the absence of a specified activity (ISO 18405:2017). It is usually a composite of sound from many sources near and far, e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation

The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium. Attenuation depends on frequency—higher frequency sounds are attenuated faster than lower frequency sounds.

auditory frequency weighting

The process of applying an auditory frequency-weighting function. An example for marine mammals are the auditory frequency-weighting functions published by Southall et al. (2007).

auditory frequency-weighting function

Frequency-weighting function describing a compensatory approach accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.

azimuth

A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also known as bearing.

bandwidth

A range within a continuous band of frequencies. Unit: hertz (Hz).

broadband level

The total level measured over a specified frequency range. If the frequency range is unspecified, the term refers to the entire measured frequency range.

cetacean

Member of the order Cetacea. Cetaceans are aquatic mammals and include whales, dolphins, and porpoises.

compressional wave

A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called a longitudinal wave. In seismology/geophysics, it's called a primary wave or P-wave. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

continuous sound

A sound whose sound pressure level remains above the background noise during the observation period and may gradually vary in intensity with time, e.g., sound from a marine vessel.

decade

Logarithmic frequency interval whose upper bound is ten times larger than its lower bound (ISO 80000-3:2006). For example, one decade up from 1000 Hz is 10,000 Hz, and one decade down is 100 Hz.

decibel (dB)

Unit of level used to express the ratio of one value of a power quantity to another on a logarithmic scale. Especially suited to quantify variables with a large dynamic range.

decidecade

One tenth of a decade. Approximately equal to one third of an octave (1 ddec ≈ 0.3322 oct), and for this reason sometimes referred to as a 1/3-octave.

decidecade band

Frequency band whose bandwidth is one decidecade. *Note*: The bandwidth of a decidecade band increases with increasing centre frequency.

delphinid

Member of the family of oceanic dolphins (Delphinidae), composed of approximately 35 extant species, including dolphins, porpoises, and killer whales.

energy source level

A property of a sound source equal to the sound exposure level measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 μPa^2 m^2 s.

energy spectral density

Ratio of energy (time-integrated square of a specified field variable) to bandwidth in a specified frequency band from f_1 to f_2. In equation form, the energy spectral density E_f is given by:
$E_f = 2\int_{f_1}^{f_2}|X(f)|^2\,\mathrm{d}f/(f_2 - f_1)$ where $X(f)$ is the Fourier transform of the field variable $x(t)$:
$X(f) = \int_{-\infty}^{+\infty} x(t)\exp(-2\pi i f t)\,\mathrm{d}t$

The field variable $x(t)$ is a scalar quantity, such as sound pressure. It can also be the magnitude or a specified component of a vector quantity such as sound particle displacement, velocity, or acceleration. The unit of energy spectral density depends on the nature of x, as follows:

- If x = sound pressure: Pa^2 s/Hz
- If x = sound particle displacement: m^2 s/Hz
- If x = sound particle velocity: (m/s)^2 s/Hz
- If x = sound particle acceleration: (m/s^2)^2 s/Hz

Note: The factor of two on the right side of the equation for E_f is needed to express a spectrum that is symmetric about f = 0, in terms of positive frequencies only. See entry 3.1.3.9 of ISO 18405 (2017).

energy spectral density level

The level ($L_{E,f}$) of the energy spectral density (E_f) in a stated frequency band and time window. Defined as: $L_{E,f} = 10\log_{10}(E_f/E_{f,0})$. Unit: decibel (dB). As with energy spectral density, energy spectral density level can be expressed in terms of various field variables (e.g., sound pressure). The reference value ($E_{f,0}$) for energy spectral density level depends on the nature of the field variable.

energy spectral density source level

A property of a sound source equal to the energy spectral density level of the sound pressure measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 μPa^2 m^2 s/Hz.

ensonified

Exposed to sound.

equal-loudness-level contour

Curve that shows, as a function of frequency, the sound pressure level required to produce a given loudness for a listener having normal hearing, listening to a specified kind of sound in a specified manner (ANSI S1.1-2013).

far field

The zone where, to an observer, sound originating from an array of sources (or a spatially distributed source) appears to radiate from a single point.

Fourier transform, Fourier synthesis

A mathematical technique which, although it has varied applications, is referenced in a physical data acquisition context as a method used in the process of deriving a spectrum estimate from time-series data (or the reverse process, termed the inverse Fourier transform). A computationally efficient numerical algorithm for computing the Fourier transform is known as the fast Fourier transform (FFT).

frequency

The rate of oscillation of a periodic function measured in cycles per unit time. The reciprocal of the period. Unit: hertz (Hz). Symbol: f. 1 Hz is equal to 1 cycle per second.

frequency weighting

The process of applying a frequency-weighting function.

frequency-weighting function

The squared magnitude of the sound pressure transfer function (ISO 18405:2017). For sound of a given frequency, the frequency-weighting function is the ratio of output power to input power of a specified filter, sometimes expressed in decibels. Examples include the following:

- *Auditory frequency-weighting function*: compensatory frequency-weighting function accounting for a species' (or functional hearing group's) frequency-specific hearing sensitivity.

functional hearing group

Category of animal species when classified according to their hearing sensitivity, hearing anatomy, and susceptibility to sound. For marine mammals, initial groupings were proposed by Southall et al. (2007), and revised groupings are developed as new research/data becomes available. Revised groupings proposed by Southall et al. (2019) include low-frequency cetaceans, high-frequency cetaceans, very high-frequency cetaceans, phocid carnivores in water, other carnivores in water, and sirenians. See auditory frequency-weighting functions, which are often applied to these groups. Example hearing groups for fish include species for which the swim bladder is involved in hearing, species for which the swim bladder is not involved in hearing, and species without a swim bladder (Popper et al. 2014).

geoacoustic

Relating to the acoustic properties of the seabed.

harmonic

A sinusoidal sound component that has a frequency that is an integer multiple of the frequency of a sound to which it is related. For a sound with a fundamental frequency of f, the harmonics have frequencies of $2f$, $3f$, $4f$, etc.

hearing threshold

For a given species or functional hearing group, the sound level for a given signal that is barely audible (i.e., that would be barely audible for a given individual in the presence of specified background noise during a specific percentage of experimental trials).

hertz (Hz)

Unit of frequency defined as one cycle per second. Often expressed in multiples such as kilohertz (1 kHz = 1000 Hz).

high-frequency (HF) cetaceans

See functional hearing group. *Note*: The mid- and high-frequency cetaceans groups proposed by Southall et al. (2007) were renamed high- and very-high-frequency cetaceans, respectively, by Southall et al. (2019).

impulsive sound

Qualitative term meaning sounds that are typically transient, brief (less than 1 s), broadband, with rapid rise time and rapid decay. They can occur in repetition or as a single event. Sources of impulsive sound include, among others, explosives, seismic airguns, and impact pile drivers.

isopleth

A line drawn on a map through all points having the same value of some specified quantity (e.g., sound pressure level isopleth).

knot (kn)

Unit of vessel speed equal to 1 nautical mile per hour.

level

A measure of a quantity expressed as the logarithm of the ratio of the quantity to a specified reference value of that quantity. For example, a value of sound pressure level with reference to 1 μPa^2 can be written in the form *x* dB re 1 μPa^2.

low-frequency (LF) cetaceans

See functional hearing group.

median

The 50th percentile of a statistical distribution.

mid-frequency (MF) cetaceans

See functional hearing group. *Note*: The mid-frequency cetaceans group proposed by Southall et al. (2007) was renamed high-frequency cetaceans by Southall et al. (2019).

monopole source level (MSL)

A source level that has been calculated using an acoustic model that accounts for the effect of the sea-surface and seabed on sound propagation, assuming a point source (monopole). Often used to quantify source levels of vessels or industrial operations from measurements. See also radiated noise level.

M-weighting

A set of auditory frequency-weighting functions proposed by Southall et al. (2007).

mysticete

Member of the Mysticeti, a suborder of cetaceans. Also known as baleen whales, mysticetes have baleen plates (rather than teeth) that they use to filter food from water (or from sediment as for grey whales). This group includes rorquals (Balaenopteridae, such as blue, fin, humpback, and minke whales), right and bowhead whales (Balaenidae), and grey whales (*Eschrichtius robustus*).

non-impulsive sound

Sound that is not an impulsive sound. Not necessarily a continuous sound.

octave

The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete

Member of Odontoceti, a suborder of cetaceans. These whales, dolphins, and porpoises have teeth (rather than baleen plates). Their skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

parabolic equation method

A computationally efficient solution to the acoustic wave equation that is used to model propagation loss. The parabolic equation approximation omits effects of backscattered sound (which are negligible for most ocean-acoustic propagation problems), simplifying the computation of propagation loss.

permanent threshold shift (PTS)

An irreversible loss of hearing sensitivity caused by excessive noise exposure. Considered auditory injury. Compare with temporary threshold shift.

point source

A source that radiates sound as if from a single point.

power spectral density

Generic term, formally defined as power in a unit frequency band. Unit: watt per hertz (W/Hz). The term is sometimes loosely used to refer to the spectral density of other parameters such as squared sound pressure. Ratio of energy spectral density, E_f, to time duration, Δt, in a specified temporal observation window. In equation form, the power spectral density P_f is given by $P_f = E_f/\Delta t$. Power spectral density can be expressed in terms of various field variables (e.g., sound pressure).

power spectral density level

The level ($L_{P,f}$) of the power spectral density (P_f) in a stated frequency band and time window. Defined as: $L_{P,f} = 10\log_{10}(P_f/P_{f,0})$. Unit: decibel (dB).

As with power spectral density, power spectral density level can be expressed in terms of various field variables (e.g., sound pressure, sound particle displacement). The reference value ($P_{f,0}$) for power spectral density level depends on the nature of the field variable.

power spectral density source level

A property of a sound source equal to the power spectral density level of the sound pressure measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 μPa^2 m^2/Hz.

propagation loss (PL)

Difference between a source level (SL) and the level at a specified location, $\mathrm{PL}(x) = \mathrm{SL} - L(x)$. Unit: decibel (dB). See also transmission loss.

radiated noise level (RNL)

A source level that has been calculated assuming sound pressure decays geometrically with distance from the source, with no influence of the sea-surface or seabed. Often used to quantify source levels of vessels or industrial operations from measurements. See also monopole source level.

received level

The level of a given field variable measured (or that would be measured) at a given location.

reference value

Standard value of a quantity used for calculating underwater sound level. The reference value depends on the quantity for which the level is being calculated:

Quantity	Reference value
Sound pressure	p_0^2 = 1 μPa² or p_0 = 1 μPa
Sound exposure	E_0 = 1 μPa² s
Sound particle displacement	δ_0^2 = 1 pm²
Sound particle velocity	u_0^2 = 1 nm²/s²
Sound particle acceleration	a_0^2 = 1 μm²/s⁴

shear wave

A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called a secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

sirenians (SI)

Members of the order Sirenia, which includes several manatee species and the dugong. See also functional hearing group.

sound

A time-varying disturbance in the pressure, stress, or material displacement of a medium propagated by local compression and expansion of the medium. In common meaning, a form of energy that propagates through media (e.g., water, air, ground) as pressure waves.

sound exposure

Time integral of squared sound pressure over a stated time interval in a stated frequency band. The time interval can be a specified time duration (e.g., 24 h) or from start to end of a specified event (e.g., a pile strike, an airgun pulse, a construction operation). Unit: pascal squared second (Pa² s). Symbol: E.

sound exposure level (SEL)

The level (L_E) of the sound exposure (E) in a stated frequency band and time window: $L_E = 10\log_{10}(E/E_0)$ (ISO 18405:2017). Unit: decibel (dB). Reference value (E_0) for sound in water: 1 μPa² s.

sound field

Region containing sound waves.

sound pressure

The contribution to total pressure caused by the action of sound (ISO 18405:2017). Unit: pascal (Pa). Symbol: p.

sound pressure level (SPL), rms sound pressure level

The level (L_p) of the time-mean-square sound pressure (p^2_{rms}) in a stated frequency band and time window: $L_p = 10\log_{10}(p^2_{\mathrm{rms}}/p^2_0) = 20\log_{10}(p_{rms}/p_0)$, where rms is the abbreviation for root-mean-square. Unit: decibel (dB). Reference value (p^2_0) for sound in water: 1 µPa^2. SPL can also be expressed in terms of the root-mean-square (rms) with a reference value of p_0 = 1 µPa. The two definitions are equivalent.

sound speed profile

The speed of sound in the water column as a function of depth below the water surface.

source level (SL)

A property of a sound source equal to the sound pressure level measured in the far field plus the propagation loss from the acoustic centre of the source to the receiver position. Unit: decibel (dB). Reference value: 1 µPa^2 m^2.

spectrum

Distribution of acoustic signal content over frequency, where the signal's content is represented by its power, energy, mean-square sound pressure, or sound exposure.

surface duct

The upper portion of a water column within which the gradient of the sound speed profile causes sound to refract upward and therefore reflect repeatedly off the surface resulting in relatively long-range sound propagation with little loss.

temporary threshold shift (TTS)

Reversible loss of hearing sensitivity caused by noise exposure. Compare with permanent threshold shift.

transmission loss (TL)

The difference between a specified level at one location and that at a different location: $\mathrm{TL}(x_1,x_2) = L(x_1) - L(x_2)$ (ISO 18405:2017). Unit: decibel (dB). See also propagation loss.

unweighted

Term indicating that no frequency-weighting function is applied.

very high-frequency (VHF) cetaceans

See functional hearing group.

wavelength

Distance over which a wave completes one cycle of oscillation. Unit: metre (m). Symbol: λ.

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Appendix A. Acoustic Metrics

This section describes in detail the acoustic metrics, impact criteria, and frequency weighting relevant to the modelling study.

A.1. Pressure Related Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Because the perceived loudness of sound, especially pulsed sound such as from seismic airguns, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. Here we provide specific definitions of relevant metrics used in the accompanying report. Where possible, we follow International Organization for Standardization definitions and symbols for sound metrics (e.g., ISO 2017, ANSI S1.1-2013).

The sound pressure level (SPL or L_p; dB re 1 μPa) is the root-mean-square (rms) pressure level in a stated frequency band over a specified time window (T; s). It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T g(t)\,p^2(t)\,dt/p_0^2\right)\text{ dB} \tag{A-1}$$

where $g(t)$ is an optional time weighting function. In many cases, the start time of the integration is marched forward in small time steps to produce a time-varying SPL function.

The sound exposure level (SEL or L_E; dB re 1 μPa^2·s) is the time-integral of the squared acoustic pressure over a duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)\,dt/T_0 p_0^2\right)\text{ dB} \tag{A-2}$$

where T_0 is a reference time interval of 1 s. SEL continues to increase with time when non-zero pressure signals are present. It is a dose-type measurement, so the integration time applied must be carefully considered for its relevance to impact to the exposed recipients.

SEL can be calculated over a fixed duration, such as the time of a single event or a period with multiple acoustic events. When applied to pulsed sounds, SEL can be calculated by summing the SEL of the N individual pulses. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right)\text{ dB .} \tag{A-3}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.5). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should also be specified.

A.2. Decidecade Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analysing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into decidecade bands, which are one tenth of a decade wide. A decidecade is sometimes referred to as a "1/3 octave" because one tenth of a decade is approximately equal to one third of an octave. Each decade represents a factor 10 in sound frequency. Each octave represents a factor 2 in sound frequency. The centre frequency of the ith band, $f_{\mathrm{c}}(i)$, is defined as:

$$f_{\mathrm{c}}(i) = 10^{\frac{i}{10}}\ \mathrm{kHz} \quad \text{(A-4)}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith decade band are defined as:

$$f_{\mathrm{lo},i} = 10^{\frac{-1}{20}} f_{\mathrm{c}}(i) \quad \text{and} \quad f_{\mathrm{hi},i} = 10^{\frac{1}{20}} f_{\mathrm{c}}(i) \quad \text{(A-5)}$$

The decidecade bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-1). The acoustic modelling spans from band 10 (f_c (10) = 10 Hz) to band 44 ($f_{\mathrm{c}}(44)$ = 25 kHz).

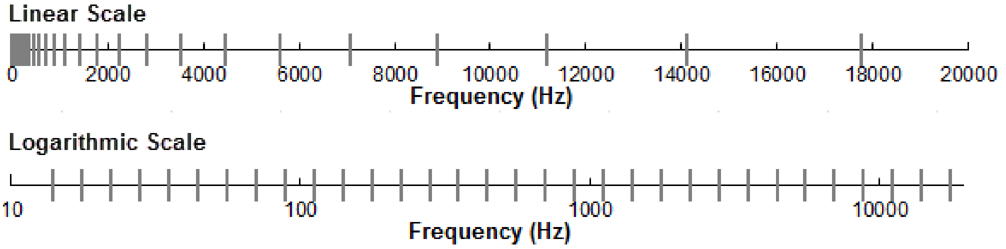


Figure A-1. Decidecade frequency bands (vertical lines) shown on a linear frequency scale and a logarithmic scale.

The sound pressure level in the ith band ($L_{p,i}$) is computed from the spectrum $S(f)$ between $f_{\mathrm{lo},i}$ and $f_{\mathrm{hi},i}$:

$$L_{p,i} = 10\, log_{10} \int_{f_{\mathrm{lo},i}}^{f_{\mathrm{hi},i}} S(f)\, \mathrm{d}f \ \ \mathrm{dB} \quad \text{(A-6)}$$

Summing the sound pressure level of all the bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_{i} 10^{\frac{L_{p,i}}{10}}\ \mathrm{dB} \quad \text{(A-7)}$$

Figure A-2 shows an example of how the decidecade band sound pressure levels compare to the sound pressure spectral density levels of an ambient sound signal. Because the decidecade bands are wider than 1 Hz, the decidecade band SPL is higher than the spectral levels at higher frequencies. Acoustic modelling of decidecade bands requires less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

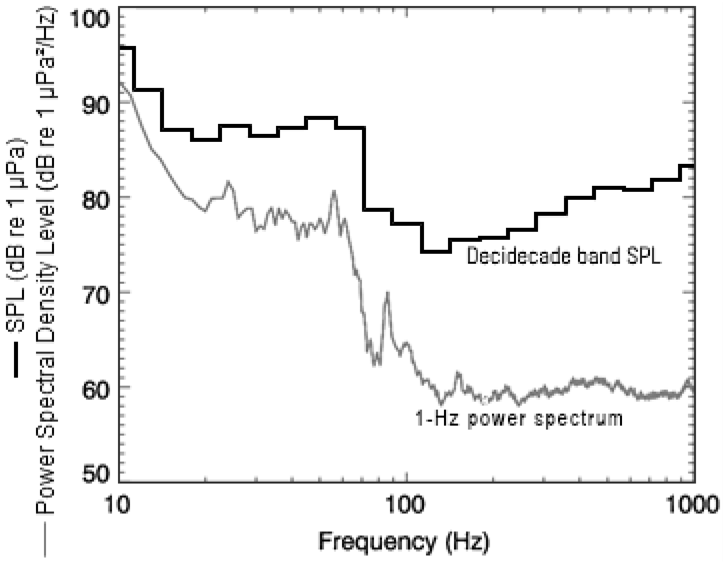


Figure A-2. Sound pressure spectral density levels and the corresponding decidecade band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.Because the decidecade bands are wider with increasing frequency, the decidecade band SPL is higher than the power spectrum.

A.3. Marine Mammal Noise Effect Criteria – Non-impulsive

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggest that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for auditory injury, impairment, and disturbance. The following sections summarise the recent development of thresholds; however, this field remains an active research topic.

A.3.1. Injury and Hearing Sensitivity Changes

In recognition of shortcomings of the SPL-only based auditory injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual auditory injury criteria for impulsive sounds that included peak pressure level thresholds and SEL24h thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas SEL24h is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for humans; see Appendix A.5). The SEL24h thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower PTS and TTS values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 μPa^2·s. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results obtained from MF cetacean studies. In particular they referenced the Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 μPa^2·s.

As of present, a definitive approach is still not apparent. There is consensus in the research community that an SEL-based method is preferable, either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes auditory injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018 (NMFS 2018). Southall et al. (2019) revisited the interim criteria published in 2007. All noise exposure criteria in NMFS (2018) and Southall et al. (2019) are identical (for impulsive and non-impulsive sounds); however, the mid-frequency cetaceans from NMFS (2018) are classified as high-frequency cetaceans in Southall et al. (2019), and high-frequency cetaceans from NMFS (2018) are classified as very-high-frequency cetaceans in Southall et al. (2019).

A.3.2. Behavioural Response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus(Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

NMFS currently uses step function (all-or-none) threshold of 120 dB re 1 µPa SPL (unweighted) for non-impulsive sounds to assess and regulate noise-induced behavioural impacts on marine mammals (NOAA 2019). The 120 dB re 1 µPa threshold is associated with continuous sources and was derived based on studies examining behavioural responses to drilling and dredging (NOAA 2018), referring to Malme et al. (1983), Malme et al. (1984), and Malme et al. (1986), which were considered in Southall et al. (2007). Malme et al. (1986) found that playback of drillship noise did not produce clear evidence of disturbance or avoidance for levels below 110 dB re 1 µPa (SPL), possible avoidance occurred for exposure levels approaching 119 dB re 1 µPa. Malme et al. (1984) determined that measurable reactions usually consisted of rather subtle short-term changes in speed and/or heading of the whale(s) under observation. It has been shown that both received level and proximity of the sound source is a contributing factor in eliciting behavioural reactions in humpback whales (Dunlop et al. 2017, Dunlop et al. 2018).

A.4. Marine Mammal Impact Criteria – Impulsive

It has been long recognised that marine mammals can be adversely affected by underwater anthropogenic noise. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater noise sources and the possibility that impulsive sources—primarily airguns used in seismic surveys—could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater noise sources (NMFS 1998, ONR 1998, Nedwell and Turnpenny 1998, HESS 1999, Ellison and Stein 1999). In the years since these early workshops, a variety of thresholds have been proposed for both injury and disturbance. The following sections summarize the recent development of thresholds; however, this field remains an active research topic.

A.4.1. Injury

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new noise exposure criteria. Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and SEL_{24h} thresholds, where the subscripted 24h refers to the accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix 0). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it implies a 3 dB exchange rate).

Wood et al. (2012) refined Southall et al.'s (2007) thresholds, suggesting lower injury values for LF and HF cetaceans while retaining the filter shapes. Their revised thresholds were based on TTS-onset levels in harbour porpoises from Lucke et al. (2009), which led to a revised impulsive sound PTS threshold for HF cetaceans of 179 dB re 1 $\mu Pa^2 \cdot s$. Because there were no data available for baleen whales, Wood et al. (2012) based their recommendations for LF cetaceans on results obtained from MF cetacean studies. In particular they referenced Finneran and Schlundt (2010) research, which found mid-frequency cetaceans are more sensitive to non-impulsive sound exposure than Southall et al. (2007) assumed. Wood et al. (2012) thus recommended a more conservative TTS-onset level for LF cetaceans of 192 dB re 1 $\mu Pa^2 \cdot s$.

As of present, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA 2013, 2015, 2016), NMFS finalised technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for the five hearing groups described by Finneran and Jenkins (2012). The latest revision to this work was published in 2018; with the criteria defined in NMFS (2018). The latest criteria are from Southall et al. (2019) which is applied in this report.

A.4.2. Behavioural response

Numerous studies on marine mammal behavioural responses to sound exposure have not resulted in consensus in the scientific community regarding the appropriate metric for assessing behavioural reactions. However, it is recognised that the context in which the sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007, Ellison and Frankel 2012, Southall et al. 2016).

For impulsive noise, NMFS currently uses step function thresholds of 160 dB re 1 µPa SPL (unweighted) to assess and regulate noise-induced behavioural impacts for marine mammals (NOAA 2018, NOAA 2019). The threshold for impulsive sound is derived from the High-Energy Seismic Survey (HESS) panel (HESS 1999) report that, in turn, is based on the responses of migrating mysticete whales to airgun sounds (Malme et al. 1984). The HESS team recognised that behavioural responses to sound may occur at lower levels, but significant responses were only likely to occur above a SPL of 140 dB re 1 µPa. Southall et al. (2007) found varying responses for most marine mammals between a SPL of 140 and 180 dB re 1 µPa, consistent with the HESS (1999) report, but lack of convergence in the data prevented them from suggesting explicit step functions.

A.5. Marine Mammal Frequency Weighting

The potential for noise to affect animals depends on how well the animals can hear it. Noises are less likely to disturb or injure an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.5.1. Marine Mammal Frequency Weighting Functions

In 2015, a US Navy technical report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is expressed as:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^2\right]^a\left[1+(f/f_{hi})^2\right]^b}\right)\right] \quad \text{(A-8)}$$

Finneran (2015) proposed five functional hearing groups for marine mammals in water: low-, mid- and high-frequency cetaceans (LF, MF, and HF cetaceans, respectively), phocid pinnipeds, and otariid pinnipeds. The parameters for these frequency-weighting functions were further modified the following year (Finneran 2016) and were adopted in NOAA's technical guidance that assesses acoustic impacts on marine mammals (NMFS 2018), and in the latest guidance by Southall (2019). The updates did not affect the content related to either the definitions of frequency-weighting functions or the threshold values, however, the terminology for mid- and high-frequency cetaceans was changed to high- and very high-frequency cetaceans. Table A-1 lists the frequency-weighting parameters for each hearing group relevant to this assessment, and Figure A-3 shows the resulting frequency-weighting curves.

Table A-1. Parameters for the auditory weighting functions used in this project as recommended by Southall et al. (2019).

Hearing group	a	b	flo (Hz)	fhi (kHz)	*K* (dB)
Low-frequency cetaceans *(baleen whales)*	1.0	2	200	19,000	0.13
High-frequency cetaceans *(most dolphins, plus sperm, beaked, and bottlenose whales)*	1.6	2	8,800	110,000	1.20
Sirenians *(Dugongs, manatees)*	1.8	2	12,000	140,000	1.36

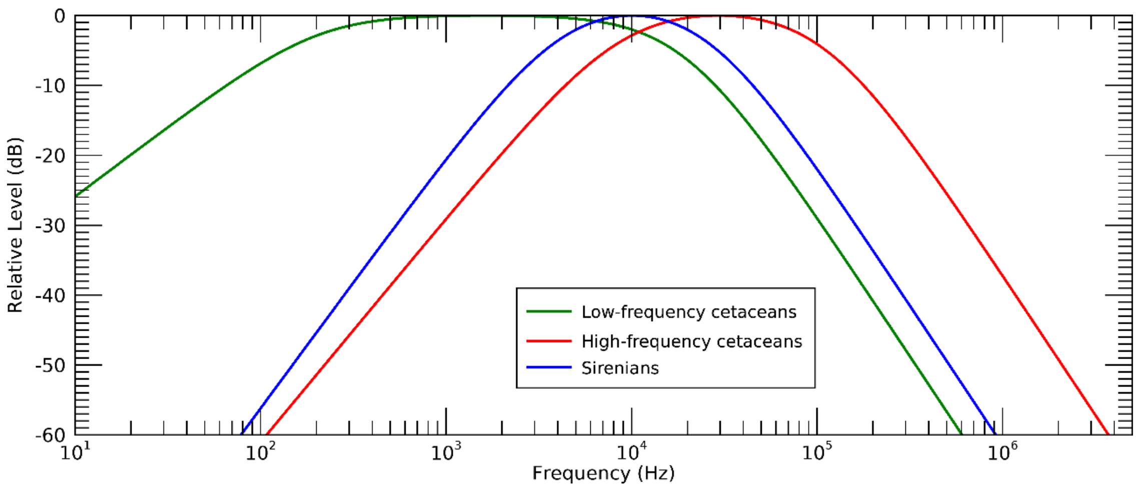


Figure A-3. Auditory weighting functions for functional marine mammal hearing groups used in this project as recommended by Southall et al. (2019).

Appendix B. Sound Propagation Models

B.1. MONM-BELLHOP

Long-range sound fields were computed using JASCO's Marine Operations Noise Model (MONM). MONM is well suited for effective long-range estimation. This model computes sound propagation at frequencies of 5 Hz to 1 kHz via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the US Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). MONM computes sound propagation at frequencies >1 kHz via the BELLHOP Gaussian beam acoustic ray-trace model (Porter and Liu 1994).

The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modelled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

This version of MONM accounts for sound attenuation due to energy absorption through ion relaxation and viscosity of water in addition to acoustic attenuation due to reflection at the medium boundaries and internal layers (Fisher and Simmons 1977). The former type of sound attenuation is significant for frequencies higher than 5 kHz and cannot be neglected without noticeably affecting the model results.

MONM computes acoustic fields in three dimensions by modelling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure B-1).

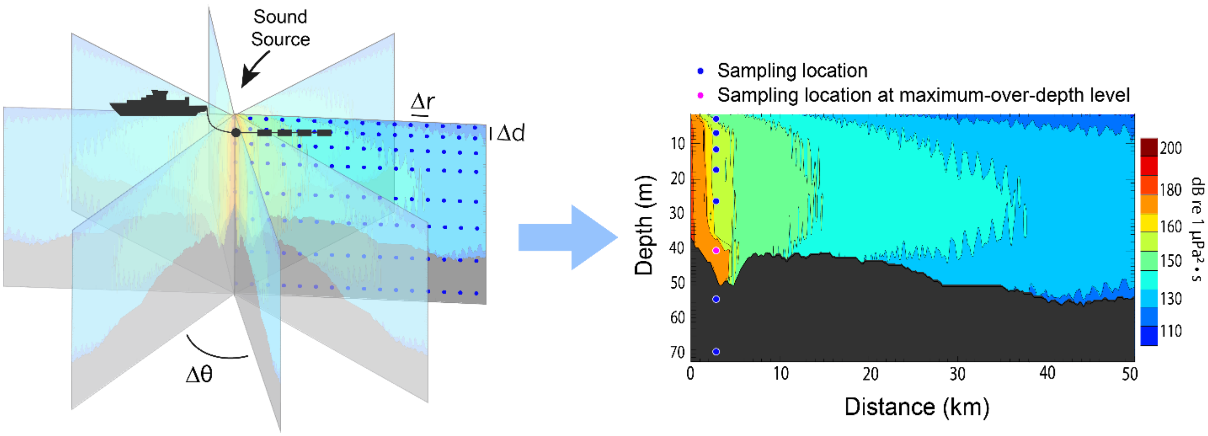


Figure B-1. The N×2-D and maximum-over-depth modelling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the centre frequencies of decidecade bands. Sufficiently many decidecade bands, starting at 10 Hz, are modelled to include most of the acoustic energy emitted by the source. At each centre frequency, the transmission loss is modelled within each of the N vertical planes as a function of depth and range from the source. The decidecade band received per-1s, for impulsive and non-impulsive noise sources respectively, SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received per-1s SEL are then computed by summing the received decidecade band levels.

The received per-1s SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. The maximum received per-1s SEL at many sampling depths are taken over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-1s SEL are presented as contours around the source.

Appendix C. Methods and Parameters

C.1. Estimating Range to Thresholds Levels

Sound level contours were calculated based on the underwater sound fields predicted by the propagation models, sampled by taking the maximum value over all modelled depths above the sea floor for each location in the modelled region. The predicted distances to specific levels were computed from these contours. Two distances relative to the source are reported for each sound level: 1) R_{max}, the maximum range to the given sound level over all azimuths, and 2) $R_{95\%}$, the range to the given sound level after the 5% farthest points were excluded (see examples in Figure C-1).

The $R_{95\%}$ is used because sound field footprints are often irregular in shape. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes. This is demonstrated in the image in Figure C-1(a). In cases such as this, where relatively few points are excluded in any given direction, R_{max} can misrepresent the area of the region exposed to such effects, and $R_{95\%}$ is considered more representative. In strongly asymmetric cases such as shown in Figure C-1(b), on the other hand, $R_{95\%}$ neglects to account for significant protrusions in the footprint. In such cases R_{max} might better represent the region of effect in specific directions. Cases such as this are usually associated with bathymetric features affecting propagation. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the non-uniformity of the acoustic environment.

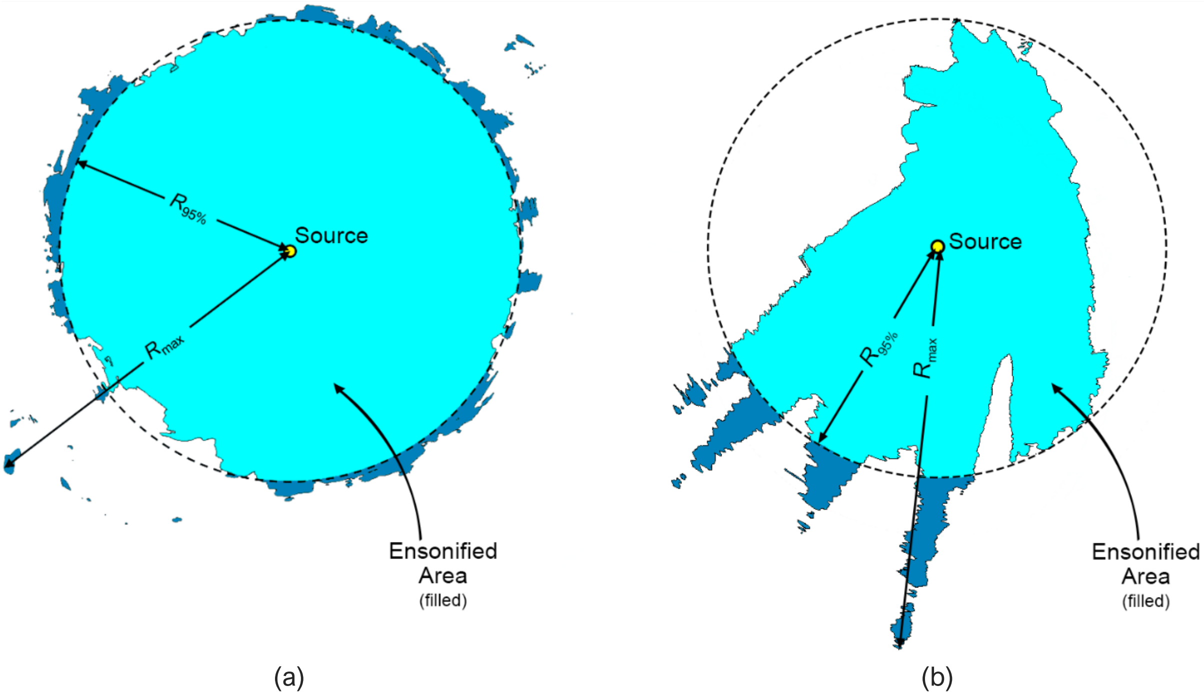


Figure C-1. Sample areas ensonified to an arbitrary sound level with R_{max} and $R_{95\%}$ ranges shown for two scenarios. (a) Largely symmetric sound level contour with small protrusions. (b) Strongly asymmetric sound level contour with long protrusions. Light blue indicates the ensonified areas bounded by $R_{95\%}$; darker blue indicates the areas outside this boundary which determine R_{max}.

C.2. Environmental Parameters

C.2.1. Bathymetry

Bathymetry throughout the modelled area was extracted from two sources, Darwin Inner Harbour with 1 m resolution (Geoscience Australia 2017) and where required this was supplemented with the high-resolution depth model for Northern Australia, a ~30 m grid rendered for Northern Australia (Beaman 2018) for the region shown in Figure 1. Bathymetry data were re-gridded and combined onto a Map Grid of Australia (MGA) coordinate projection (Zone 52) with a regular grid spacing of 40 × 40 m (Figure C-2). Bathymetry data is used at three different vertical height datums at lowest astronomical tide, mean sea level, and highest astronomical tide. For a reference level for LAT at 0.0 m, MSL is 3.2, and HAT at 8.1 m from Australian hydrographic charts AUS25 and AUS26.

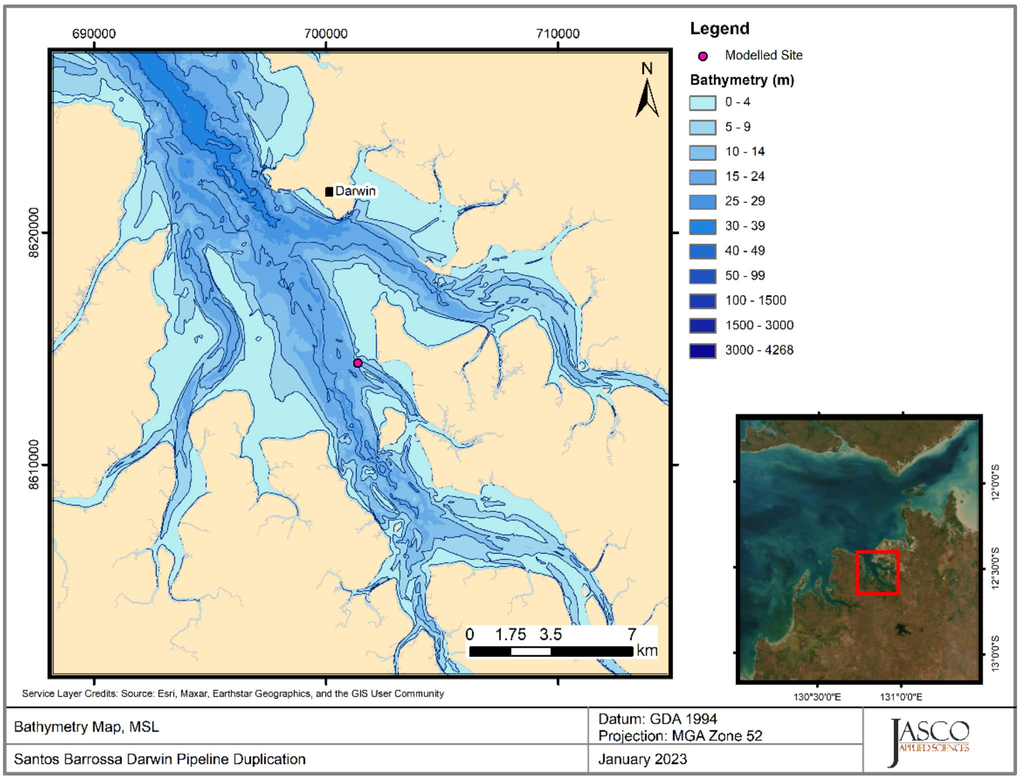


Figure C-2. Bathymetry in the modelled area.

C.2.2. Sound Speed Profile

The sound speed profiles for the modelled sites were derived from temperature and salinity profiles from the US Naval Oceanographic Office's Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the US Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to Coppens (1981).

Mean monthly sound speed profiles were derived from the GDEM profiles within a 40 km box radius encompassing each of the three areas. To determine the sound speed profile that is expected to be most favourable to longer-range sound propagation during the proposed survey time frame, each month was modelled for each area and the ranges were compared. As such, April was selected for sound propagation modelling to ensure precautionary estimates of distances to received sound level thresholds. Figure C-3 shows the resulting profile used as input to the sound propagation modelling.

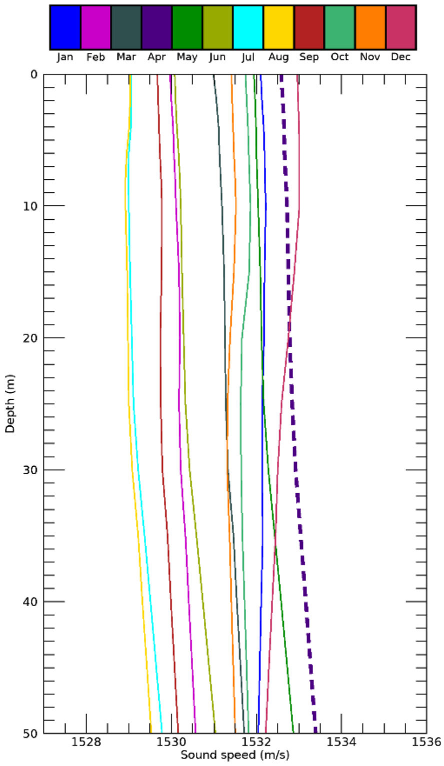


Figure C-3. The modelling sound speed profile corresponding to April is shown as the dotted line The profile is calculated from temperature and salinity profiles from Generalized Digital Environmental Model V 3.0 (GDEM; Teague et al. 1990, Carnes 2009).

C.2.3. Geoacoustics

The geoacoustic profile in this area was constructed using client-supplied geotechnical reports. Multiple bore holes near the modelled site were considered such that the geologic profile that was most representative of the seabed within Darwin Harbour was chosen. The geology was modelled as thin layer of sand, over a layer of silt, underlain with increasingly consolidated sandstone. Representative grain sizes and porosity were used in the grain-shearing model proposed by Buckingham (2005) to estimate the geoacoustic parameters required by the sound propagation models.

Table C-1. Geoacoustic profile for Darwin Harbour.

Depth below seafloor (m)	Material	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–1.5	Fine to coarse Sand with clay and gravel	2.09	1695–1910	0.18–0.92	283	3.65
1.5–5	Silt	2.01	1702–1754	0.40–0.59		
5–100	Sandstone	2.09	2039–2926	1.26–2.49		

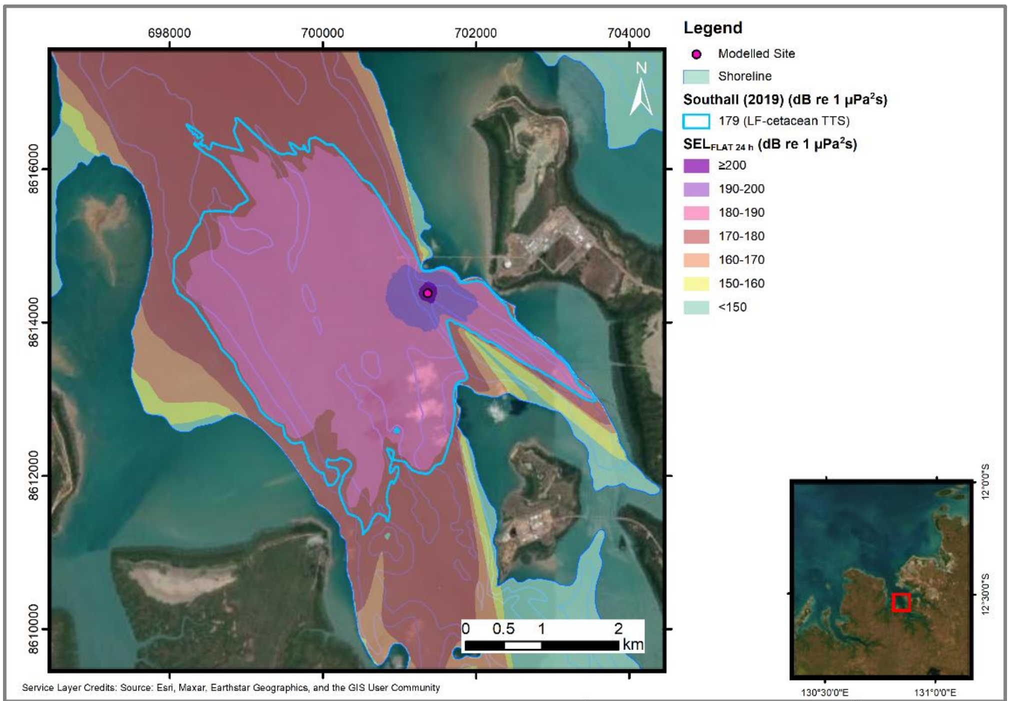
Appendix D. Model Validation Information

Predictions from JASCO's propagation models (MONM, FWRAM, and VSTACK) have been validated against experimental data from a number of underwater acoustic measurement programs conducted by JASCO globally, including the United States and Canadian Artic, Canadian and southern United States waters, Greenland, Russia, and Australia (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Matthews and MacGillivray 2013, Martin et al. 2015, Racca et al. 2015, Martin et al. 2017a, Martin et al. 2017b, Warner et al. 2017, MacGillivray 2018, McPherson et al. 2018, McPherson and Martin 2018).

In addition, JASCO has conducted measurement programs associated with a significant number of anthropogenic activities that have included internal validation of the modelling (including McCrodan et al. 2011, Austin and Warner 2012, McPherson and Warner 2012, Austin and Bailey 2013, Austin et al. 2013, Zykov and MacDonnell 2013, Austin 2014, Austin et al. 2015, Austin and Li 2016, Martin and Popper 2016, Austin et al. 2018, Beach Energy Limited 2020).

Appendix E. Additional Maps

E.1. Accumulated SEL_{24h} sound level contour maps



Scenario 1, Ripper LAT: Modelled maximum-over-depth SEL_{24h} sound field	Datum: GDA 1994 Projection: MGA Zone 52	JASCO APPLIED SCIENCES
Santos Barossa Darwin Pipeline Duplication	January 2023	

Figure E-1. *Xcentric Ripper, LAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

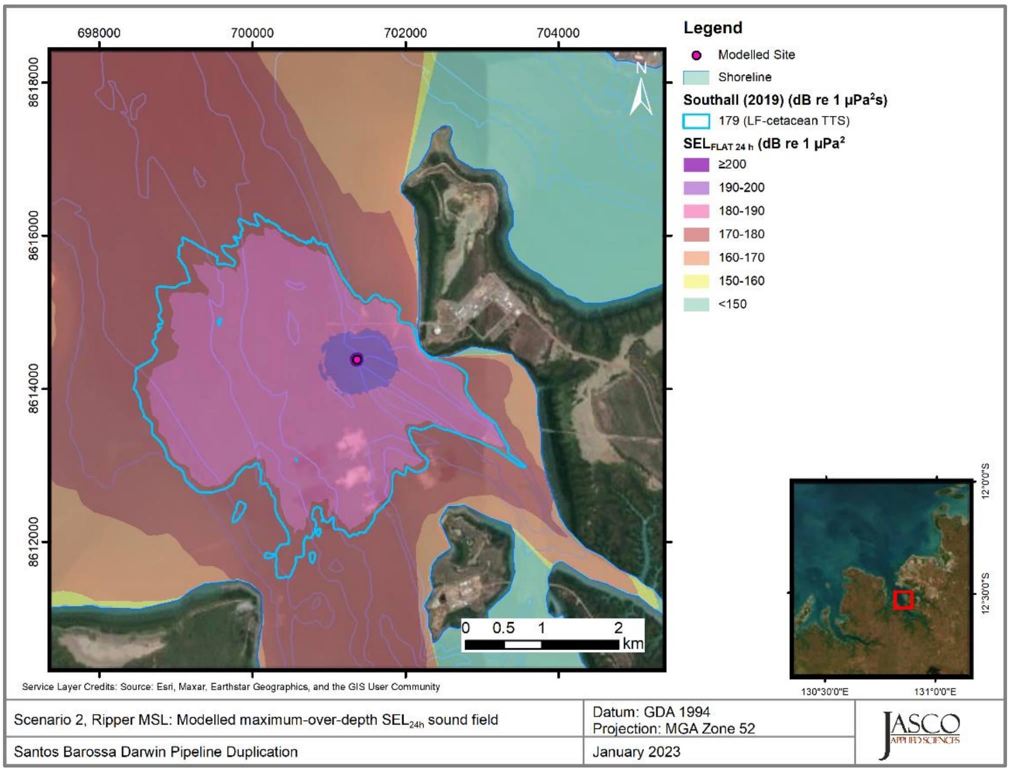


Figure E-2. *Xcentric Ripper, MSL:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

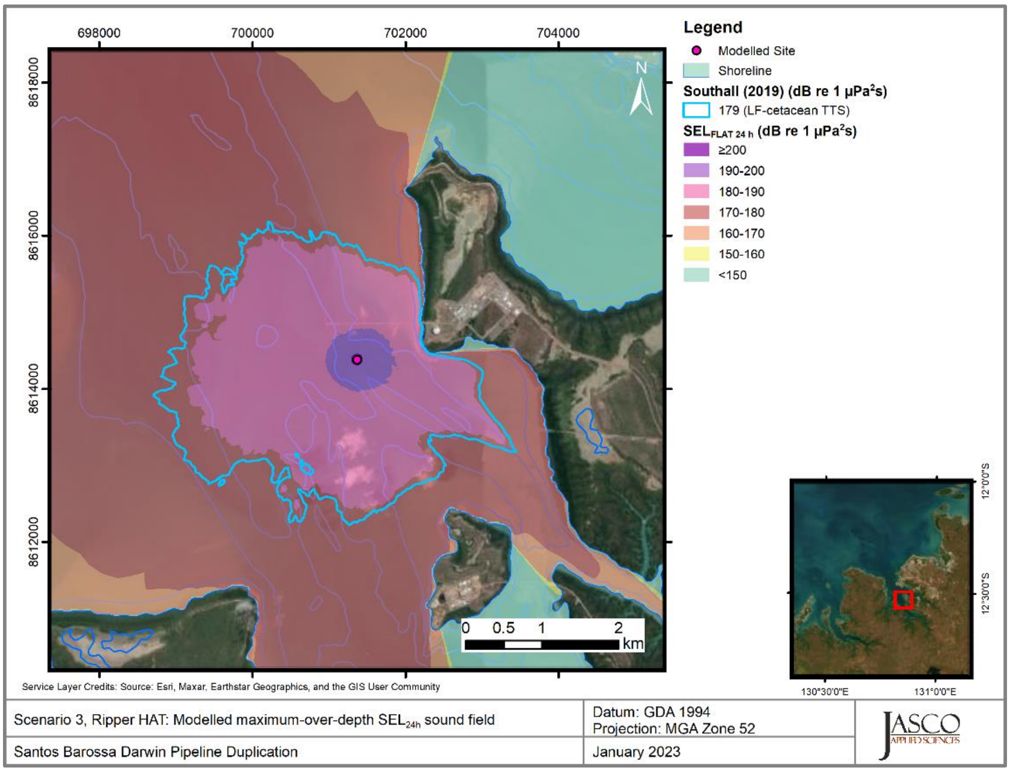


Figure E-3. *Xcentric Ripper, HAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

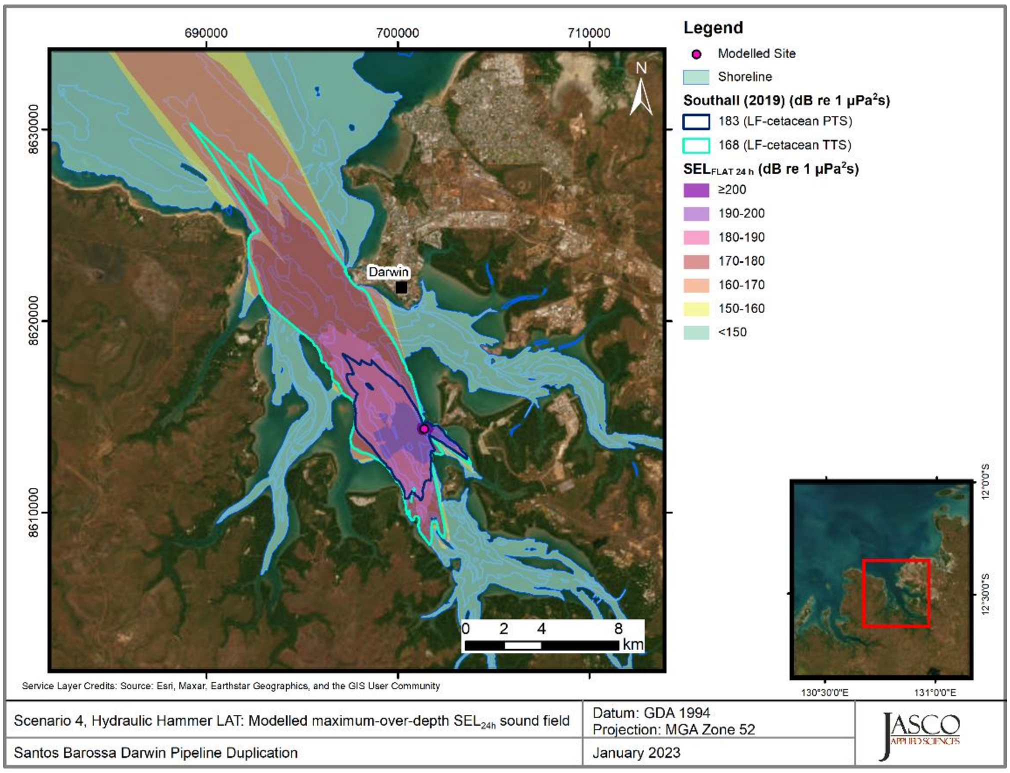


Figure E-4. *Hydraulic Hammer, LAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

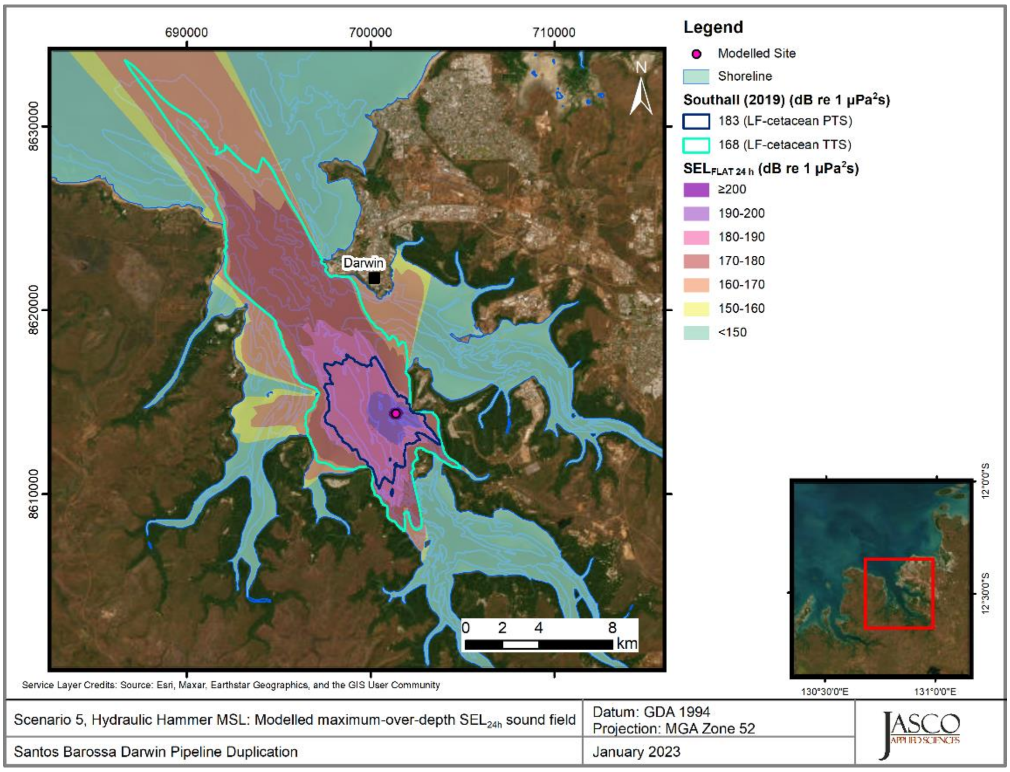


Figure E-5. *Hydraulic Hammer, MSL:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

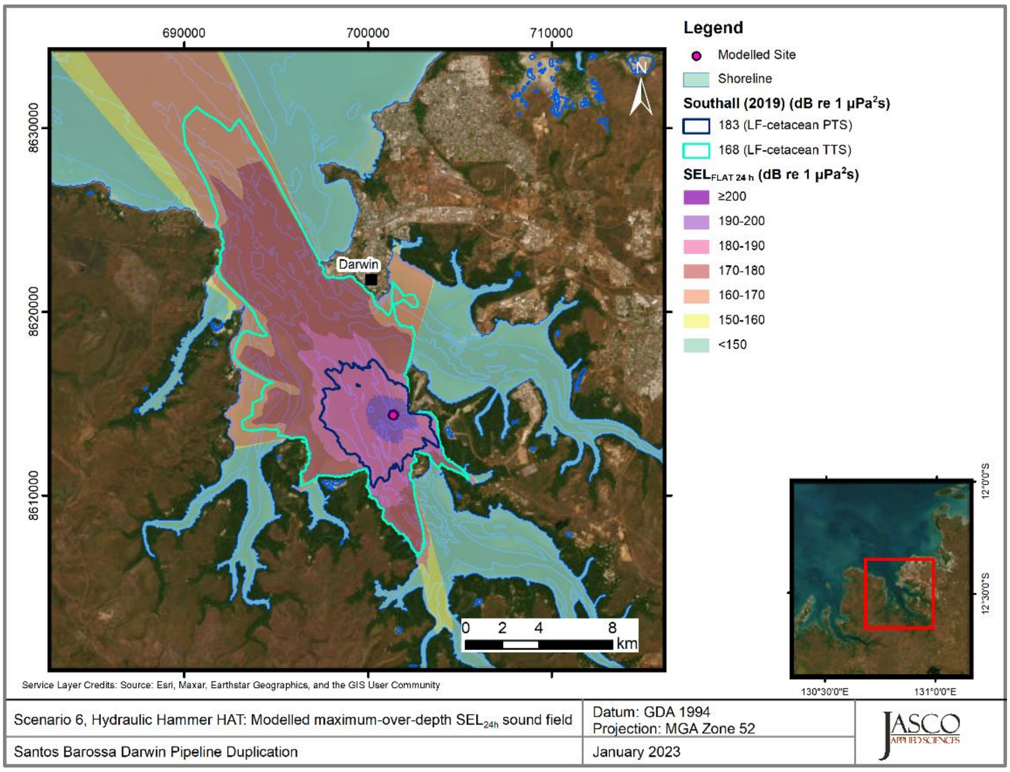


Figure E-6. *Hydraulic Hammer, HAT:* sound level contour map of unweighted maximum-over-depth SEL_{24h} results, along with isopleths for LF cetaceans. Thresholds omitted here were not reached or not large enough to display graphically. Refer to Table 14 for threshold distances.

Appendix F. Hydraulic hammer operational time per day

This section outlines the effect that the operation duration of the hydraulic hammer has on the range to threshold for accumulated SEL. Table F-1 to Table F-5 outline the range to PTS and TTS for the considered hearing groups over operation times of 2, 4, 6, and 8 h.

Table F-1. *Hydraulic Hammer*: Summary of maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} TTS for HF cetaceans, Sirenians, and Sea Turtles based on Southall et al. (2019) and Finneran et al. (2017) for different operation durations.

Operation Duration (h)	HF Cetacean TTS			Sirenians TTS			Sea Turtle TTS		
	LAT	MSL	HAT	LAT	MSL	HAT	LAT	MSL	HAT
	R_{max} (km)	R_{max} (km)	R_{max} (km)	R_{max} (km)	R_{max} (km)	R_{max} (km)	R_{max} (km)	R_{max} (km)	R_{max} (km)
2	0.89	0.67	0.57	1.14	0.84	0.67	0.48	0.38	0.34
4	1.39	1.20	0.98	1.65	1.41	1.20	0.70	0.58	0.53
6	1.70	1.51	1.33	2.37	1.79	1.58	1.04	0.74	0.69
8	2.44	1.83	1.63	2.78	2.50	1.94	1.18	0.95	0.90

Table F-2. *Hydraulic Hammer 2 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2). A dash indicates the level was not reached within the limits of the modelled resolution (20 m). A slash indicates that the area is less than an area associated with the modelled resolution (0.0013 km^2).

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	LAT		MSL		HAT	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS							
LF cetaceans	183	2.75	7.51	1.88	5.62	1.7	5.49
HF cetaceans	185	0.05	0.01	0.03	\	0.03	\
Sirenians	190	0.06	0.01	0.05	0.01	0.03	\
Sea Turtles	204	0.03	\	0.03	\	–	–
TTS							
LF cetaceans	168	11.8	39.9	11.47	58.0	12.5	71.5
HF cetaceans	170	0.89	0.94	0.67	0.90	0.57	0.75
Sirenians	175	1.14	1.45	0.84	1.21	0.67	0.99
Sea Turtles	189	0.48	0.4	0.38	0.33	0.34	0.28

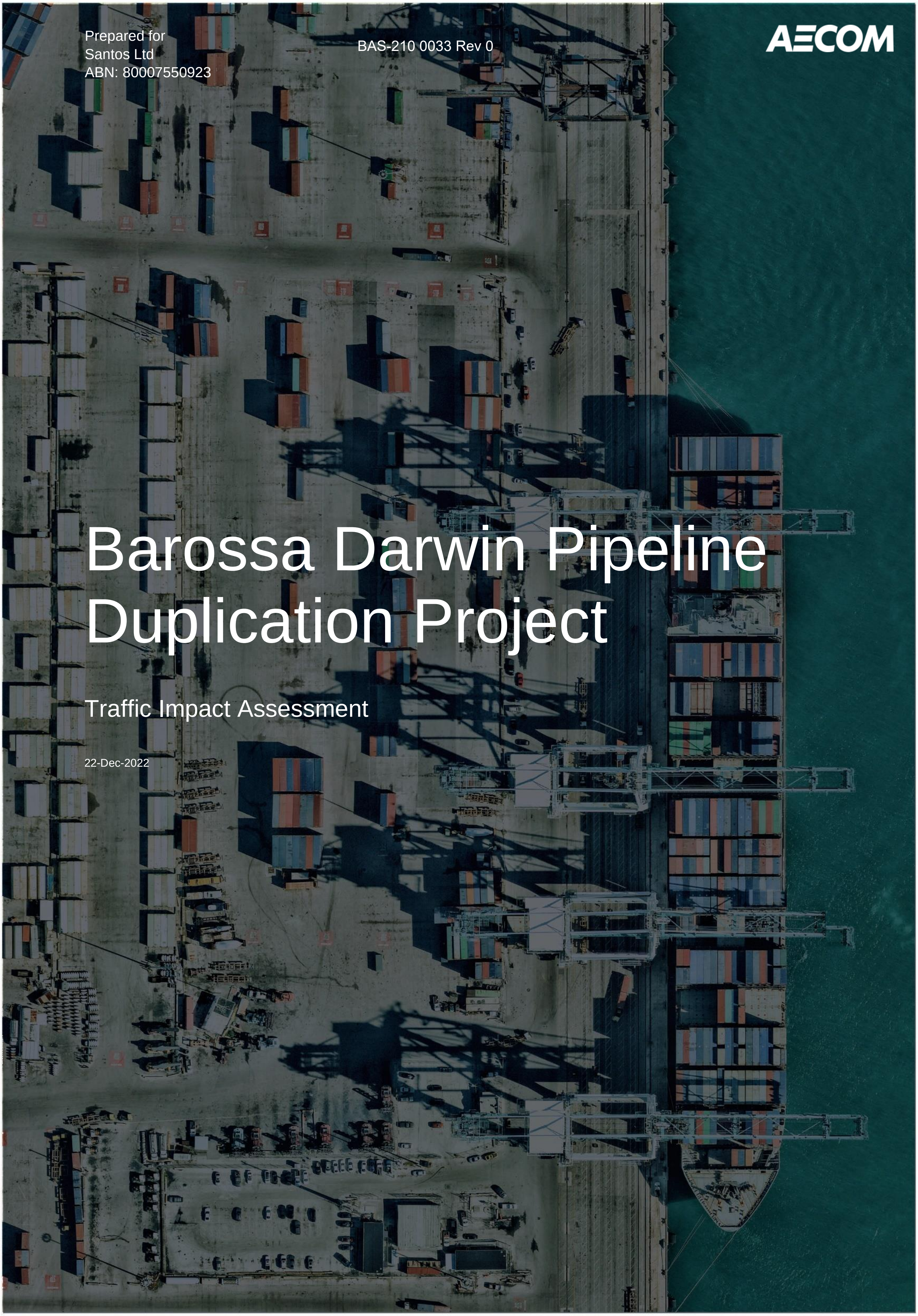
Table F-3. *Hydraulic Hammer 4 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2).

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	LAT		MSL		HAT	
		R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)	R_{max} (km)	Area (km^2)
PTS							
LF cetaceans	183	4.15	13.8	3.34	13.4	3.03	12.5
HF cetaceans	185	0.10	0.03	0.06	0.01	0.06	0.01
Sirenians	190	0.12	0.04	0.08	0.02	0.06	0.01
Sea Turtles	204	0.06	0.01	0.05	0.01	0.05	0.01
TTS							
LF cetaceans	168	15.5	54.5	15.5	78.4	14.8	96.9
HF cetaceans	170	1.39	2.57	1.20	2.42	0.98	2.07
Sirenians	175	1.65	3.35	1.41	3.32	1.20	2.87
Sea Turtles	189	0.70	0.78	0.58	0.68	0.53	0.64

Table F-4. *Hydraulic Hammer 6 h:* Maximum (R_{max}) horizontal distances (in km) to frequency-weighted SEL_{24h} PTS and TTS thresholds based on Southall et al. (2019) and Finneran et al. (2017) from the most appropriate location for considered sources per scenario, and ensonified area (km^2).

Hearing group	Frequency-weighted SEL_{24h} threshold ($L_{E,24h}$; dB re 1 µPa²·s)	LAT		MSL		HAT	
		R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)	R_{max} (km)	Area (km²)
PTS							
LF cetaceans	183	4.86	16.9	4.25	18.8	3.80	18.9
HF cetaceans	185	0.15	0.05	0.09	0.03	0.07	0.02
Sirenians	190	0.18	0.07	0.11	0.04	0.09	0.03
Sea Turtles	204	0.09	0.02	0.06	0.01	0.06	0.01
TTS							
LF cetaceans	168	17.3	63.1	17.9	89.3	17.6	117.1
HF cetaceans	170	1.70	3.79	1.51	4.00	1.33	3.58
Sirenians	175	2.37	4.67	1.79	5.13	1.58	4.79
Sea Turtles	189	1.04	1.40	0.74	1.05	0.69	1.00

Appendix 10: Traffic Impact Assessment



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Santos Ltd
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AECOM

Barossa Darwin Pipeline Duplication Project

Traffic Impact Assessment

22-Dec-2022

Barossa Darwin Pipeline Duplication Project

Traffic Impact Assessment

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Table of Contents

Executive Summary i
Abbreviations iii
Glossary iv
1.0 Introduction 1
1.1 Background 1
1.2 Project overview 1
2.0 Terms of Reference 4
3.0 Evaluation Framework 5
3.1 Legislation, policy, guidelines and standards 5
3.2 Assessment criteria 7
4.0 Consultation and Engagement 9
5.0 Methodology 10
6.0 Existing Conditions 11
6.1 Study area 11
6.2 Existing road network 12
6.2.1 Arnhem Highway 12
6.2.2 Stuart Highway 12
6.2.3 Tiger Brennan Drive 13
6.2.4 Berrimah Road 14
6.2.5 Wishart Road 14
6.2.6 Kirkland Road 15
6.2.7 Elrundie Avenue 17
6.2.8 Jenkins Road 17
6.2.9 Channel Island Road 18
6.2.10 Wickham Point Road 19
6.2.11 Heavy vehicle networks 20
6.3 Existing traffic volumes 22
6.4 Critical intersections 27
6.5 Existing sustainable modes of transport 29
6.5.1 Pedestrians and cyclists 29
6.5.2 Public transport 30
6.6 Crash history 32
7.0 Project Description 34
7.1 Construction 34
7.1.1 Construction schedule 34
7.1.2 Construction hours 34
7.1.3 Overview of construction traffic generating activities 34
7.2 Operation 36
7.3 Decommissioning 36
7.4 Site access 36
7.4.1 DLNG site 36
7.4.2 Darwin Port 36
8.0 Heavy vehicle route assessment 37
8.1 Rock haulage route 37
8.1.1 Darwin Port 37
8.1.2 DLNG 38
8.2 Other haulage routes 38
9.0 Traffic Generation 40
9.1 Construction phase 40
9.1.1 Construction staff 40
9.1.2 Rock haulage 42
9.1.3 Equipment and materials 42
9.2 Operation phase 44
9.3 Decommissioning phase 45

10.0 Traffic Network Impact 46
10.1 Criteria and assumptions 46
10.1.1 Traffic generation and distribution 46
10.1.2 Lane capacities 47
10.1.3 Annual background traffic growth 47
10.1.4 Passenger car unit equivalency factors 48
10.2 Road mid-block capacity impact 48
10.2.1 Traffic volume data 48
10.2.2 Mid-block capacity assessment 52
10.3 Intersection capacity and performance impact 54
10.3.1 Performance indicators and targets 54
10.3.2 Intersection impact results 55
10.4 Recommended mitigation measures 57
11.0 Cumulative Impacts 58
11.1 Coolalinga Road Safety Upgrades 58
11.2 Tiger Brenan Drive / Berrimah Road overpass works 59
11.3 Darwin Ship Lift 60
11.4 Recommended mitigation measures 61
12.0 Other Impacts and Mitigation Measures 62
12.1 Pedestrians and cyclists 62
12.2 Public transport 62
12.3 Road maintenance 62
12.4 Driver fatigue 62
12.5 Incident management 63
13.0 Summary and Conclusions 64
14.0 References 66

Appendix A
Mid-block capacity assessment A

Appendix B
SIDRA Intersection results C

Executive Summary

Overview

Santos proposes to construct and operate a new pipeline segment, the Darwin Pipeline Duplication Project (the Project), enabling natural gas from the Barossa Field in the Timor Sea to be transported to the Santos-operated Darwin Liquified Natural Gas (DLNG) Facility at Wickham Point. The new gas pipeline would extend the existing Barossa Gas Export Pipeline and would comprise of approximately 100 kilometres of pipeline in Northern Territory waters and 23 kilometres of pipeline in Commonwealth waters.

The purpose of this report is to assess the potential traffic and transport impacts associated with the Project. This assessment will inform the preparation of the Supplementary Environmental Report (SER) for the DPD Project which will be submitted to the Northern Territory Environmental Protection Authority (NT EPA) for assessment in accordance with the Northern Territory Environmental Protection Act 2019 (NT EP Act).

Existing conditions

An existing transport conditions review was undertaken, which was informed via a combination of desktop reviews, site visit, crash/traffic data analysis and review of relevant policies and legislation. The key existing condition findings are summarised below:

- The road network within the study area is comprised of several Territory roads including Arnhem Highway and Stuart Highway. The Stuart Highway is the most heavily trafficked road in the area, with up to 27,800 vehicles travelling on the road on an average day.
- Stuart Highway, Tiger Brennan Drive and Berrimah Road all form part of the National Land Transport Network. Heavy vehicles (>3 axles) account for between 3.6% and 27.4% of traffic volumes on these roads.
- Traffic volumes on key roads in the study area generally peak during the month of September. Reduced levels of traffic are observed during the wet season (November to April).
- Arnhem Highway, Stuart Highway, Tiger Brennan Drive, Berrimah Road, Kirkland Road, Elrundie Avenue, Jenkins Road, Channel Island Road and Wickham Point Road all form part of the approved network for 53.5 m Road Train vehicles.
- Dedicated cyclist infrastructure in the study area is limited to an on-road bicycle lane on the eastern side of Berrimah Road between Marlow Road and Wishart Road. Several shared footpaths are provided adjacent to key roads in the study area including Berrimah Road, Tiger Brennan Drive, Stuart Highway and Arnhem Highway.
- There are no existing or proposed public bus services within 400 m of the DLNG facility or the intermediate stockpile site at Darwin Port, however CDC Northern Territory operates seven regular public bus services on roads forming part of the proposed Project haulage routes.
- The Adelaide-Darwin railway alignment is located approximately 750 m north-west of the intermediate stockpile site at Darwin Port. This railway line is grade separated from Berrimah Road at East Arm. However, two level railway crossings are located on Kirkland Road and one is located on Channel Island Road.
- In the five-year period from 2015 to 2019, a total of seven fatalities occurred on key roads in the study area. Five of these fatalities occurred on Tiger Brennan Drive.

Impact assessment

The key findings of the construction phase impact assessment are as follows:

- Mid-block capacity: a mid-block capacity assessment was undertaken for key roads in the study area to assess the impact of the Project on road capacity. The results indicate that all roads would operate under capacity in 2024 with the exception of Stuart Highway (between Temple Terrace and Howard Springs Road) and Wishart Road during the AM peak hour. Project-generated traffic would account for a very minor proportion of traffic on the local road network in 2024 and where the available capacity of a road has been exceeded, it is not a result of Project traffic.

- Intersection capacity and performance: traffic modelling using SIDRA Intersection (version 9.0) was performed to assess the impacts of the Project on the capacity and performance of three critical intersections. The modelling results indicate additional traffic movements generated by the construction of the Project in 2024 would result in negligible impacts.
- Preliminary haulage route assessment: routes have been established based on the approved road network for 53.3 metre Road Train vehicles. No road upgrades are anticipated to be required to accommodate Project traffic.

Overall, impacts to the local transport network during Project construction are expected to be negligible given the very low proportion of Project-generated traffic on the local road network.

Mitigation measures

To mitigate the potential impacts of the Project, the following mitigation measures have been recommended:

- All vehicle movements associated with the Project should be planned to occur outside of the identified AM and PM peak hours
- Group transport, such as shuttle buses and car-pooling schemes, should be implemented where practical to reduce the number of light vehicle movements on the local road network
- Heavy vehicle movements should be scheduled to minimise traffic disruption to the road network. This may include:
    - Scheduling of the movement of rock, equipment and other materials to occur outside of the identified AM and PM peak hours
    - Scheduling heavy vehicle movements to be evenly dispersed as far as practical to minimise the potential of convoying or platoons on the road network.
- The loading and unloading of heavy vehicles should be planned so that the capacity of each individual vehicle is fully utilised to reduce the total number of movements on the local road network
- A separate Traffic Management Plan (TMP) should be prepared, approved and implemented during the construction phase of the Project. The TMP will confirm final haulage routes and provide the necessary mitigation measures to ensure that construction vehicle movements can be accommodated on the local road network with minimal impacts.
- Coordination and consultation with key stakeholders to manage the interface of other projects occurring in the study area at the same time. This may include the coordination of traffic management arrangements between projects and the provision of regular project updates.
- Investigation of potential alternative haulage routes in the event that road closures or access restrictions are required to facilitate other projects in the study area.

Abbreviations

Abbreviation	Term
AADT	Average Annual Daily Traffic
AECOM	AECOM Australia Pty Ltd
DIPL	Department of Infrastructure, Planning and Logistics
DLNG	Darwin Liquified Natural Gas
DOS	Degree of saturation
FCGT	Flood / Clean / Gauge / Testing
Km	Kilometre
Km/h	Kilometres per hour
LOS	Level of service
M	Metre
NT	Northern Territory
OD	Over-dimensional vehicle
OSOM	Oversize Overmass
SER	Supplementary Environmental Report
TIA	Transport Impact Assessment
TMP	Traffic Management Plan
ToR	Terms of Reference

Glossary

Term	Description
AADT	This measurement provides the total volume of vehicle traffic of a road for a year divided by 365 days.
Access track	Tracks that are built by the project to facilitate construction, operation and maintenance.
Average delay	This is the average amount of time it takes a vehicle to negotiate an intersection, including the time to negotiate corners and the time stopped in queues or waiting for a green signal.
DOS	Ratio of demand to capacity. A DOS of 1.0 or more in theory represents saturated conditions where the demand exceeds the capacity. For a signalised intersection, a DOS of 0.9 is usually adopted as the capacity threshold.
Land	Any land, whether publicly or privately owned, and includes groundwater.
Landholder	A general term used to refer to the legal owner or manager of a parcel of land. It may be private landholder, Government or private utility, or a Government Agency responsible for management of a particular parcel of Crown land (e.g., National Parks or Forestry areas).
LOS	This is an alpha-numeric rating of the overall performance of an intersection, ranging from LOS A (very good) to LOS F (very poor).
Mid-block	A location around the mid-point between two intersections.
OD vehicle	Over-dimensional (OD) vehicles are those that exceed 5.0 metres wide/high or 30.0 metres long or 100.0 tonnes gross mass. OD vehicles should be reviewed for transportation with the DIPL permit process to permit travel. Other additional permits/conditions are required for access, such as escorts, travel times, etc.
OSOM vehicle	All vehicles travelling on NT roads must comply with the maximum dimension limits and maximum standard mass limits unless the vehicle has been given an exemption. The maximum vehicle dimensions for standard haulage vehicles are 4.3m height and 2.5m width and 22.5m tonne mass limit. Vehicles which fall outside of these dimensions are considered Oversized and/or Overmass and must apply for a permit to operate.
Trenching	Excavation of a trench for burial of a cable or pipeline system.

1.0 Introduction

1.1 Background

AECOM Pty Ltd Australia (AECOM) has been engaged by Santos NA Barossa Pty Ltd (Santos) to prepare a Traffic Impact Assessment (TIA) for the Barossa Darwin Pipeline Duplication Project (the Project). This assessment forms part of the Supplementary Environmental Report (SER) for the Project and has been undertaken to address the comment received from the Department of Infrastructure, Planning and Logistics (DIPL) – Transport and Civil Services Division relating to traffic and transport. Specifically:

> **Issue:** Insufficient information has been provided to assess the risks to land based transport networks. Traffic and transport regimes have changed considerably in this locality since the original establishment of Darwin LNG but are also expected to increase in the near future as a result of further industrial developments in this area. This will result in greater risks to road users and transport infrastructure along the routes to and from the proposal.
>
> **Recommended Action:** The proponent to submit a Traffic Impact Statement (TIS) to assess the road traffic impacts, to ensure the road authority can measure the proponent's acknowledgement of the risks associated with the works impact on NTG Roads, infrastructure and road safety. The assessment is to include, but is not limited to: details on what materials will be transported and their loads, traffic volumes and types of vehicles used for the transportation including the haulage routes and duration of the haulage operation specific to onshore movements including a risk assessment as part of the process to reflect how all roads and infrastructure on a local and regional level will be affected.

The SER and supporting TIA will be submitted to the Northern Territory Environmental Protection Authority (NT EPA) for assessment in accordance with the Northern Territory Environmental Protection Act 2019 (NT EP Act).

1.2 Project overview

Santos proposes to construct and operate a new pipeline segment, the Darwin Pipeline Duplication Project (the Project), enabling natural gas from the Barossa Field in the Timor Sea to be transported to the Santos-operated Darwin Liquified Natural Gas (DLNG) Facility at Wickham Point. The new gas pipeline would extend the existing Barossa Gas Export Pipeline and would comprise of approximately 100 kilometres of pipeline in Northern Territory waters and 23 kilometres of pipeline in Commonwealth waters. Project construction activities will include pre-lay works, including trenching of section of the pipeline route, installation of the pipeline and installation of rock armour along some sections of the pipeline.

The Project has been split into three geographical areas. These areas are:

- **Offshore NT waters** – the offshore Project Area extends from the Territorial waters limit, with a typical water depth of between 30-40 metres (m), through to the limit of Darwin Harbour, as shown in Figure 1-1. It includes a proposed spoil disposal ground directly adjacent to the existing INPEX Ichthys spoil ground.
- **Darwin Harbour** – the Darwin Harbour part of the Project area includes the Project Area from the outer boundary of Darwin Harbour to the location of the shore crossing at the existing DLNG facility as shown in Figure 1-1. The Project pipeline within Darwin Harbour follows the route of existing Bayu-Undan and Ichthys gas pipelines.
- **Shore crossing and onshore** – the shore crossing and onshore location for the Project is within the existing DLNG facility disturbance envelope at Wickham Point within the Middle Arm Peninsula industrial area, approximately 6 km south-to-south-east of Darwin (Figure 1-1).

The key phases of the Project are:

- Surveys
- Construction, including:
    - Pre-lay works
    - Spoil disposal
    - Pre-lay span rectification and foundation installation
    - Cable crossings
    - Onshore construction
    - Pipeline installation and pre-commissioning
- Commissioning and operations
- Decommissioning.

The Project phases of relevance to this TIA are discussed in Section 7.0. Subject to regulatory approval, construction of the Project is anticipated to commence in Quarter 4 of 2023 and is expected to be complete by the end of 2024, with first gas from the Barossa Field expected in the first half of 2025. The key components required for the construction of the Project include:

- **Pipeline** – approximately 23 km of pipeline would be constructed in Commonwealth waters and 100 km in NT waters and lands. The Project pipeline will run parallel to the existing Bayu-Undan to Darwin pipeline and comes onshore at the DLNG facility.
- **Shore crossing** – the pipeline will be trenched and buried at the shore crossing. The length of pipeline trenching onshore will be approximately 300 m.
- **Spoil disposal ground** – spoil that is collected during the trenching activities will be disposed at a location north-east of Darwin Harbour (Figure 1-1).
- **Onshore facilities** – all onshore facilities including the shore pull, laydown and ancillary facilities would be located within the existing DLNG disturbance envelope (Figure 1-1).
- **Quarry** – rock would be used to provide pipeline protection and stability within Darwin Harbour. The rock is proposed to be sourced from the HB Quarry at Mount Bundey (approximately 85 km south-east of Darwin.

Activities within the Project area will be vessel-based, for construction activities in Offshore NT waters and Darwin Harbour, or shore-based, for construction activities at the shore crossing and onshore at the DLNG facility. Transfer of personnel, materials and equipment via road networks will therefore be to vessel loading points in Darwin Harbour (primarily East Arm wharf, in the case of rock movements) and to the onshore/shore-crossing area at the DLNG facility.

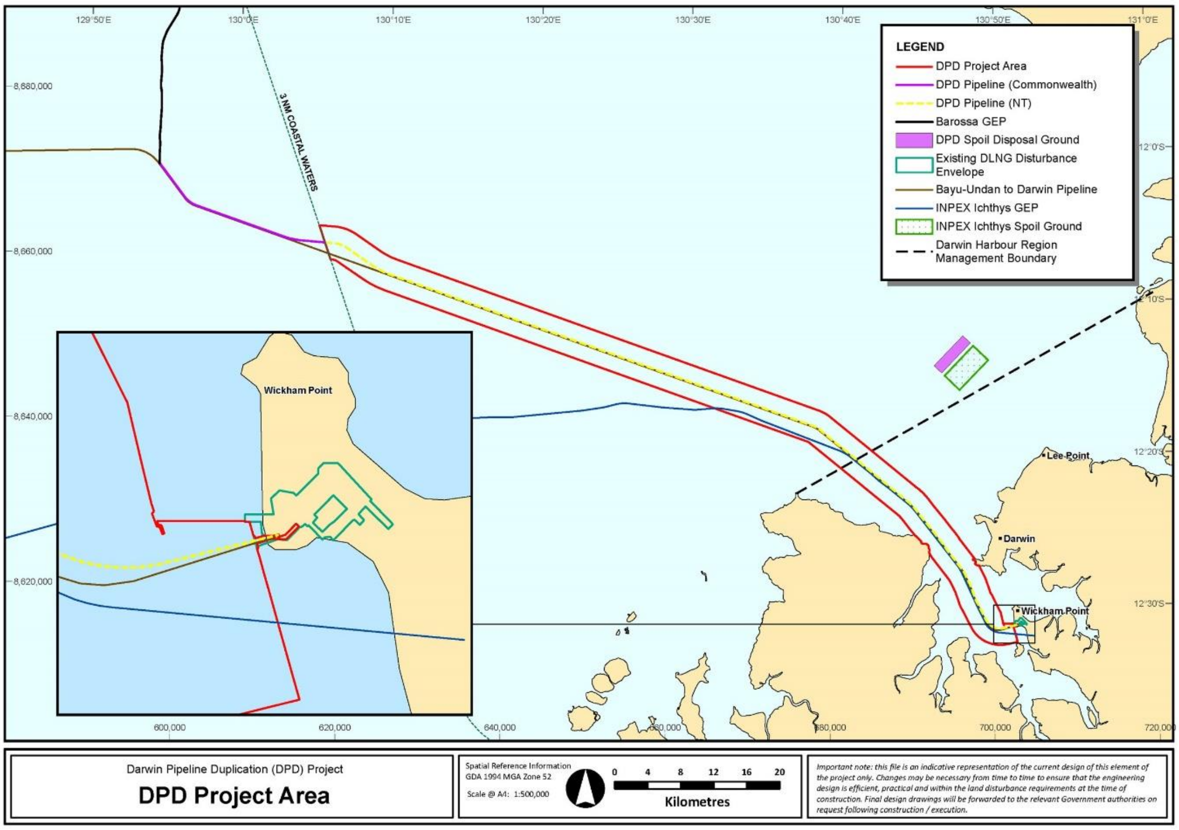

Figure 1-1 Project Area

Image source: Santos, 2021

2.0 Terms of Reference

The ToR for the Project SER identifies requirements for assessment and mitigation of impacts on transport and traffic in terms of social surroundings. This assessment addresses the requirements of the ToR.

Requirements of particular relevance to this report and where they have been addressed within this report are summarised as follows:

- Describe land traffic and transport activities during construction and operation including details on access, haulage routes, vehicle types, volumes of traffic (Section 7.0, 8.0, 9.0).
- Describe and quantify the potential impacts of Project infrastructure and activities, such as land transport and traffic impacts (Section 9.0, 10.0, 11.0)
- Address all potential impacts and risks identified through the impact assessment, and identify measures to avoid, reduce or mitigate these impacts (10.0, 11.0, 12.0)

3.0 Evaluation Framework

The assessment will consider legislation, policy and standards relevant to transport along with specific assessment criteria that have been derived for the purposes of the study.

3.1 Legislation, policy, guidelines and standards

The legislation, policy, guidelines and standards relevant to this study are summarised in Table 3-1.

Table 3-1 Legislation, policy, guidelines and standards relevant to the assessment

Document title	Summary	Relevance to the project
National		
Austroads – Guide to Traffic Management Part 3: Traffic Studies and Analysis	The *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads, 2018) is concerned with the collection and analysis of traffic data for the purpose of traffic management and traffic control within a network. It serves as a means to ensure some degree of consistency in conducting traffic studies and surveys. It provides guidance on the different types of traffic studies and surveys that can be undertaken, their use and application, and methods for traffic data collection and analysis.	The *Guide to Traffic Management Part 3: Traffic Studies and Analysis* has been used to guide the collection and analysis of traffic data used in this assessment.
Austroads – Guide to Traffic Management Part 12: Integrated Transport Assessments for Developments	The *Guide to Traffic Management Part 12: Integrated Transport Assessments for Developments* (Austroads, 2020) is concerned with identifying and managing the impacts on the road system arising from land use developments. It provides guidance on the need and criteria for impact assessments, and a detailed procedure for identifying, assessing and mitigating traffic impacts. The aim is to ensure consistency in the assessment and treatment of traffic impacts, including addressing the needs of all road users and the effect upon the broader community.	The *Guide to Traffic Management Part 12: Integrated Transport Assessments for Developments* has been used to guide the structure and development of this assessment.
Austroads – Guide to Road Design Part 3: Geometric Design	The *Guide to Road Design Part 3: Geometric Design* (Austroads, 2021) provides road designers and other practitioners with information about the geometric design of road alignments. The purpose of the guide is to provide the information necessary to enable designers to develop safe and coordinated road alignments that cater for the traffic demand at the chosen speed. The guide also presents information leading to the choice of appropriate cross-section standards.	The *Guide to Road Design Part 3: Geometric Design* has been used to determine the potential impacts of the Project and associated traffic generation on the local road network.
Austroads – Guide to Road Design Part 4: Intersections and Crossings	The *Guide to Road Design Part 4: Intersections and Crossings* (Austroads, 2021) provides guidance on intersection design such as design considerations, design process, choice of design vehicle, pedestrian and cyclist crossing treatments, provision for public transport and property access.	The *Guide to Road Design Part 4: Intersections and Crossings* has been used to determine the potential impacts of the Project and associated traffic generation on intersections and crossings.

Document title	Summary	Relevance to the project
Northern Territory		
Northern Territory Environment Protection Act 2019	The *Northern Territory Environment Protection Act* aims to promote ecological sustainable development, manage significant disturbances through an environmental approval process, provide for broader community involvement and recognise the importance of participation of Aboriginal people and communities in environmental decisions. Under the Act, the NT EPA regulates the environment impact assessment process to identify potential environmental impacts of development proposals. There are four assessment methods provided for within the NT approvals process: 1) Assessment on referral information (Tier 1) 2) Assessment on a Supplementary Environmental Report (SER) (Tier 2) 3) Assessment by Environmental Impact Statement (EIS) (Tier 3) 4) Assessment by inquiry.	This impact assessment has been prepared to support the assessment by Supplementary Environmental Report (SER).
Control of Roads Act 1953	The Act, subject to section 64 of the *Planning Act 1999* and Part 12.3 of the *Local Government Act 2019*, stipulates that all roads in the Northern Territory, are under the care, control and management of the Minister. The Act outlines the process in which public roads can be opened and closed.	Any closure or change of access to a public road as a result of the Project would be required to follow the provisions of the *Control of Road Act 1953*.
Traffic Act 1987	The objective of this Act is to regulate traffic, which includes provisions in relation to the erection and operation of traffic control devices. Traffic control devices refer to signals, signs or markings displayed for the purpose of regulating, warning, or guiding traffic.	Under the *Traffic Act 1987*, consent from the applicable competent authority would be required prior to the erection and operation of traffic control devices.
Development Guidelines for Northern Territory Government Controlled Roads 2015	The *Development Guidelines for Northern Territory Government Controlled Roads* (Department of Transport, 2015) sets out the requirements for any development or infrastructure project that may impact the road or that will ultimately be transferred to the NTG for ongoing care, control and management. These Guidelines also outline the Department of Transport's involvement in the assessment of land use development applications under the Planning Act and provide details of the Department's approval processes.	The Project would be required to follow the requirements of the Guidelines.
Towards Zero Action Plan 2018-2022	The *Towards Zero Road Safety Action Plan* (DIPL, 2018) outlines a vision of zero deaths or accidents on roads within the Northern Territory. The plan establishes a strategy to reducing road deaths and accidents using a 'Safe Systems' approach, which considers how the whole road system can be more forgiving to reduce the consequence of mistakes by road users.	Road safety considerations represent a critical focus of this TIA.

Document title	Summary	Relevance to the project
Territory 2030 Strategic Plan	The Territory 2030 Strategic Plan (Northern Territory Government, 2009) provides a 20-year roadmap for development across the Northern Territory. The Plan foreshadows the establishment of Darwin as a key centre for oil and gas operations, maintenance and workforce.	The Project supports the Plan by further securing Darwin's place as an oil and gas hub.
Greater Darwin Plan 2012	The *Greater Darwin Plan 2012* (Northern Terriory Government, 2012) outlines seven strategic directions to support growth and sustainable development within the Greater Darwin area in the context of the broader strategic framework provided by the *Territory 2030 Strategic Plan*. The plan identifies that economic growth in the Darwin area will likely be sustained over the next decade and beyond by the oil and gas industries, as well as the mining and defence sectors. As such, the release of suitable land for industrial development is essential to realising the opportunities offered by economic growth.	The Project aligns with the Plan by further expanding Darwin's gas-based industry.
10 Year Infrastructure Plan 2019-2028	The *10 Year Infrastructure Plan* (DIPL, 2019) aims to provide transparency in planning and prioritises projects that have been identified as supporting future growth and prosperity of the Northern Territory. The Plan identifies natural resources, such as gas, to be integral to the growth of the Northern Territory's economy.	The Project will further grow and diversify the Northern Territory's gas industry in line with the Plan's vision.
Local Government		
City of Palmerston Development Guidelines 2015	The *Development Guidelines 2015* (City of Palmerston, 2015) establish the approvals and permits required for development within the City of Palmerston and provide minimum standards acceptable for a new development. The guidelines specify that a developer shall avoid obstruction or damage to roadways and footpaths, drains and watercourses and any public utility or other services on or adjacent to the site which are visible or the location of which can be ascertained by the developer from the appropriate authority and shall have any obstruction removed immediately and at own cost shall have made good all damage caused.	Ensuring access to and maintenance of the road network and adjacent public infrastructure represents a key consideration of this TIA.

3.2 Assessment criteria

The assessment criteria relevant to this TIA are outlined below.

TIAs include an evaluation against relevant State/Territory and industry guidelines (as summarised in Table 3-1) whilst also addressing specific local government planning clauses where applicable.

Ultimately the findings and proposed mitigation measures detailed in the TIA need to be agreed with the relevant road authorities. Once planning approval has been obtained for the project, those stakeholders will be consulted regarding the development of a Traffic Management Plan (TMP). Additionally, where secondary approvals are required under transport legislation, these approvals would be sought from the relevant road authorities.

4.0 Consultation and Engagement

Development of the project and preparation of the TIA have been informed by consultation with key stakeholders. Feedback from the Department of Infrastructure, Planning and Logistics (DIPL), local councils and other statutory parties is summarised in Table 4-1.

Table 4-1 Feedback from key stakeholders in relation to traffic and transport

Stakeholder feedback	Consideration in project design or impact assessment
Department of Infrastructure, Planning and Logistics (DIPL)	
A meeting with DIPL was held on Monday 19 September 2022, with the following feedback received: • There are several road projects proposed along the haulage route from HB Quarry to Darwin Port. Alternative haulage routes to Darwin Port will need to be considered in the event road closures are required to facilitate these road projects. • Impacts to level railway crossings, including traffic queuing and delays to trains, will need to be considered. • Transportation of staff, including vehicle type and timing of movements in relation to peak traffic periods, will need to be discussed. • Construction of the new overpass at the intersection of Tiger Brennan Drive and Berrimah Road will likely require traffic to be diverted. The assessment will need to consider the impacts of cumulative traffic diversion, including general traffic, project related traffic and traffic generated by other concurrent projects. • There are several other projects in the area (including mining projects) utilising Port Darwin. Traffic activity and use of the port by other projects will need to be aligned with the project, particularly as there is only one route in/out of Port Darwin.	The items outlined have been considered as reasonably possible at this planning stage of the Project, with the following items addressed in this TIA report: • Transportation of Project staff has been discussed in Section 9.1.1. • A cumulative impact assessment has been completed to assess the potential impacts of concurrent Projects. This assessment is included in Section 11.0.
City of Darwin and City of Palmerston	
Not undertaken at this stage, comments to be received as part of TRG process.	TBC

5.0 Methodology

The following tasks have been undertaken to complete the traffic and transport impact assessment for the Project:

- An initial review of the existing site and network conditions in the context of the Project.
- A review of relevant strategic plans to: contextualise this Project within the greater Darwin region; identify proposed cumulative impact of development; and identify relevant proposed network upgrades for land-based traffic that may impact this Project.
- A desktop analysis of the Project area to: establish existing traffic conditions; identify multi-modal networks and services; identify safety and accessibility issues particularly for heavy vehicles on proposed haulage routes.
- The collection and analysis of traffic data representative of existing site and network operations.
- A review of recent crash history for the Project study area to assist definition and avoidance of existing problem areas.
- Route selection and rock haulage duration associated with the construction of the Project, based on sourcing of rock material from the HB Quarry at Mount Bundey, fleet operation assumptions and heavy vehicle route restrictions.
- A review of the proposed Barossa Darwin Pipeline Duplication Project and estimated traffic generation based on an indicative construction program, construction transport fleet options and proposed hours of construction works and proposed operational activities and workforce.
- Undertake traffic impact assessment of the Project for the construction and operational phases. The assessment includes:
  - Haulage route option identification from the HB Quarry at Mount Bundey, to determine appropriate travel routes and any approvals required Project access.
  - Assessment of construction and operational traffic generation, including:
    - Traffic generation during the construction and operation of the Project, with the peak hour frequencies identified for the impact analysis
    - Potential impacts on the local road network, specifically mid-block road capacity assessments and intersection modelling
    - Undertake traffic impact review and summarise the potential impacts to multi-modal networks and services.
- Evaluation of potential cumulative impacts (where relevant) caused by the concurrent construction of the Project and other existing or proposed projects in the study area.
- Following the assessment of the potential Project traffic and transport impacts, recommendations for management and potential mitigation measures identified impacts have been made.

6.0 Existing Conditions

6.1 Study area

The study area for this impact assessment consists of the transport network servicing Darwin Port at East Arm, the DLNG facility at Wickham and the HB Quarry at Mount Bundey. The key roads of relevance to this impact assessment are shown in Figure 6-1 and include:

- Arnhem Highway
- Stuart Highway
- Tiger Brennan Drive
- Berrimah Road
- Wishart Road
- Kirkland Road
- Elrundie Avenue
- Jenkins Road
- Channel Island Road
- Wickham Point Road.

These roads are described in further detail in Section 6.2.

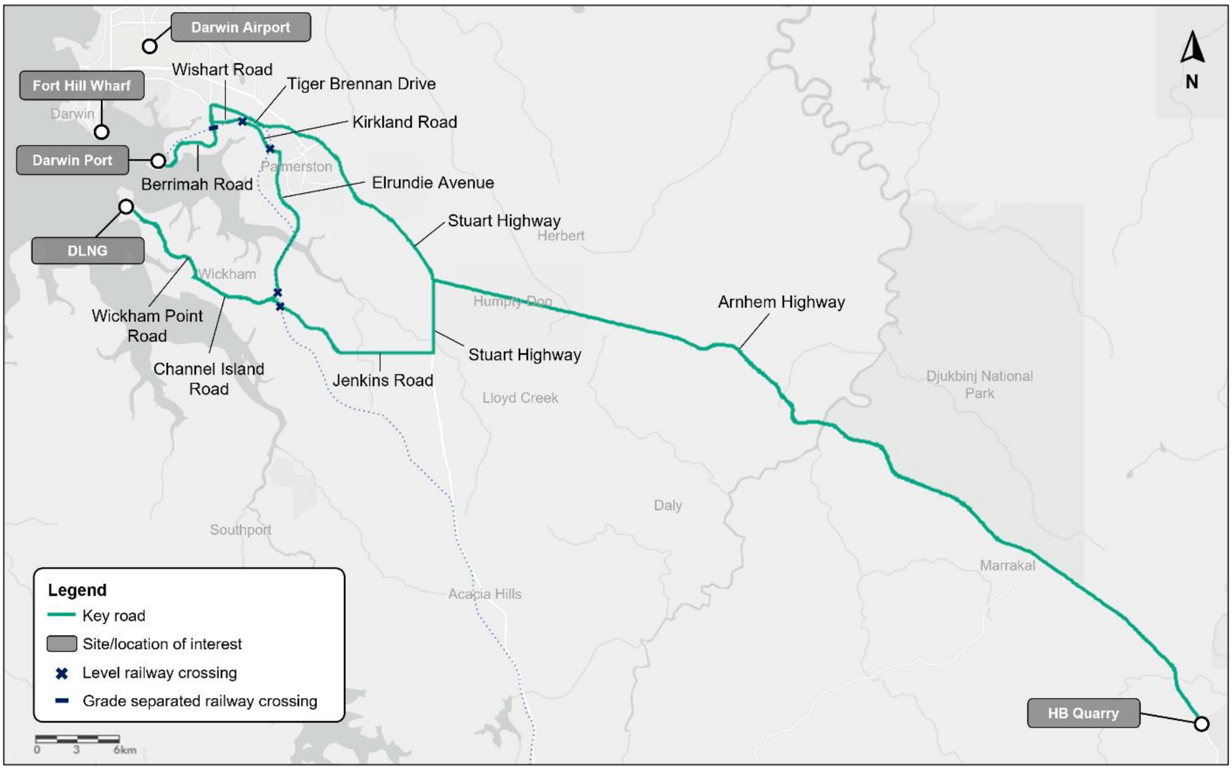

Figure 6-1 Study area

Basemap source: Esri

6.2 Existing road network

6.2.1 Arnhem Highway

The Arnhem Highway is a sealed road extending approximately 230 kilometres in the east-west direction between the outer rural area of Darwin and the Kakadu National Park. The road is classified as a State road and generally comprises a single carriageway with one traffic lane in each direction. The road features relatively narrow sealed shoulders along its entire length. A typical cross section of the Arnhem Highway is shown in Figure 6-2.

The posted speed limit of the Arnhem Highway varies along the proposed haulage route. Between the Stuart Highway and Kennedy Road at Humpty Doo, the road has a posted speed limit of 80 kilometres per hour (km/h). A variable speed limit zone is located adjacent to the Humpty Doo town centre with a speed limit of 60 km/h or 80 km/h typically enforced. Between Edwin Road at Humpty Doo and Anzac Parade at Middle Point, the Arnhem Highway has a posted speed limit of 100 km/h. The posted speed limit increases to 110 km/h east of Anzac Parade.

The western terminus of the Arnhem Highway connects with the Stuart Highway via a signalised intersection located 35 kilometres south-east of Darwin. There are no other signalised intersection treatments located along the Arnhem Highway.

Figure 6-2 Arnhem Highway west of Barr Road, facing east

Image source: Google Street View, December 2021

6.2.2 Stuart Highway

The Stuart Highway (A1) is a sealed major highway extending approximately 2,700 km from Darwin, NT to Port Augusta, South Australia (SA). The road forms part of the National Land Transport Network and functions as the principal north-south route for freight and passenger movements between the NT and SA.

In the study area, the Stuart Highway is a four-lane, two-way dual carriageway road with a grass median. The road reservation east of Yarrawonga Road is typically 50-55 m wide, expanding to provide dedicated right and left turn lanes at signalised intersections. A typical cross section of the Stuart Highway in the vicinity of the study area is shown in Figure 6-3. The road has a posted speed limit of 100 km/h in the study area.

Figure 6-3 Stuart Highway north of Sayer Road, facing north-west
Image source: Google Street View, December 2021

6.2.3 Tiger Brennan Drive

Tiger Brennan Drive (A15) is a major arterial road providing east-west connectivity between Darwin and Palmerston. The road forms part of the National Land Transport Network and generally extends parallel to the Stuart Highway, providing the most direct route for vehicles travelling to and from the port facilities at East Arm. In the study area, Tiger Brennan Drive is a two-lane, two-way dual carriageway road with a grass median. A typical cross section of Tiger Brennan Drive is shown in Figure 6-4.

Posted speed limits on Tiger Brennan Drive vary from 100 km/h in undeveloped and heavy commercial zones, to 60 km/h as the road approaches the Darwin CBD. The majority of major junctions on Tiger Brennan Drive are signalised with some residential streets connected via limited access slip roads. At its eastern end, Tiger Brennan Drive merges onto Stuart Highway via a grade separated interchange with Roystonea Avenue.

Figure 6-4 Tiger Brennan Drive west of Marjorie Street, facing west
Image source: Google Street View, December 2021

6.2.4 Berrimah Road

Berrimah Road is a major arterial road that provides north-south connectivity between the Stuart Highway at Berrimah and the port facilities at East Arm. Between the Stuart Highway and Tiger Brennan Drive, Berrimah Road is a single carriageway road with one lane in each direction. The road is a two-lane, two-way dual carriageway road between Tiger Brennan Drive and Cochrane Road at East Arm. South of Cochrane Road, Berrimah Road continues as a single carriageway road with one lane in each direction. A typical cross section of Berrimah Road is shown in Figure 6-5.

The posted speed limit of the Berrimah Road varies from 70 km/h between the Stuart Highway and Tiger Brennan Drive, to 80 km/h just south of Tiger Brennan Drive and 60 km/h approaching the port facilities at East Arm. A 40 km/h school zone exists near College Road from 7 am until 5 pm on school days.

Figure 6-5 Berrimah Road north of Tiger Brennan Road, facing south

Image source: Google Street View, December 2021

6.2.5 Wishart Road

Wishart Road provides a direct east-west connection from Berrimah Road to Tiger Brennan Drive and Kirkland Road. Wishart Road typically has one lane in each direction with dedicated left and right turn lanes provided at its intersection with Berrimah Road and Tiger Brannan Drive. The posted speed limit of Wishart Road is 80 km/h. A typical cross section of the road in the vicinity of the study area is shown in Figure 6-6.

Figure 6-6 Wishart Road between Tiger Brennan Drive and Kirkland Road, facing west
Image source: Google Street View, December 2021

6.2.6 Kirkland Road

Kirkland Road facilitates east-west travel between Tivendale and Palmerston. The road is generally a single carriageway road with one lane in each direction. The carriageway widens to provide dedicated left and right turns onto Woodlake Boulevard, Bree Street, Toft Road, Fowlestone Road and Syrimi Road. Figure 6-7 shows a typical cross section of Kirkland Road.

At its western end, Kirkland Road becomes a dual carriageway road and connects to Wishart Road via a signalised intersection. At its eastern end, Kirkland Road connects to Elrundie Avenue and University Avenue via a dual lane roundabout. Kirkland Road has a posted speed limit of 100 km/h reducing to 80 km/h at the intersections with Elrundie Avenue and Wishart Road. It has two level crossings for trains on the carriageway that are not grade separated, consequently resulting in some delay to traffic when barriers are activated. These are located at 200 m west of Woodlake Boulevard (Figure 6-8) and 50 m south of Wishart Road (Figure 6-9).

Figure 6-7 Kirkland Road
Image source: Google Street View, December 2021

Figure 6-8 At grade level crossing Kirkland Road facing west, 200 m west of Woodlake Boulevard
Image source: Google Street View, December 2021

Figure 6-9 At grade level crossing Kirkland Road facing north, 50 m south of Wishart Road
Image source: Google Street View, December 2021

6.2.7 Elrundie Avenue

Elrundie Avenue extends south from Kirkland Road and provides access to several residential areas at Driver, Marlow Lagoon, Moulden and Bellamack. At its southern end, Elrundie Avenue continues as Channel Island Road. Elrundie Avenue is a single carriageway road with one lane in each direction. The road has a posted speed limit of 80 km/h. A typical cross section of Elrundie Avenue is shown in Figure 6-10.

Figure 6-10 Elrundie Avenue south of Kirkland Road, facing north
Image source: Google Street View, December 2021

6.2.8 Jenkins Road

Jenkins Road extends in the east-west direction between the Stuart Highway and Channel Island Road. The road connects to the Stuart Highway via a signalised intersection and Channel Island Road via a priority ('Stop') controlled T-intersection. Jenkins Road is a single carriageway road with one lane in each direction. A typical cross section of Jenkins Road is shown in Figure 6-11.

Jenkins Road has a posted speed limit of 100 km/h. A level railway crossing is located on the road approximately 600 m east of its intersection with Channel Island Road (Figure 6-12).

Figure 6-11 Jenkins Road west of the Stuart Highway, facing west
Image source: Google Street View, December 2021

Figure 6-12 At grade level crossing Jenkins Road facing west, 600 m east of Channel Island Road
Image source: Google Street View, December 2021

6.2.9 Channel Island Road

Channel Island Road provides access to several industrial facilities at Wickham including the Weddell Power Station and Channel Island Power Station. The road extends south from Elrundie Avenue over

Elizabeth River before heading in the western direction to Channel Island where it terminates. Channel Island Road is a single carriageway road with one lane in each direction.

The road has a posted speed limit of 80 km/h. A typical cross section of Channel Island Road is shown in Figure 6-13. A level railway crossing is located on the road approximately 400 m north east of its intersection with Jenkins Road (Figure 6-14).

Figure 6-13 Channel Island Road south of Elizabeth River, facing south
Image source: Google Street View, December 2021

Figure 6-14 At grade level crossing Channel Island Road facing north, 400 m north east of Jenkins Road
Image source: Google Street View, December 2021

6.2.10 Wickham Point Road

Wickham Point Road extends in the northern direction from Channel Island Road and provides access to the DLNG facility and Ichthys Liquefied Natural Gas Plant. The road connects to Channel Island

Road via a channelised T-intersection. Wickham Point Road is a single carriageway road with one lane in each direction. The road has a posted speed limit of 80 km/h. A typical cross section of Wickham Point Road is shown in Figure 6-15.

Figure 6-15 Wickham Point Road north of Channel Island Road, facing north

Image source: Google Street View, May 2008

6.2.11 Heavy vehicle networks

The approved roads for 53.5 m Road Train vehicles are shown in Figure 6-16 and include the Arnhem Highway, Stuart Highway, Tiger Brennan Drive, Berrimah Road, Kirkland Road, Elrundie Avenue, Jenkins Road, Channel Island Road and Wickham Point Road (Northern Territory Govenment, 2011).

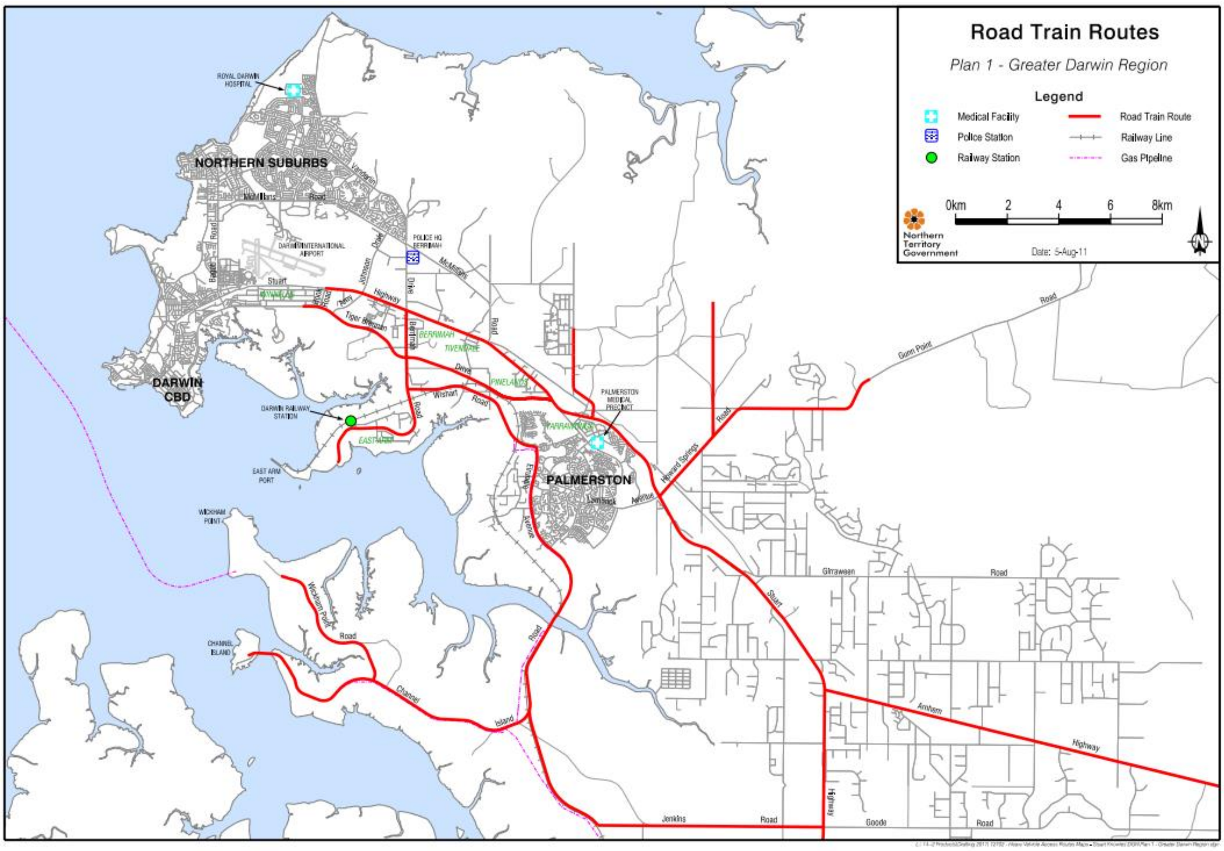

Figure 6-16 Approved roads for 53.5 m Road Train vehicles in the vicinity of the study area
Image source: Northern Territory Government, 2011

6.3 Existing traffic volumes

Traffic count data was extracted from DIPL's Annual Traffic Report for key roads within the study area (DIPL and Territory Traffic Surveys, 2021). A summary of the count stations is provided in Table 6-1 and the location of each count stations is shown in Figure 6-17.

Table 6-1 Traffic count stations on key roads in the study area

Road	Station ID	Location of station
Arnhem Highway	UDVDP019	500 m east of Stuart Highway
	RDVDP007	2 km west of Adelaide River Bridge
Berrimah Road	UDVDP028	400 m south of Tiger Brennan Drive
	UDVDP029	350 m west of Casey Street
Channel Island Road	UDVDC072	South of Elizabeth River Bridge
Elrundie Avenue	UDVDC062	100 m North of Chung Wah Terrace
Kirkland Road	UDVDP085	500 m west of West of Wishart Road
Stuart Highway	UDVDP017	500 m west of Howard Springs Road
	UDVDP020	500 m north of Arnhem Highway
	UDVDP034	500 m south of Bees Creek Road
Tiger Brennan Drive	UDVDP022	800 m west of Berrimah Road

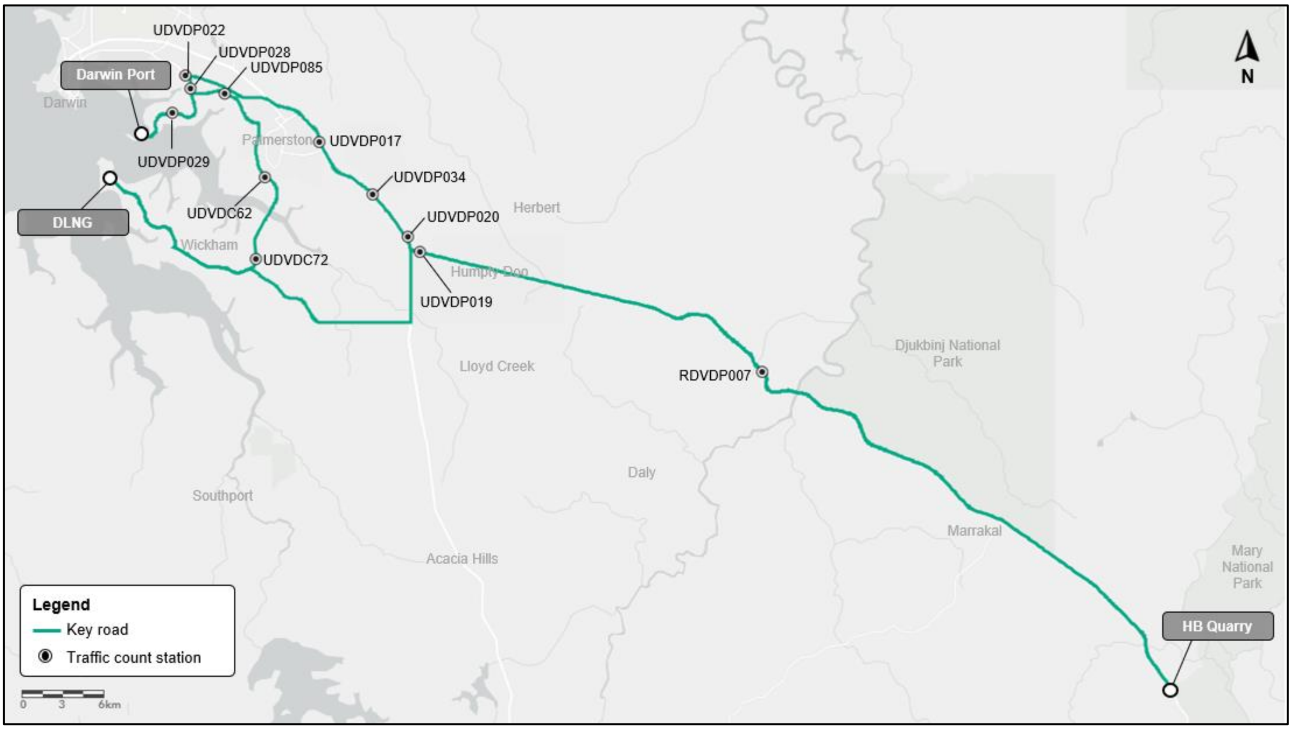

Figure 6-17 Locations of traffic count stations in the study area

Basemap source: Esri

A summary of the Annual Average Daily Traffic (AADT) volumes over the past five-year period (2017-2021) is shown in Table 6-2. The Stuart Highway experiences the highest traffic volumes in the study area, with an average of 27,790 vehicles travelling on the road each day west of Howard Springs Road. West of Berrimah Road, approximately 20,880 vehicles travelled Tiger Brennan Drive on an average day.

Traffic volumes on the Arnhem Highway typically range between 1,400 and 7,700 vehicles per day. The western end of Arnhem Highway experiences the highest volume of traffic due to a high proportion of vehicles entering and exiting the road from the surrounding residential land uses at Humpty Doo. Approximately 7,330 vehicles travel along Berrimah Road each day near Tiger Brennan Drive. Towards the port facilities at East Arm, traffic volumes on Berrimah Road reduce to 1,180 vehicles per day. Traffic volumes on Channel Island Road are relatively low with an average of 1,670 vehicles using the road each day.

Table 6-2 AADT volumes by year (2017-2021)

Road	Station ID	Station location	Direction of travel	Year				
				2017	2018	2019	2020	2021
Arnhem Highway	UDVDP019	500 m east of Stuart Highway	Inbound	3773	3703	3487	3465	3891
			Outbound	3732	3641	3442	3392	3829
			Both	7505	7344	6929	6857	7720
	RDVDP007	2 km west of Adelaide River Bridge	Inbound	629	599	588	567	693
			Outbound	657	621	613	559	704
			Both	1286	1220	1201	1126	1397
Berrimah Road	UDVDP029	350 m west of Casey Street	Inbound	609	677	606	514	576
			Outbound	630	696	623	533	602
			Both	1239	1373	1229	1047	1178
	UDVDP028	400 m south of Tiger Brennan Drive	Inbound	4784	4663	4291	4139	4201
			Outbound	3670	3729	3460	3117	3124
			Both	8454	8392	7751	7256	7325
Channel Island Road	UDVDC072	South of Elizabeth River Bridge	Inbound	1520	1821	950	741	829
			Outbound	1535	1810	944	737	842
			Both	3055	3631	1894	1478	1671
Elrundie Avenue	UDVDC062	100 m north of Chung Wah Terrace	Inbound	2835	2889	2670	2576	2980
			Outbound	2765	2734	2520	2428	2857
			Both	5600	5623	5190	5004	5837
Kirkland Avenue	UDVDP085	500 m west of Wishart Road	Inbound	6134	5898	5757	5668	5798
			Outbound	5806	5543	5449	5281	5481
			Both	11940	11441	11206	10949	11279
Stuart Highway	UDVDP017	500 m west of Howard Springs Road	Inbound	13666	13523	12765	12265	14101
			Outbound	13350	13158	12331	12209	13688
			Both	27016	26681	25096	24474	27789
	UDVDP020	500 m north of Arnhem Highway	Inbound	5875	5853	5595	5431	7051
			Outbound	6525	6431	6119	5940	7630
			Both	12400	12284	11714	11371	14681
	UDVDP034	500 m south of Bees Creek Road	Inbound	No data available	6666	6460	6023	6916
			Outbound		6850	6431	6229	6881
			Both		13516	12891	12252	13797
Tiger Brennan Drive	UDVDP022	800 m west of Berrimah Road	Inbound	10335	10490	10295	9868	10794
			Outbound	9134	9390	9581	8965	10087
			Both	19469	19880	19876	18833	20881

Data source: DIPL and Territory Traffic Surveys, 2021

Monthly average daily traffic volumes are shown in Figure 6-18 to Figure 6-22. Traffic volumes in the study area generally peak during the month of September. Reduced traffic volumes are observed during the wet season (November to April).

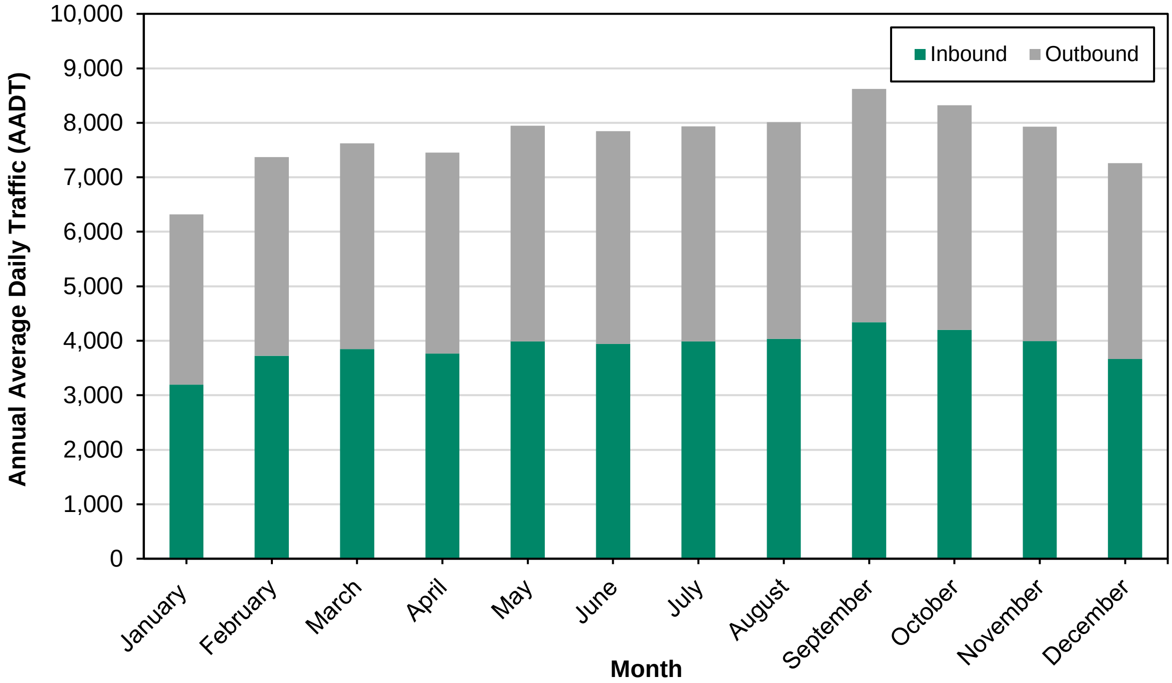

Figure 6-18 Traffic volumes on Arnhem Highway east of Stuart Highway (Station UDVDP019) by month of year

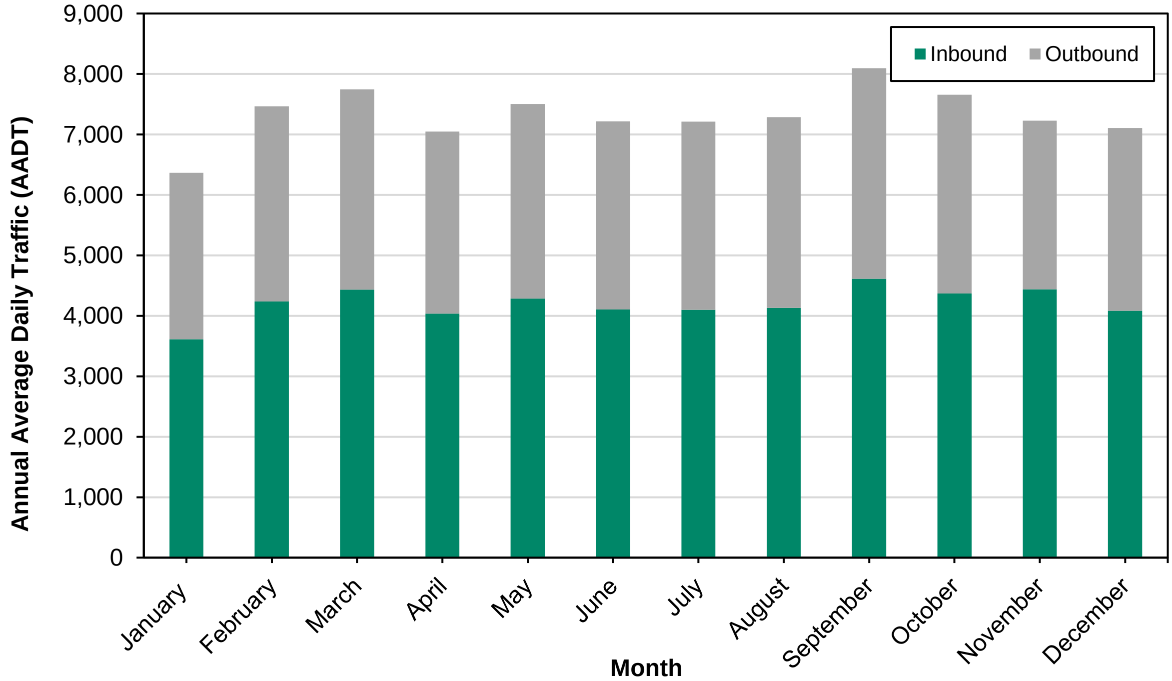

Figure 6-19 Traffic volumes on Berrimah Road south of Tiger Brennan Road (Station UDVDP028) by month of year

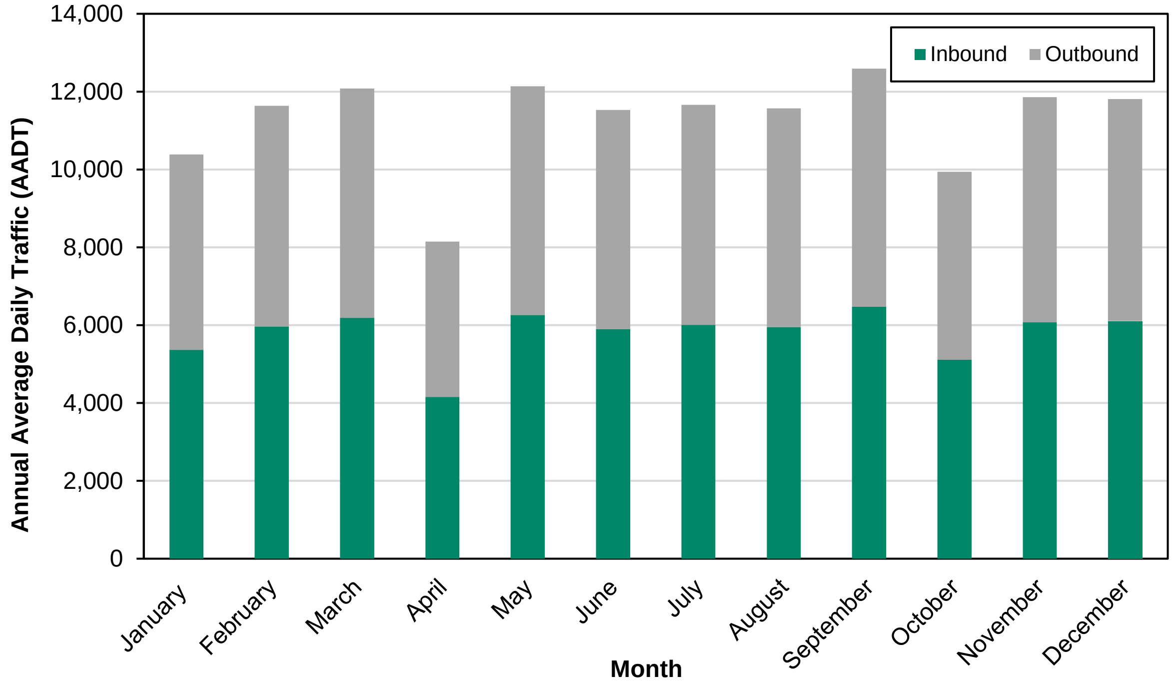

Figure 6-20 Traffic volumes on Kirkland Avenue (Station UDVDP085) by month of year

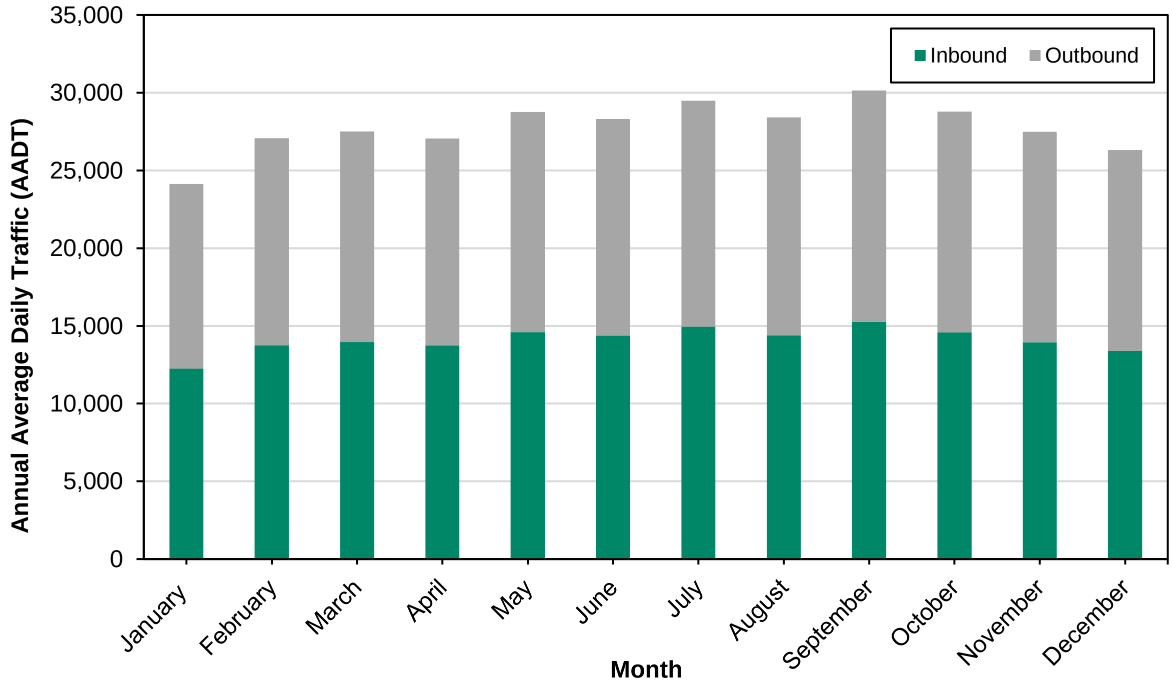

Figure 6-21 Traffic volumes on Stuart Highway (Station UDVDP017) by month of year

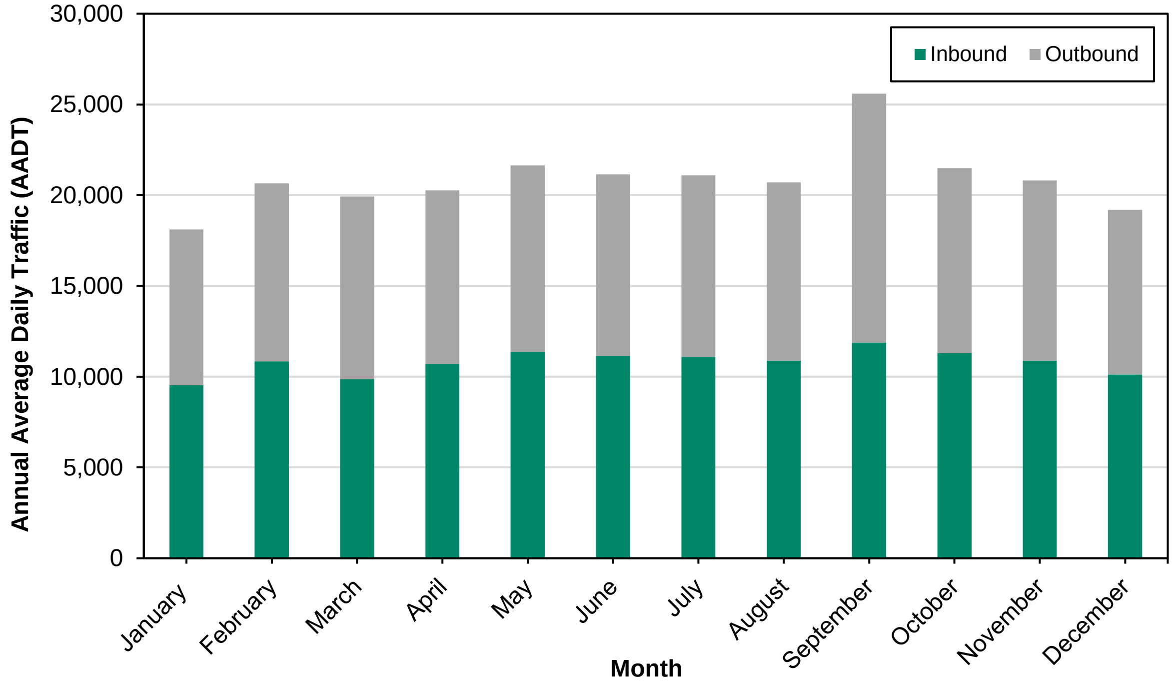

Figure 6-22 Traffic volumes on Tiger Brennan Drive (Station UDVDP022) by month of year

Table 6-3 shows a breakdown of traffic volumes by vehicle classification. Light vehicles (≤3 axles) account for the majority traffic on the local road network. Heavy vehicles (>3 axles) account for 3.6% of traffic volumes on the Arnhem Highway near the Stuart Highway and 11.6% of traffic volumes west of the Adelaide River Bridge.

Berrimah Road forms part of the National Land Transport Network, and as such, experiences a relatively high proportion of heavy vehicles (8.3% to 27.4%). The proportion of heavy vehicles increases on Berrimah Road west of Casey Street upon the approach to the port. It should be noted that while Tiger Brennan Drive also forms part of the National Land Transport Network, a low proportion of heavy vehicles is reflected in Table 6-3 as the count station is located to the west of Berrimah Road (where vehicles divert to access the port and rail facilities at East Arm).

Table 6-3 Traffic volume composition by vehicle classification

Road	Station ID	Station location	Direction of travel	Composition of traffic volume (%)		
				Light vehicles (≤3 axles)	Heavy vehicles (3 - 6 axles)	Long vehicles (>6 axles)
Arnhem Highway	UDVDP019	500 m east of Stuart Highway	Inbound	96.5	1.6	2.0
			Outbound	96.4	1.6	2.1
			Both	96.4	1.6	2.0
	RDVDP007	2 km west of Adelaide River Bridge	Inbound	87.8	3.2	9.0
			Outbound	89.0	2.6	8.4
			Both	88.4	2.9	8.7
Berrimah Road	UDVDP029	350 m west of Casey Street	Inbound	71.1	6.8	22.1
			Outbound	74.0	6.1	19.9
			Both	72.6	6.4	21.0
	UDVDP028	400 m south of Tiger Brennan Drive	Inbound	92.1	3.2	4.7
			Outbound	91.1	3.6	5.3
			Both	91.7	3.4	4.9

Road	Station ID	Station location	Direction of travel	Composition of traffic volume (%)		
				Light vehicles (≤3 axles)	Heavy vehicles (3 - 6 axles)	Long vehicles (>6 axles)
Stuart Highway	UDVDP017	500 m west of Howard Springs Road	Inbound	Data not available		
			Outbound			
			Both			
	UDVDP020	500 m north of Arnhem Highway	Inbound			
			Outbound			
			Both			
	UDVDP034	500 m south of Bees Creek Road	Inbound	96.3	1.5	2.1
			Outbound	96.6	1.4	1.9
			Both	96.5	1.5	2.0
Tiger Brennan Drive	UDVDP022	800 m west of Berrimah Road	Inbound	99.9	0.1	0.0
			Outbound	99.9	0.1	0.0
			Both	99.9	0.1	0.0
Channel Island Road	UDVDC072	South of Elizabeth River Bridge	Inbound	97.2	2.0	0.9
			Outbound	97.5	1.7	0.8
			Both	97.3	1.8	0.8
Elrundie Avenue	UDVDC062	100 m north of Chung Wah Terrace	Inbound	96.8	2.2	1.0
			Outbound	97.1	2.0	0.9
			Both	96.9	2.1	1.0
Kirkland Avenue	UDVDP085	500 m west of Wishart Road	Inbound	97.9	1.3	0.9
			Outbound	98.0	1.1	0.9
			Both	98.0	1.2	0.9

Data source: DIPL and Territory Traffic Surveys, 2021

6.4 Critical intersections

This section describes the intersections that are expected to be impacted most by additional traffic volumes generated by the Project. The key intersections include:

A. Quarry Access Road / Arnhem Highway

B. Arnhem Highway / Stuart Highway

C. Stuart Highway / Henning Road / Girraween Road

D. Stuart Highway / Lambrick Avenue / Howard Springs Road

E. Stuart Highway / Temple Terrace / Glyde Point Road

F. Tiger Brennan Drive / Wishart Road / Tivendale Road

G. Tiger Brennan Drive / Berrimah Road

H. Berrimah Road / Wishart Road

I. Stuart Highway / Jenkins Road

J. Stuart Highway / Channel Island Road

K. Channel Island Road / Wickham Point Road.

The layout of each intersection is shown in Figure 6-23.

A) Quarry Access Road / Arnhem Highway
(uncontrolled intersection)

B) Stuart Highway / Arnhem Highway
(signalised intersection)

C) Stuart Highway / Henning Road
(signalised intersection)

D) Stuart Highway / Lambrick Avenue
(signalised intersection)

E) Stuart Highway / Temple Terrace
(signalised intersection)

F) Tiger Brennan Drive / Wishart Road
(signalised intersection)

G) Tiger Brennan Drive / Berrimah Road
(signalised intersection)

H) Berrimah Road / Wishart Road
(signalised intersection)

I) Stuart Highway / Jenkins Road
(signalised intersection)

Figure 6-23: Key intersections in the study area
Basemap source: Google Maps

6.5 Existing sustainable modes of transport

6.5.1 Pedestrians and cyclists

The active transport network surrounding the Project site is shown in Figure 6-24 and includes the following infrastructure for pedestrians and cyclists:

- An on-road bicycle lane on the eastern side of Berrimah Road between Marlow Road and Wishart Road
- A shared footpath on the southern side of Tiger Brennan Drive between Berrimah Road and the Darwin CBD
- A shared footpath on the northern side of the Stuart Highway between Coolalinga and the Darwin CBD
- A shared footpath on the southern side of the Arnhem Highway near Humpty Doo
- A shared footpath along the western side of Berrimah Road between Marlow Road the Stuart Highway.

Figure 6-24 Active transport network

Basemap source: Esri

6.5.2 Public transport

Seven regular public bus routes operate on roads forming part of the site access routes. These routes are operated by CDC Northern Territory and generally facilitate travel between Darwin, Palmerston and Humpty Doo, as shown in Figure 6-25. The frequencies of weekday bus services are shown in Table 6-4. Approximately 55 bus services travel along the proposed haulage routes on an average weekday (Northern Territory Government, 2022).

There are no existing or proposed public bus services within 400 m of the Project site at the DLNG facility or the intermediate stockpile site at Darwin Port, a distance that best represents the walkable catchment for access to bus stops.

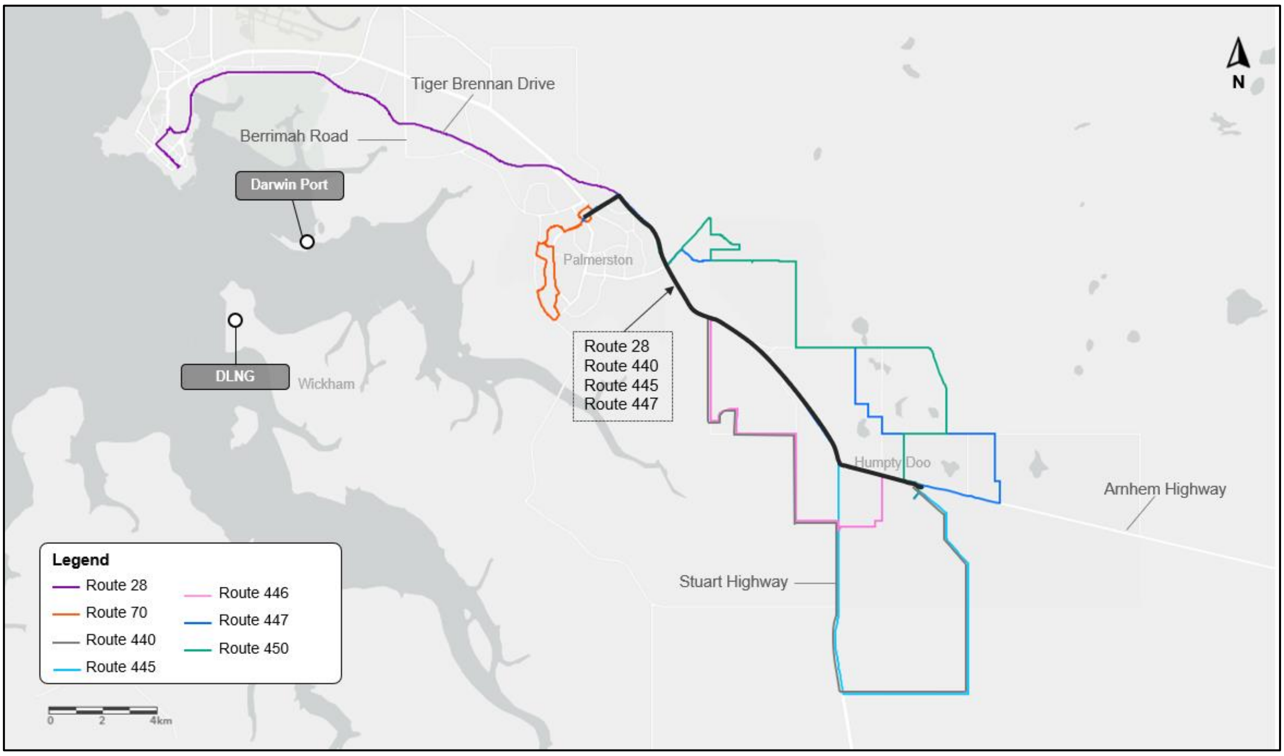

Figure 6-25 Public bus routes in the study area

Basemap source: Esri

Table 6-4 Public bus routes that travel along the proposed site access routes

Bus route	Direction	Number of weekday services	
		AM	PM
28	Humpty Doo Park and Ride to Darwin via Coolalinga Park and Ride and Palmerston	3	0
	Darwin to Humpty Doo Park and Ride via Palmerston and Coolalinga Park and Ride	0	3
70	Palmerston to Palmerston via Driver and Moulden	10	18
440	Humpty Doo Park and Ride to Humpty Doo Park and Ride via Coolalinga Park and Ride, Virginia, Noonamah and Palmerston	1	1
445	Humpty Doo Park and Ride to Palmerston via Cox Peninsula, Noonamah and Coolalinga Park and Ride	2	0
	Palmerston to Humpty Doo Park and Ride via Coolalinga Park and Ride, Noonamah and Cox Peninsula Road	0	3
446	Bees Creek to Palmerston	2	
	Palmerston to Bees Creek		3
447	Humpty Doo Park and Ride to Palmerston via McMinns Lagoon and Howard Springs	2	1
	Palmerston to Humpty Doo Park and Ride 447 via Howard Springs and McMinns Lagoon	0	4

Bus route	Direction	Number of weekday services	
		AM	PM
450	Humpty Doo Park and Ride to Palmerston via Girraween and Howard Springs	1	0
	Palmerston to Humpty Doo Park and Ride via Howard Springs and Girraween	0	1
	Total	**21**	**34**

Source: Northern Territory Government, 2022

The Adelaide-Darwin railway alignment is located approximately 750 m north-west of the intermediate stockpile site at Darwin Port. This transcontinental railway line serves both passenger and freight traffic and extends in the north-south direction between Adelaide and Darwin via Alice Springs.

The Ghan is a passenger service operated by the Great Southern. Two passenger services are provided per week from June until September and one service is provided per week during all other months. The Ghan passenger service originate / terminates at the Darwin Train Station located on Saloo Street, East Arm. Aurizon (formerly One Rail Australia) provides six weekly freight services between Adelaide and Darwin (Aurizon, 2022). A number of additional bulk trains operate on the line between various mine sites and the Port of Darwin.

The Adelaide-Darwin railway line is grade separated from Berrimah Road at East Arm. However, two level railway crossings are located on Kirkland Road and one is located on Channel Island Road.

6.6 Crash history

A review of historical crash data was undertaken to provide an assessment of crash statistics and trends associated with key roads in the study area. A summary of the results is provided in Table 6-5. It should be noted that the results include crashes recorded on the entire length of the carriageway and therefore some crashes may have occurred outside of the study area.

In the five-year period from 2015 to 2019, a total of 135 crashes were recorded on the Stuart Highway. 19 of these crashes occurred at the intersection of the Stuart Highway and Howard Springs Road and 13 occurred at the intersection of the Stuart Highway and Lambrick Avenue. Several road improvements works are proposed for the Stuart Highway corridor, including the road safety upgrades at Coolalinga and intersection works at Howard Springs Road and Lambrick Avenue.

Tiger Brennan Drive recorded a total of 91 crashes over the five-year period resulting in a total of five fatalities. Seven crashes occurred intersection of Tiger Brennan Drive and Berrimah Road. A grade-separated overpass is proposed to be constructed at the Tiger Brennan Driver and Berrimah Road. The overpass will enable the continuous flow of traffic along Tiger Brennan Drive and separate major traffic flows, reducing the crash risk at the intersection.

Berrimah Road recorded a total of 19 accidents of which one was fatal. Five of accidents occurred at the Wishart intersection and seven occurred at the Tiger Brennan Drive intersection. Much of the network has undergone upgrades since these incidents occurred, particularly at key, high profile intersections such as Stuart Highway / Howard Springs Road and intersections on Wishart Road.

Table 6-5 Crash history (2015-2019)

Road	Total accidents	Intersection	Total persons	
			Fatal	Admitted to hospital
Berrimah Road	19	Wishart Road – 5	1	2
		Tiger Brennan Drive – 7		
Kirkland Road	36	Elrundie Avenue – 2	0	9

Road	Total accidents	Intersection	Total persons	
			Fatal	Admitted to hospital
		Wishart Road – 6		
		University Avenue – 2		
Stuart Highway	135	Howard Springs Road – 19	1	33
		Roystonea Avenue – 4		
		Lambrick Avenue – 13		
		Tiger Brennan Drive – 1		
Tiger Brennan Drive	91	Tivendale Drive – 17	5	23
		Wishart Road – 6		
Wishart Road	18	Berrimah Road – 2	0	4
		Kirkland Road – 5		
		Tiger Brennan Drive – 4		

Source: Darwin Ship Lift Traffic Impact Assessment, 2021

7.0 Project Description

7.1 Construction

7.1.1 Construction schedule

While construction activities may begin in Q3, subject to regulatory approvals, for the purposes of the TIA an indicative construction schedule commencing in Quarter 4 of 2023 has been used which extends over a duration of approximately 12 months. This indicative construction schedule is shown in Figure 7-1, noting the precise timing and duration of construction activities will be subject to the Project design refinement and construction requirements.

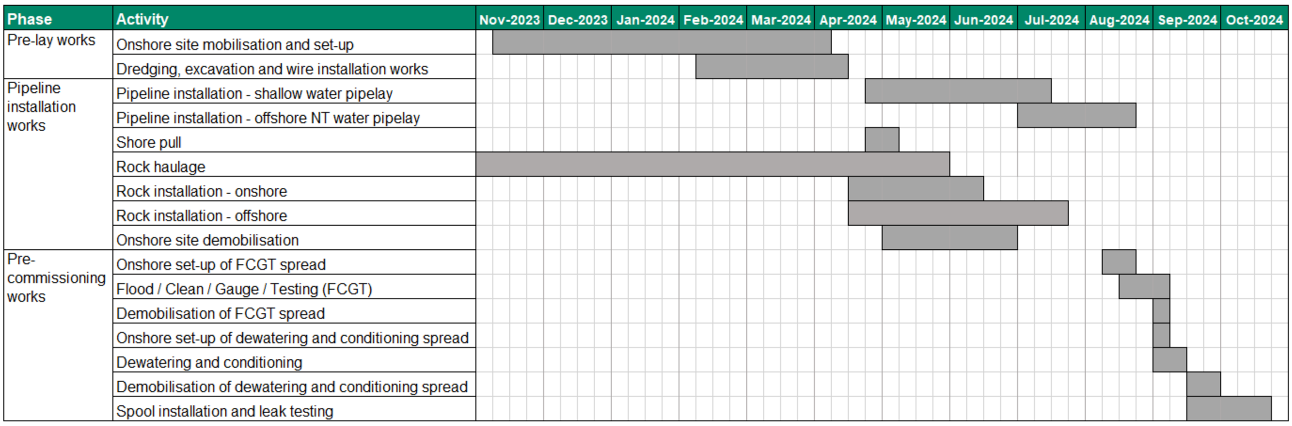

Figure 7-1 Indicative construction schedule

7.1.2 Construction hours

To enable the construction of the Project to be completed within the proposed timeline, construction activities are proposed to be undertaken on a 24-hour day and seven days per week basis. The current planning is two 12-hour shifts each day, commencing at 6:00 am and 6:00 pm.

7.1.3 Overview of construction traffic generating activities

7.1.3.1 Pre-lay works

Mobilisation at shore crossing

The onshore crossing site is located within the existing DLNG disturbance envelop at Wickham Point. This site would support the shore pull scope of works and would be used for the flood, clean, gauge, testing (FCGT) scope once the Project pipeline has been fully installed.

Mobilisation at the shore crossing would involve the following activities:

- Vegetation regrowth clearing
- Civil works and grading of the onshore shore pull site location, construction of a levelled lay-down area for the winch foundation
- Import of clean fill
- Preparation of lay down areas, access roads, hardstand (geotextile and road base) and site fencing
- Installation of the winch spread, including winch pad, holdback anchor and/or sheet piling
- Installation of bedding rock and or rollers for the shore pull
- Installation of facilities including offices, amenities, chemical and fuel storage, ASS storage and treatment.

Dredging and excavation

In shallower waters, some sections of the Project pipeline will require stabilisation due to exposure to waves, currents and tidal movement, and impact protection from third-party activities (i.e. anchors). As such, some sections of the Project pipeline will be installed in a trench in the seafloor to protect it from such instabilities and activities. Trenching will be required in both the Darwin Harbour (i.e. nearshore) and shore crossing locations.

Dredging vessels will be used to perform trenching within Darwin Harbour. Excavators would be used from onshore to dig the trench through the shore crossing at the DLNG facility. To support this, some temporary shoreline modifications may be required, including the construction of a cofferdam using sheet piling to help retain trench walls and a temporary groyne so the excavators can operate further from the current shoreline. The temporary groyne would be built with imported rock and fill and pushed out with the tide.

7.1.3.2 Pipeline installation

Shallow water and deep-water pipelay

The Project pipeline will be laid using a continuous assembly pipe-welding installation method, which involves the assembly of the single pipe joins (approximately 12 m in length) in a horizontal working plane onboard the pipelay vessel. The Project pipeline is proposed to be sequentially laid, beginning at the shore crossing and moving through Darwin Harbour. Shallow water pipelay, including waters of Darwin Harbour, will be performed using a shallow water pipelay barge. A deepwater pipelay vessel will be used in deeper water outside of Darwin Harbour. Some shallow water and deep-water pipelay may occur concurrently.

Pipeline shore pull

The Project pipeline will be pulled ashore from the pipelay vessel using a conventional winch operation. The arrangement for the shore pull consists of a winch spread installed on a winch pad and attached to a hold back anchor located onshore. The pulling arrangement will allow for the shore pull to be completed as a continuous operation, which may take approximately two weeks.

Trench backfill

The primary method of maintaining pipeline stability on the seabed will be through the concrete weighted pipeline coating. It will also be necessary to install localised secondary stabilisation/protection for sections within Darwin Harbour where the concrete weighted coating alone is not considered sufficient to provide stability and/or protection. Backfilling will be required at trench locations in Darwin Harbour and shore crossing to maintain pipeline stability and protection.

Rock is proposed to provide pipe stabilisation and protection. Rock placement works would likely occur via fallpipe vessel or side dump vessel; self-propelled dynamically-positioned vessels that are used to install rock the seabed with support barges used to transport rock. Backhoe dredges shall also be used to install rock in shallow water at the shore crossing with the rock being bought alongside the Backhoe dredges on barges.

The rock material is proposed to be sourced onshore from the HB Quarry at Mount Bundey and would be delivered via the road network to an intermediate stockpile located at Port Darwin (East Arm Wharf). The rock material would be internally transferred from the intermediate stockpile to quayside by means of trucks. Approximately two or three cranes would place the rock onto the vessel for rock placement activities.

A smaller proportion of rock material would be transported via the road network to the DLNG site for rock installation works at the shore crossing.

7.1.3.3 Pre-commissioning

Flood / Clean / Gauge / Testing (FCGT) and dewatering

Once installed, the Project pipeline internal surfaces need to be cleaned, tested and preserved in preparation to carry hydrocarbons. This is conducted through pigging. A series of pigs (inspection gauge used to manage liquid accumulation) will be pushed through the pipeline to clean the pipeline, gauge the pipeline and ensure all air is removed during the flooding process. Pig launcher/receivers

(PLRs) will be installed on the pipeline end termination point in Commonwealth waters and at the shore crossing.

7.1.3.4 Demobilisation at shore crossing

Following the completion of shoreline construction activities (i.e. shore pull and winch spread) and pre-commissioning activities, the pipeline will be backfilled with the remaining 20-30 m (at the DLNG end) left in the ground unburied for a period of time ready for plant tie-in. Following these works the pipeline trench will be completely backfilled, and the site returned to an agreed condition.

7.2 Operation

Operation of the Project is anticipated to commence in the first half of 2025. The activities associated with the operations phase include:

- Commissioning and transport of dry hydrocarbons through the pipeline
- Inspection, maintenance and repair (IMR) of the installed infrastructure.

Operations and maintenance of the Project pipeline is expected to follow the same, or very similar management procedures currently used by Santos to operate and manage the Bayu-Undan to Darwin pipeline. Routine planned vessel-based IMR activities are expected to occur on a scale of year/s between surveys. Therefore vessel-based activities during operations will be far lesser than for construction.

7.3 Decommissioning

The Project field life is expected to be approximately 25 years. At the end of the Project, the Project pipeline and associated facilities would be decommissioned in accordance with regulatory requirements at that time.

7.4 Site access

7.4.1 DLNG site

The DLNG site at Wickham Point would be accessed from Wickham Point Road. Access to the DLNG site would be required for the construction, operation and decommissioning phases of the Project. Normal pipeline operations will not require additional personnel over and above normal staffing of the DLNG facility.

Travel between the DLNG site and major centres located to the north of the Project, including Darwin and Palmerston, would be via Wickham Point Road, Channel Island Road and Elrundie Avenue. The delivery of rock materials to the DLNG site from the HB Quarry would occur via Wickham Point Road, Channel Island Road, Jenkins Road, Stuart Highway and Arnhem Highway. This haulage route is further discussed in Section 8.1.

7.4.2 Darwin Port

Darwin Port would be accessed via a secure gated entrance on Berrimah Road. Access to Darwin Port would be required during the construction phase of the Project for the delivery of rock materials to the intermediate stockpile. The proposed haulage route between the HB Quarry and Darwin Port is detailed in Section 8.1.

8.0 Heavy vehicle route assessment

8.1 Rock haulage route

The proposed transportation route of rock materials from the supplier, HB Quarry at Mount Bundey, to the stockpile area in Darwin Port at East Arm and DLNG facility at Wickham is have been reviewed for this TIA. Two routes are explored as below:

- **To DLNG** – Approximately 102 km from HB Quarry, estimated one-way trip – 1 hr 7 minutes.
- **To Darwin Port** – Approximately 98 km from HB Quarry, estimated one-way trip – 1 hr 11 minutes.

8.1.1 Darwin Port

The majority of rocks will be transported to the intermediate stockpile area at Darwin Port to provide pipe stabilisation and protection.

This haulage route will begin at HB Quarry and trucks will travel westbound on Arnhem Highway to reach the signalised intersection with Stuart Highway in Humpty Doo. The route will continue northbound via a dedicated right turn to stay on Stuart Highway and eventually merging with Tiger Brennan Drive (grade separated). Upon reaching the signalised interchange with Wishart Road, trucks will turn left, then make another left at Berrimah Road before reaching Darwin Port at the end of the road. It is expected that the same route will be taken in reverse for outbound trips.

This journey provides a direct and efficient route to Darwin Port. Additionally, these roads and intersections currently provide access for heavy vehicles meaning there are no additional provisions required and no concerns regarding turning movements.

The route will bypass the following intersections:

- Arnhem Highway / Stuart Highway
- Tiger Brennan Drive / Berrimah Road
- Berrimah Road / Wishart Road

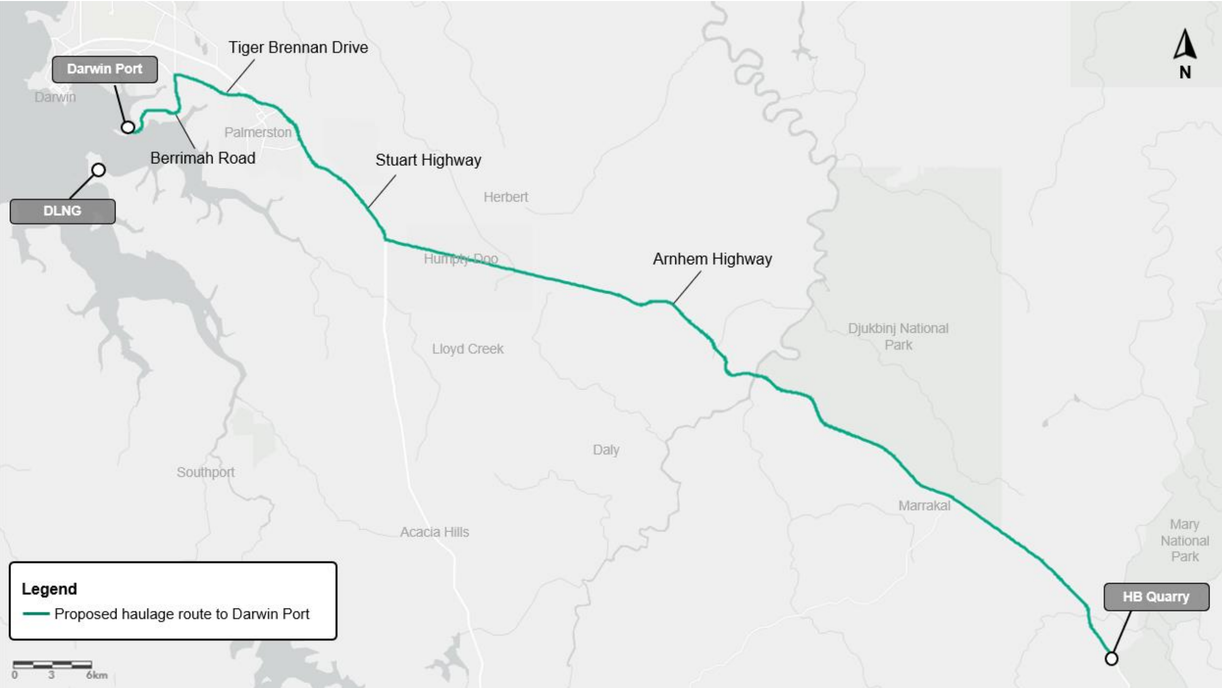

Figure 8-1: Proposed haulage route to Darwin Port

Source: Google Maps © 2022

8.1.2 DLNG

A small proportion of rock materials would be transported via the road network to the DLNG site for rock installation works at the shore crossing.

The haulage route to DLNG will begin at HB Quarry and take the same route as Darwin Port until the intersection of Arnhem Highway and Stuart Highway in Humpty Doo. Trucks will turn at the priority controlled left turn leg and continue on Stuart Highway then turn right at the Jenkins Road and Stuart Highway signalised intersection. At the end of Jenkins Road, the route will continue by taking a left onto Channel Island Road and then a right at Wickham Point Road intersection where the DLNG will be found at the end of the road. It is expected that the same route will be taken in reverse for outbound trips.

This haulage route provides the most direct and efficient route to DLNG. It uses roads and intersections which currently provide access for heavy vehicles meaning there are no additional provisions required and no concerns regarding turning movements.

The route will bypass the following intersections:

- Arnhem Highway / Stuart Highway
- Stuart Highway / Jenkins Road
- Jenkins Road / Channel Island Road
- Channel Island Road / Wickham Point Road

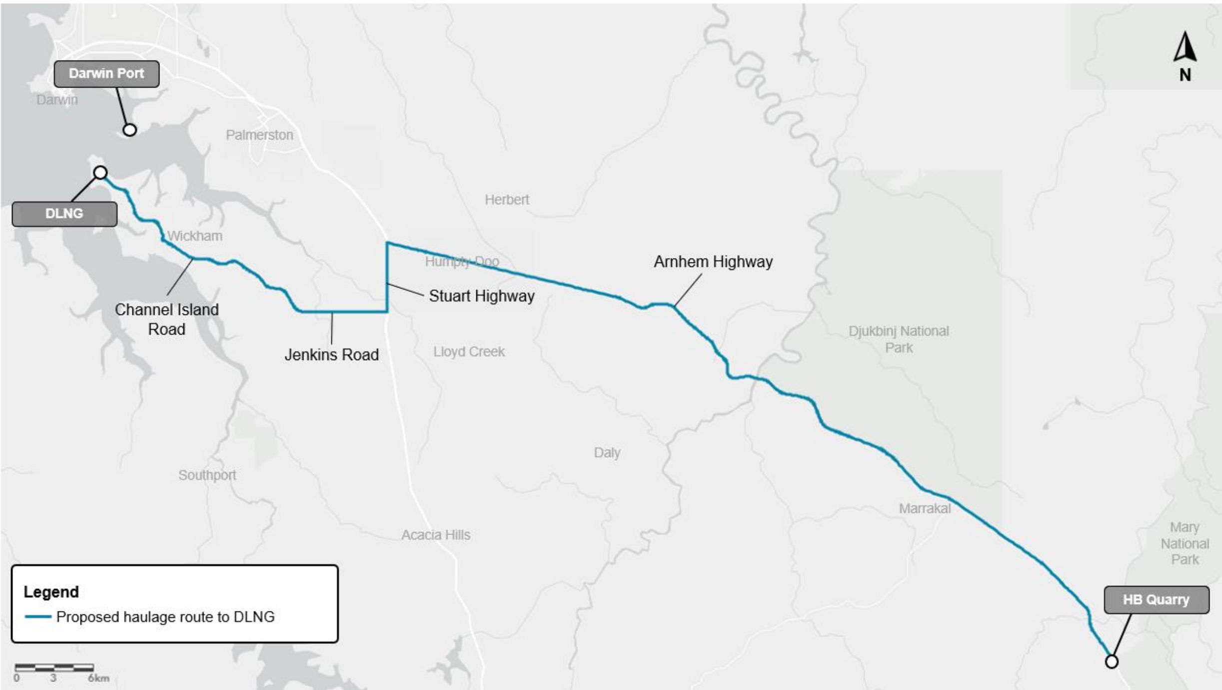

Figure 8-2: Proposed haulage route to DLNG

Source: Google Maps © 2022

8.2 Other haulage routes

General construction equipment (e.g. earth moving machinery and cranes) would likely be sourced from the greater Darwin region. As there may be multiple locations of suppliers, the exact haulage route will need to be planned prior to transportation by the relevant contractor. The routes must follow the road train route outline in Figure 8-3. In general, the Greater Darwin region is within 20 minute drive from the Darwin Port and accessible to many road train approved roads.

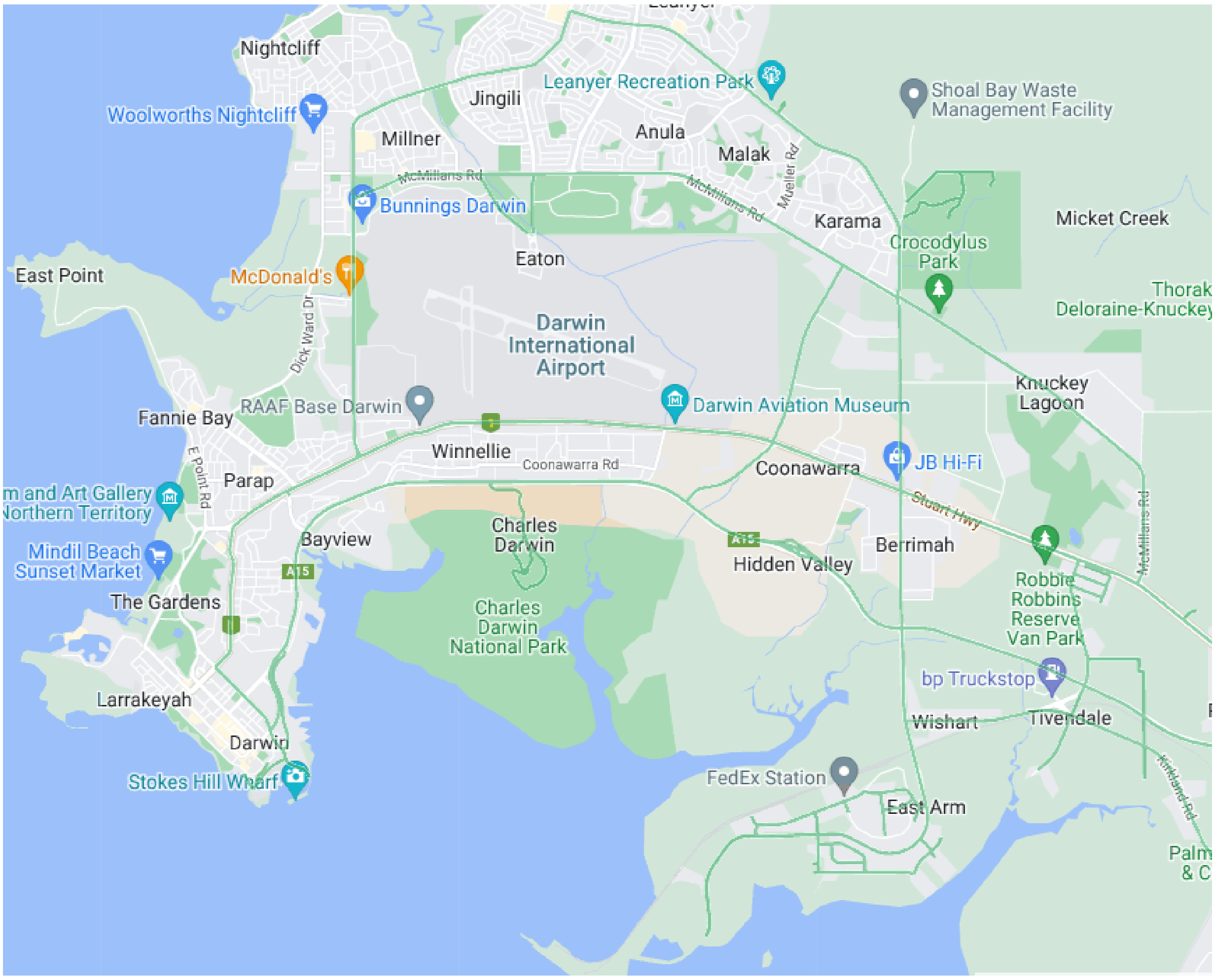

Figure 8-3: Road Train 53.5m approved networks in Greater Darwin

9.0 Traffic Generation

9.1 Construction phase

The traffic generating activities associated with the construction of the Project include the transportation of staff, haulage of rock and delivery of equipment and materials to Darwin Port, the DLNG site and Fort Hill Wharf. Further details on these traffic generating activities are provided in the sections below.

9.1.1 Construction staff

Accommodation would be provided on the Project vessel fleet for the majority of construction staff. Liveaboard construction staff are expected to be sourced from two locations. A portion of liveaboard construction staff will arrive at Darwin Airport and would be transported to the Fort Hill Wharf where staff will transfer to the vessels. Bus movements are anticipated to peak in July 2024, with up to seven buses transporting 364 personnel to the Fort Hill Wharf for the deep-water pipelay component of the Project every month.[1] There will also be liveaboard staff sourced locally in the Darwin region who will transfer daily between Fort Hill Wharf and residential areas within Darwin. The liveaboard construction staff will be responsible for the pipeline installation, offshore rock installation and dredging and excavation works.

Construction staff associated with the onshore works would likely commute daily to the DLNG site from an established workforce accommodation facility which is still to be determined. For the purpose of this TIA, the workforce accommodation facility is assumed to be located at Bladin Village, noting that any change to this arrangement may necessitate further assessment. Bladin Village can accommodate up to 750 people and is located approximately 8 km from the DLNG site on Channel Island Road. Staff are anticipated to travel to and from the DLNG site using a mix of light vehicles including cars, light utility trucks and vans.

Figure 9-1 provides a breakdown of the anticipated number of onshore based staff by construction activity. The number of staff commuting to the Project daily is expected to peak at 160 in March 2024. Approximately 120 staff would commute to the DLNG site each day, with the remaining 40 staff commuting to either the HB Quarry or Port Darwin to support the rock haulage scope of works. The majority of staff movements to the DLNG site would be split between the two 12-hour shifts commencing at 6:00 am and 6:00 pm. Staff movements associated with the site mobilisation and rock haulage activities are assumed to occur over the 12-hour day shift only. Staff are expected to arrive within the 30-minute period prior to shift start and depart within the 30-minute period after shift end. As such, the peak hours of traffic generation would be from 5:30 am to 6:30 am and 5:30 pm to 6:30 pm. The indicative peak number of light vehicle movements during construction is summarised in Table 9-1.

Table 9-1 Indicative light vehicle movements during peak construction

Site	AM Peak (5:30am-6:30am)		PM Peak (5:30pm-6:30pm)	
	To site	From site	To site	From site
DLNG	22	0	0	22
Port Darwin	18	0	0	18
HB Quarry	20	0	0	20
Fort Hill Wharf	50	50	50	50

[1] A bus capacity of 55 passengers has been assumed in this TIA

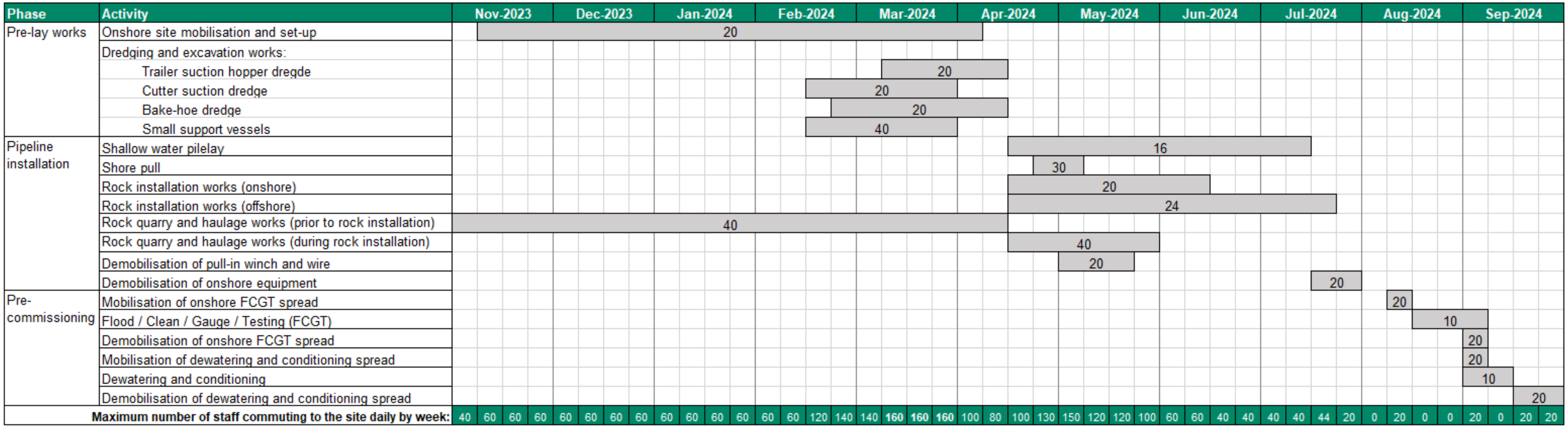

Figure 9-1 Indicative staff movements during construction of the Project

9.1.2 Rock haulage

As discussed in Section 7.1, large quantities of rock will be required to provide pipeline protection and stability within Darwin Harbour. The rock is proposed to be sourced from the HB Quarry at Mount Bundey and would be transported via the road network to Port Darwin and the DLNG site. The proposed haulage routes to are discussed in Section 7.1.2.

It is anticipated that 175,000 tonnes of rock will be required for the Project. The majority of rock (87.5%) will be delivered to the intermediate stockpile at Port Darwin, with the remaining rock (12.5%) delivered to Project area at the DLNG site.

The indicative number of one-way heavy vehicle movements generated by the transportation of rock summarised in Table 9-2. For the purpose of this impact assessment, the number of movements has been conservatively estimated by assuming the rock will be transported by Triple Road Trains (75 tonne payload). However, it is acknowledged that the local road network would support Quadruple Road Trains (100 tonne payload), which may achieve higher productivity and reduce the total number of heavy vehicle movements required.

Approximately 75% of the rock (1,750 loads) are proposed to be transported prior to the start of the rock placement works. The remaining 25% of rock (585 loads) would be transported while rock installation is ongoing. As shown in Table 9-3, the duration of rock installation works is anticipated to be 6.5 weeks, requiring approximately 13 loads to be delivered per day. The majority of heavy vehicle movements are expected to occur seven days a week during daylight hours.

Table 9-2 Indicative number of heavy vehicle movements required for rock transportation

Destination	Rock type	Quantity (tonnes)	Number of heavy vehicle movements (one-way)[1]
Port Darwin	Bedding	7,900	105
	Filter 30mm	42,800	570
	Armour 400mm	102,500	1,365
	Total	**153,200**	**2,040**
DLNG facility	Bedding	870	10
	Filter 30mm	1,400	20
	Armour 500mm	19,700	265
	Total	**22,000**	**295**

Table notes:

[1] Based on a vehicle payload of 75 tonnes and values have been rounded to the nearest five.

Table 9-3 Indicative daily and hourly heavy vehicle movements

	Indicative timing / duration	Number of loads per day	Number of one-way movements per hour[1]
Prior to rock placement works[2]	52 weeks	5	1
During rock placement works	Mid-April to May 2024 (6.5 weeks)	13	2

Table notes:

[1] Deliveries are assumed to be evenly distributed over a 12-hour period and occur seven days per week.

[2] Rock haulage prior to placement works is assumed to occur over a 52-week period.

9.1.3 Equipment and materials

Pipe for the offshore component of the pipeline would be shipped from international waters and transferred to the pipelaying vessel offshore. Pipe required to construct the onshore component of the pipeline is proposed to be transported to the Project area via the road network. Other equipment that would be transported to the DLNG site via the road network is detailed in Table 9-4.

General construction equipment (e.g. earth moving machinery and cranes) would likely be sourced from the greater Darwin region. Specialist equipment required for the pre-commissioning scope of works (FCGT and dewatering) is expected to originate from Perth. This equipment would be transported via the road network to a designated staging area located outside of Darwin prior to being transported to the DLNG site.

Heavy vehicle movements associated with the delivery of equipment and materials are expected to peak in September 2024 during the demobilisation of the FCGT spread and mobilisation of the dewatering spread. Up to 66 vehicles would be required, generating up to 132 one-way movements (66 movements to the DLNG site and 66 movements from the DLNG site) over a two-day period. Assuming heavy vehicle movements are evenly distributed over the two-day period and would occur over a 10-hour window, up to four inbound and four outbound movements would be generated each hour.

Table 9-4 Equipment to be transported to/from the DLNG site

Activity	Equipment	Delivery vehicle type	Number of vehicles	Indicative timings and duration	
				Mobilisation	Demobilisation
Earth moving	Offices/storage containers/workshop	Flatbed	6	November 2023 to March 2024 (30 days)	June 2024 (14 days)
	Gensets and miscellaneous equipment	Flatbed	2		
	Excavators	Low-loader	3		
	Front-end loaders	Low-loader	2		
	Moxies	Moxies	4		
	Dozer	Low-loader	1		
Crane[1]	100T self-drive crane	Crane	1	November 2023 to March 2024 (30 days)	September 2023 (10 days)
	20T self-drive Franna crane	Crane	1		
	Telehandlers	Low-loader	2		
Winch spread (pipe-pull to shore)	Linear winch	Flatbed	1	December 2023 to March 2024 (90 days)	May 2024 (14 days)
	Winch drums[2]	Low-loader	2		
	Control cabin and power packs	Flatbed	3		
Pipe (onshore pipelaying sections)	700m of onshore pipe[3]	Flatbed	30	November 2023 to March 2024 (30 days)	June 2024 (14 days)
	Telehandler	Low-loader	1		
	Side booms or excavators	Low-loader	4		
	Offices/storage containers /workshop	Flatbed	6		
	Gensets and miscellaneous equipment	Flatbed	2		
Flood / Clean / Gauge / Testing (FCGT)	20m^3 Iso Tanks for waste/condensate and hydrosure chemicals	Flatbed/ semi-trailer	3	August 2024 (3 days)	September 2023 (2 days)
	Hoses	Flatbed/ semi-trailer	2		
	Ablutions	Flatbed/ semi-trailer	2		

Activity	Equipment	Delivery vehicle type	Number of vehicles	Indicative timings and duration	
				Mobilisation	Demobilisation
	Stores container, workshop container, test cabin	Flatbed/ semi-trailer	3		
	Office	Flatbed/ semi-trailer	1		
	Water Winning Pontoon	Flatbed/ semi-trailer	1		
	Water Winning HDPE pipe	Flatbed/ semi-trailer	3		
	Frank tank	14.5 m wheeled trailer	1		
	Gensets and miscellaneous equipment	Flatbed/ semi-trailer	3		
	Pumps	Flatbed/ semi-trailer	3		
	Fuel tank	Flatbed/ semi-trailer	1		
	FCGT Pig launcher	Flatbed/ semi-trailer	1		
Dewatering	Compressors	Flatbed/ semi-trailer	16	September 2023 (2 days)	September 2023 (10 days)
	Air dryers	Flatbed/ semi-trailer	4		
	Nitrogen membrane units	Flatbed/ semi-trailer	4		
	Booster compressors	Flatbed/ semi-trailer	4		
	$20m^3$ Iso Tanks for MEG	Flatbed/ semi-trailer	10		
	Hoses and miscellaneous equipment	Flatbed/ semi-trailer	3		
	Hydrotest/dewatering Pig Launcher	Flatbed/ semi-trailer	1		

Table notes:

[1] Assumed to remain onsite for both pipelay and pre-commissioning scope of works

[2] Removed from site only

[3] Delivered to site only

9.2 Operation phase

Typical operation of the Project would involve the transportation of gas through the pipeline and the inspection, maintenance and repair of subsea and onshore infrastructure. Once construction of the Project has been completed, the DLNG facility would revert to the previous operational arrangements that have been in place since 2006. As such, operation of the Project is not expected to generate additional traffic movements on the local road network relative to existing operations and will not be further considered in this impact assessment.

9.3 Decommissioning phase

At the end of the Project, the Project pipeline and associated facilities would be decommissioned in accordance with regulatory requirements at that time. Traffic generated by the decommissioning phase of the Project would therefore be dependent on a Project decommissioning plan to be prepared and approved at a later date. As such, the decommissioning phase will not be further considered in this impact assessment.

10.0 Traffic Network Impact

10.1 Criteria and assumptions

10.1.1 Traffic generation and distribution

A summary of the traffic generation and distribution assumptions applied to this TIA is provided in Table 10-1.

Table 10-1 Summary of traffic generation and distribution assumptions

Assumption	
Liveaboard construction staff	
1.	The portion of liveaboard construction staff arriving at Darwin Airport travelling to Fort Hill Wharf would consist of up to 7 buses every 3-8 weeks and will avoid peak hour traffic.
2.	As the number of trips generated by the fly-in liveaboard staff is low and only occurs during the non-peak period once every 3-8 weeks, the impact is considered negligible and will not be considered in further detail.
3.	The exact routes and origin location of liveaboard staff residing in Darwin and transfer daily to and from the site are unknown at this stage. However, it can be assumed that the transfer routes and timings are unlikely to coincide. Alongside the low transfer volumes, the impact can be considered negligible and will not be considered in further detail.
Onshore construction staff	
4.	All staff commuting to the Project daily would originate from the existing workforce accommodation facility located at Bladin Village.
5.	All light vehicle movements generated by construction staff would occur within the 30-minute period prior to shift start and after shift end (i.e. 5:30 am to 6:30 am and 5:30 pm to 6:30 pm).
6.	The traffic generation rate in the peak periods would be one light vehicle per construction worker (i.e. no car-pooling or buses have been assumed).
7.	Construction staff would commute to the Project using a mix of light vehicles including cars, light utility trucks and vans.
8.	Staff movements associated with onshore site mobilisation/demobilisation and rock haulage activities would occur over the 12-hour day shift only.
9.	A cumulative maximum of 20 staff would be needed to support onshore mobilisation and demobilisation activities.
10.	Staff movements associated with general construction activities would be split between the two 12-hour shifts commencing at 6:00 am and 6:00 pm.
11.	Staff supporting the rock haulage scope of works would be split between the HB Quarry and the rock destination sites at Port Darwin and DLNG. An 87.5/12.5 percent staff split between Port Darwin and DLNG has been assumed in proportion to the rock distribution between the two sites.
Rock haulage activities	
12.	A vehicle payload of 75-tonnes has been assumed to provide a conservative impact assessment. It is acknowledged that the local road network would support Quadruple Road Trains (100 tonne payload), which may achieve higher productivity and reduce the total number of heavy vehicle movements required.

Assumption	
13.	Heavy vehicle movements generated by the rock haulage activities would occur seven days per week and be evenly distributed over daylight hours.
14.	Approximately 75% of the rock would be transported prior to the start of the rock placement works. The remaining 25% of rock would be transported over a 6.5 week period while the rock installation works is ongoing.
Equipment and material deliveries	
15.	Heavy vehicle movements associated with the delivery of equipment and materials would be evenly distributed over a 10-hour delivery window.

10.1.2 Lane capacities

Uninterrupted flow facilities

Section 4.2 in Austroads *Guide to Traffic Management Part 3: Traffic Studies and Analysis* establishes the capacity for a two-lane highway to be 1,700 passenger car units per hour (pcu/h) for each traffic lane. Accordingly, a capacity of 1,700 pcu/h for each traffic lane has been adopted for highways in the study area including the Arnhem Highway and Stuart Highway.

Interrupted flow facilities

Table 5.1 in Austroads *Guide to Traffic Management Part 3: Traffic Studies and Analysis* sets out typical one-way mid-block capacities for various types of urban roads with interruptions from cross and turning traffic at minor intersections. A capacity of 900 pcu/h for each traffic lane has been adopted for:

- Berrimah Road
- Wishart Road
- Kirkland Road
- Elrundie Avenue
- Jenkins Road
- Channel Island Road.

As Tiger Brennan Drive is a dual carriageway road with flaring at major intersections and absence of parking, a higher mid-block capacity of 1,200 pcu/h for each traffic lane has been adopted in accordance with Section 5.2.1 in Austroads *Guide to Traffic Management Part 3: Traffic Studies and Analysis.*

10.1.3 Annual background traffic growth

Growth factors have been applied to the 2022 traffic volumes in order to consider background traffic growth between existing conditions and the peak year of construction activity (2024).

The annual background traffic growth rates used in this study has been estimated based on the average growth in Annual Average Daily Traffic (AADT) observed over the last five-year period (2017-2021). As shown in Table 10-2, the Arnhem Highway has observed an average annual traffic growth rate of 2.2% near the Adelaide River Bridge since 2017. The Stuart Highway has experienced the highest average traffic growth rate in the study area at 4.6%. Several roads in the study area observed a decrease in AADT volumes including Berrimah Road, Channel Island Road and Kirkland Road. A growth rate of 0.0% has been adopted in this study for these roads to provide a conservative assessment.

Table 10-2 Growth in AADT on key roads within in the study area (2017-2021)

Road	Station	Location of station	Data range	Average annual traffic growth rate (%)[1]
	UDVDP019	500 m east of Stuart Highway	2017-2021	0.7

Road	Station	Location of station	Data range	Average annual traffic growth rate (%)[1]
Arnhem Highway	RDVDP007	2 km west of Adelaide River Bridge	2017-2021	2.2
Berrimah Road	UDVDP028	400 m south of Tiger Brennan Drive	2017-2021	-3.3
	UDVDP029	350 m west of Casey Street	2017-2021	-1.2
Channel Island Road	UDVDC072	South of Elizabeth River Bridge	2017-2021	-11.3
Elrundie Avenue	UDVDC062	100 m North of Chung Wah Terrace	2017-2021	1.1
Kirkland Road	UDVDP085	500 m west of West of Wishart Road	2017-2021	-1.4
Stuart Highway	UDVDP017	500 m west of Howard Springs Road	2017-2021	0.7
	UDVDP020	500 m north of Arnhem Highway	2017-2021	4.6
Tiger Brennan Drive	UDVDP022	800 m west of Berrimah Road	2017-2021	1.8

Table notes:

[1] *Where the growth rate is negative, a value of 0.0% has been adopted to provide a conservative assessment*

10.1.4 Passenger car unit equivalency factors

A passenger car unit equivalent (PCE) value of 2 will be used for heavy vehicles as per Table 4.1 in Austroads *Guide to Traffic Management Part 3: Traffic Studies and Analysis.*

10.2 Road mid-block capacity impact

10.2.1 Traffic volume data

Table 10-3, Table 10-4 and Table 10-5 compare the projected background 2024 traffic volumes with the estimated 2024 total traffic volume inclusive of construction volumes for each peak hour. The volumes have been calculated to represent a conservative estimate of the maximum traffic generated by the project on the road network at any given point. It is noted that these estimates are considered conservative as some works are unlikely to occur simultaneously following further refinement of the construction program for the Project.

The traffic volumes have been estimated based on the following:

- 2022 SCAT's data provided by DIPL (insert date provided)
- AADT data provided by DIPL (converted to peak hour volumes where SCAT's was not provided)
- Growth rates and other assumptions detailed in Section 10.1
- Construction traffic generation estimated in Chapter 9.0

The full assessment can be found in Appendix A.

The following conclusions are drawn from these findings:

- Berrimah Road, Wishart Road and Tiger Brennan Drive are used by heavy vehicles significantly more relative to the other assessed roads

- Traffic volumes are much lower in the midday peak than the AM or PM peaks for high use roads
- Project generated traffic makes up only a very small amount of the projected 2024 traffic.

Table 10-3 Two-Way Traffic generation AM peak

Road	Road Section	Without construction of Project (2024)			With construction of Project (2024)		
		LV	HV	HV%	LV	HV	HV%
Arnhem Highway	East of Stuart Highway	914	34	3.7	934	36	3.8
Berrimah Road	Between Tiger Brennan Drive and Wishart Road	835	315	37.7	835	325	38.9
Channel Island Road	South of Elizabeth River Bridge[1]	141	4	2.7	158	12	7.4
Elrundie Avenue	North of Chung Wah Terrace[1]	506	12	2.3	523	20	3.7
Jenkins Road	West of Stuart Highway	206	1	0.7	226	6	2.8
Kirkland Avenue	East of Wishart Road[1]	43	1	2.1	63	3	4.6
Stuart Highway	Between Temple Terrace and Howard Springs Road	4837	175	8.8	4837	177	3.7
Tiger Brennan Drive	West of Berrimah	2862	165	5.8	2862	167	5.8
Wishart Road	East of Berrimah Road	645	243	37.7	662	251	38.0

Table notes:

[1] Peak hour traffic volumes have been estimated from AADT data

Table 10-4 Two-Way Traffic generation midday peak

Road	Road Section	Without construction of Project (2024)			With construction of Project (2024)		
		LV	HV	HV%	LV	HV	HV%
Arnhem Highway	East of Stuart Highway	315	16	5.1	315	18	5.8
Berrimah Road	Between Tiger Brennan Drive and Wishart Road	391	148	37.7	391	158	40.3
Channel Island Road	South of Elizabeth River Bridge[1]	141	4	2.7	141	12	8.3
Elrundie Avenue	North of Chung Wah Terrace[1]	506	16	3.2	506	24	4.8
Jenkins Road	West of Stuart Highway	269	8	3.0	269	13	4.8

Road	Road Section	Without construction of Project (2024)			With construction of Project (2024)		
		LV	HV	HV%	LV	HV	HV%
Kirkland Avenue	East of Wishart Road[1]	38	1	1.7	38	3	6.9
Stuart Highway	Between Temple Terrace and Howard Springs Road	2546	91	3.6	2546	93	3.7
Tiger Brennan Drive	West of Berrimah	1832	189	10.3	1832	191	10.4
Wishart Road	East of Berrimah Road	251	95	37.7	251	103	40.9

Table notes:

[1] Peak hour traffic volumes have been estimated from AADT data

Table 10-5 Two-way Traffic generation PM peak

Road	Road Section	Without construction of Project (2024)			With construction of Project (2024)		
		LV	HV	HV%	LV	HV	HV%
Arnhem Highway	East of Stuart Highway	730	27	3.7	750	29	3.8
Berrimah Road	Between Tiger Brennan Drive and Wishart Road	694	262	37.7	694	272	39.2
Channel Island Road	South of Elizabeth River Bridge[1]	106	3	2.7	123	11	8.8
Elrundie Avenue	North of Chung Wah Terrace[1]	380	12	3.2	397	20	5.1
Jenkins Road	West of Stuart Highway	232	6	2.6	250	11	4.4
Kirkland Avenue	East of Wishart Road[1]	77	1	1.4	97	3	3.2
Stuart Highway	Between Temple Terrace and Howard Springs Road	3676	131	3.6	3676	133	3.6
Tiger Brennan Drive	West of Berrimah	2727	189	6.9	2727	191	7.0
Wishart Road	East of Berrimah Road	620	234	37.7	638	242	38.0

Table notes:

[1] Peak hour traffic volumes have been estimated from AADT data

10.2.2 Mid-block capacity assessment

The results of the mid-block capacity assessment for the AM peak, midday peak and PM peak periods are shown in Figure 10-1, Figure 10-2 and Figure 10-3, respectively. It illustrates and compares the midblock volume to capacity ratio (V/C) of the existing road network and the construction volume added road network. Where a road's V/C is greater than 1, the volume of the road is deemed to have exceeded the capacity of the road and may affect the performance of road users.

The mid-block capacity has been assessed based on the following:

- Traffic volume data for the mid-block is sourced from Section 10.2.1
- Road capacity and other assumptions detailed in Section 10.1
- Where multiple sections of one road have been assessed, results are shown for the section of road presenting the maximum V/C ratio

The full assessment can be found in Appendix A.

The following conclusions are drawn from these findings:

- All roads in the study area would operate under capacity with the exception of the following two roads during the AM peak hour:
  - Stuart Highway between Temple Terrace and Howard Springs Road
  - Wishart Road
- Where V/C exceeds 1, it has already surpassed capacity in the existing case and is not a result of additional project volume
- On average, V/C is higher for most roads during the peak hour and lower during the midday peak.

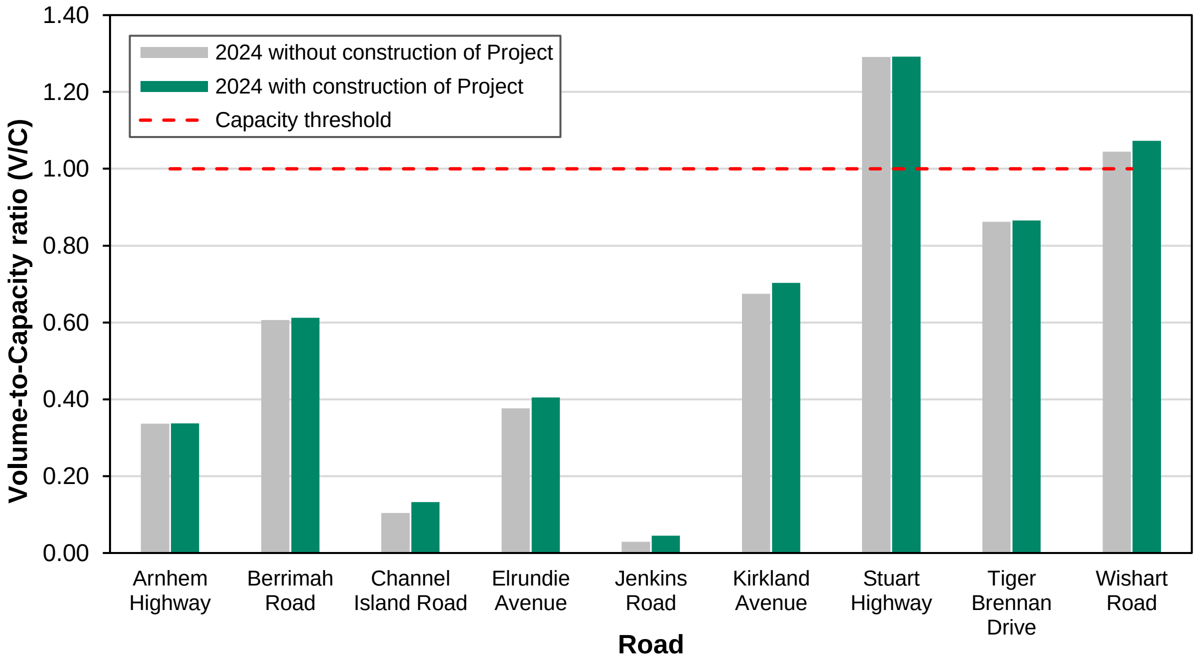

Figure 10-1 Mid-block capacity results for the 2024 AM peak

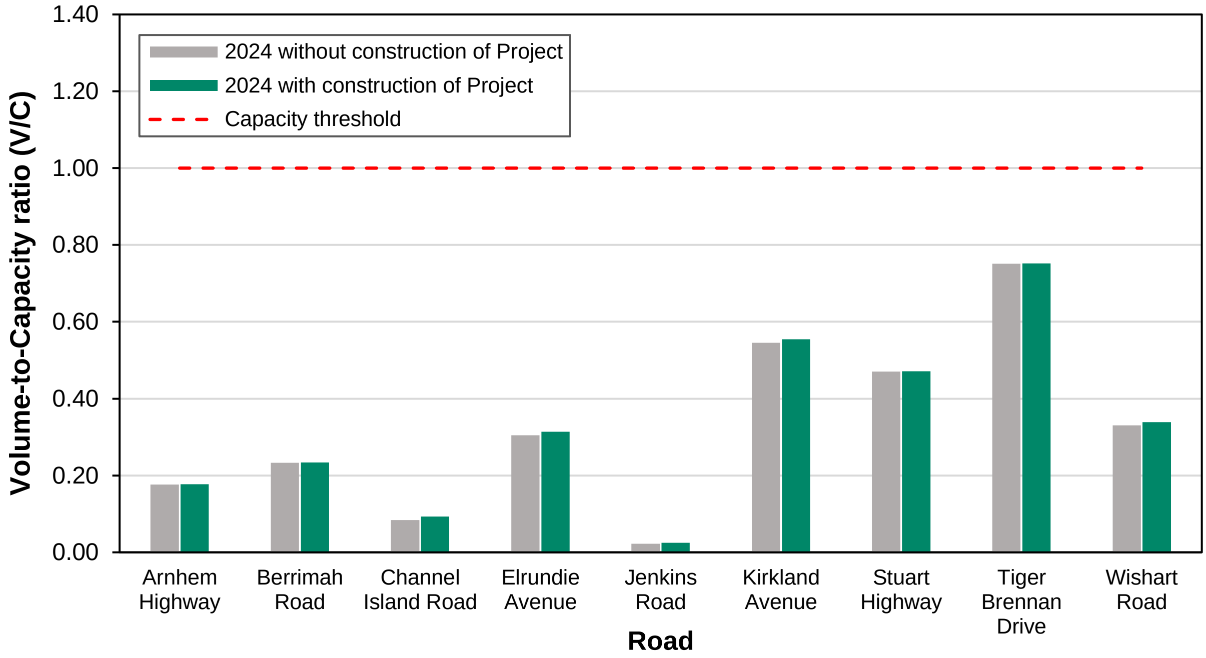

Figure 10-2 Mid-block capacity results for the 2024 midday peak

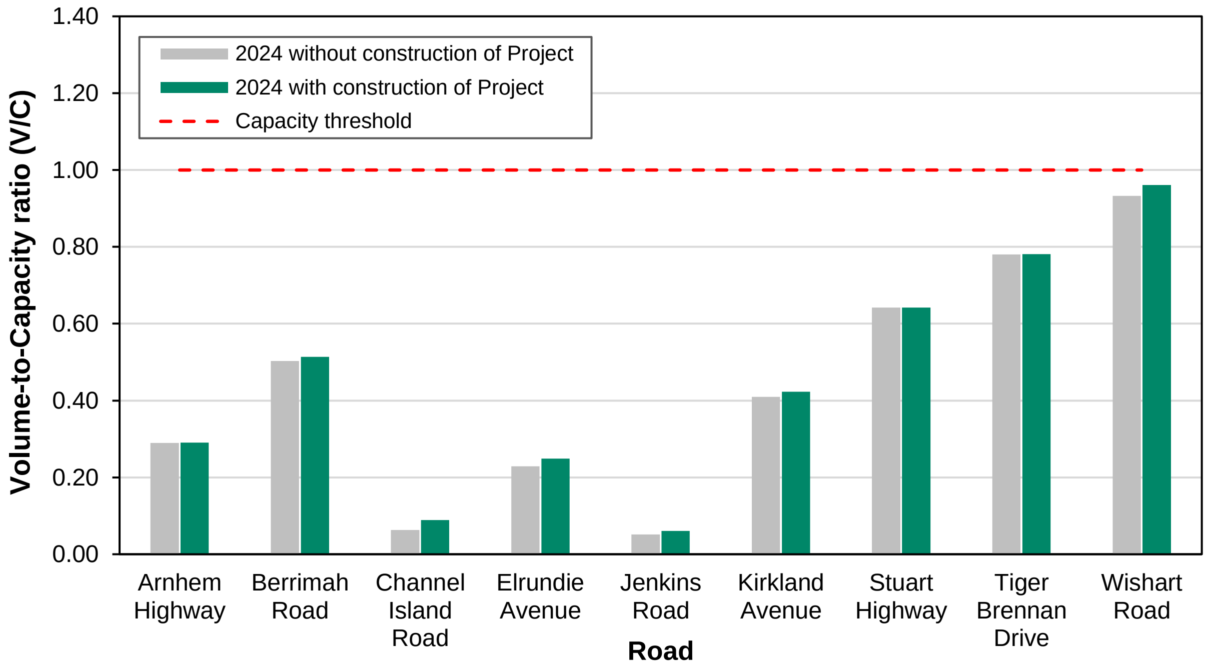

Figure 10-3 Mid-block capacity results for the 2024 PM peak

10.3 Intersection capacity and performance impact

To determine whether further intersection modelling and analysis was necessary, the critical intersections identified in Section 6.4 were assessed based on the following:

- Number of additional turning movements (particularly right turns) resulting from the Project
- Number of additional Project related movements compared to the overall volume of the intersection
- A high V/C midblock ratio for any roads within the intersection
- Any known intersection capacity issues.

From this assessment, the following intersections were deemed to have triggered further modelling and analysis:

- Tiger Brennan Drive / Wishart Road / Tivendale Road
- Tiger Brennan Drive / Berrimah Road
- Berrimah Road / Wishart Road.

Models for the critical intersections were developed using the SIDRA Intersection (version 9.0) software package. SIDRA Intersection is a micro-analytical tool used to evaluate intersection performance in terms of Degree of Saturation (DoS), delay, Level of Service (LoS), queue length and a variety of other performance measures. Key intersection performance measures are further discussed in Section 10.3.1.

It should be noted that the following constraints and assumptions are relevant to the intersection capacity and performance assessment:

- Intersection modelling was undertaken for the AM and PM peak hours only as these hours represent the periods when the road network experiences the maximum traffic demand and the available spare capacity of the road network is at its most limited. As such, the modellings results are indicative of a worst-case scenario as the traffic volumes throughout the remainder of the day decrease significantly. All intersections are assumed to perform adequately during the midday peak period.
- Signal cycle timing and phasing is based on Friday 9 September 2022 SCATS data. Average cycle time was determined via SCATS and individual phase times were determined by SIDRA.
- Background traffic growth has been assumed as per Section 10.1.3 of the report
- No calibration or validation has been undertaken as part of this assessment.

10.3.1 Performance indicators and targets

10.3.1.1 Level of Service

The criteria for evaluating the operational performance of intersections in summarised in Table 10-6. For signalised intersections, the performance is based on the average delay per vehicle across all movements. This average vehicle delay is equated to a corresponding Level of Service (LoS) from A (best) to F (worst). LoS D is typically considered as the minimum desirable performance level; a deterioration of LoS under this level would imply suitable remedial measures should be sought to improve performance.

Table 10-6 Level of Service definitions for signalised intersections

Level of Service	Average delay (seconds per vehicle)	General description
A	≤ 10	Free flow
B	11 to 20	Stable flow (slight delays)
C	21 to 35	Stable flow (acceptable delays)

Level of Service	Average delay (seconds per vehicle)	General description
D	36 to 55	Approaching unstable flow (tolerable delays)
E	56 to 80	Unstable flow (intolerable delay)
F	>80	Forced flow (jammed)

Source: SIDRA and Highway Capacity Manual 2016

10.3.1.2 Degree of Saturation

The Degree of Saturation (DoS) is defined as the ratio of arrival flow (demand) to the approach capacity. In general, a lower DoS indicates a better level of traffic service. A DoS greater than 1.0 indicates oversaturated conditions in which long queues of vehicles build up on the critical approaches. In theory, a DoS of 1.0 means that the intersection is operating at maximum capacity. However, a lower practical DoS is normally used, depending on the intersection control type. For signalised intersections, the practical DoS is 0.9. The intersection DoS is based on the highest DOS of all movements.

10.3.1.3 95th percentile queue

95th percentile queue is the length (in metres) below which 95% of all observed cycle queues lengths fall. In other words, this queue length is expected to be exceeded only for 5% of observed queues. Ideally, the 95th percentile queue should fit within the provided turning lane without spilling into adjacent lanes.

10.3.1.4 Average delay

Average delay refers to the average additional amount of time it takes a vehicle to pass through the intersection compared to free flow conditions. The average delay is measured in seconds per vehicle.

10.3.2 Intersection impact results

The results for the ‘without construction of Project’ (without vehicles generated by the construction of the Project) and ‘with construction of the Project’ (with vehicles generated by the construction of the Project) scenarios are presented in Table 10-7 for the AM and PM peak hours. The full assessment results can be found in Appendix B.

The following conclusions are drawn from the analysis:

- The model results indicate that all critical intersections are expected to operate at LoS D or above in 2024 without the construction of the Project. No critical intersection is expected to experience a deterioration in LoS due to additional traffic volumes generated by the construction of the Project.
- All critical intersections are expected to operate at a satisfactory DoS in 2024 with the exception of Tiger Brennan Drive / Berrimah Road during the AM peak hour. The DoS of this intersection is anticipated to exceed the generally accepted practical DoS value of 0.9 for signalised intersections. However, the Tiger Brennan Drive intersection will be upgraded to an overpass during the rock haulage period and this will likely impact on the use of this intersection. It is likely that the Project will instead use Wishart Road during these works.
- The maximum increase in average delay as a result of the Project is anticipated to be approximately two seconds and would occur at the intersection of Tiger Brennan Drive / Wishart Road / Tivendale Road during the PM peak hour. The increase in average delay at all remaining intersections is expected to be less than one second.

Therefore, the construction of the Project is expected to have an imperceptible impact on the capacity and performance of the critical intersections.

Table 10-7 Intersection performance results

Intersection	Peak Period	Without construction of Project (2024)				With construction of Project (2024)			
		Degree of Saturation	Average intersection delay (seconds)	Level of Service	95th percentile queue length (metres)	Degree of Saturation	Average intersection delay (seconds)	Level of Service	95th percentile queue length (metres)
Tiger Brennan Drive / Berrimah Road	AM	0.933	42.0	D	389.1	0.933	42.2	D	389.1
	PM	0.857	34.4	C	345.5	0.880	34.9	C	348.3
Tiger Brennan Drive / Wishart Road / Tivendale Road	AM	0.592	39.1	D	180.5	0.593	39.1	D	180.9
	PM	0.801	39.8	D	286.0	0.844	41.8	D	317.4
Berrimah Road / Wishart Road	AM	0.524	21.0	C	69.3	0.524	20.9	C	69.3
	PM	0.545	15.0	B	56.9	0.579	15.2	B	61.5

10.4 Recommended mitigation measures

To mitigate the potential impacts of the Project on road capacity and performance, the following mitigation measures are recommended:

- All vehicle movements associated with the Project should be planned to occur outside of the identified AM and PM peak hours
- Group transport, such as shuttle buses and car-pooling schemes, should be implemented where practical to reduce the number of light vehicle movements on the local road network
- Heavy vehicle movements should be scheduled to minimise traffic disruption to the road network. This may include:
    - Scheduling of the movement of rock, equipment and other materials to occur outside of the identified AM and PM peak hours
    - Scheduling heavy vehicle movements to be evenly dispersed as far as practical to minimise the potential of convoying or platoons on the road network.
- The loading and unloading of heavy vehicles should be planned so that the capacity of each individual vehicle is fully utilised to reduce the total number of movements on the local road network
- A separate Traffic Management Plan (TMP) should be prepared, approved and implemented during the construction phase of the Project. The TMP will confirm final haulage routes and provide the necessary mitigation measures to ensure that construction vehicle movements can be accommodated on the local road network with minimal impacts.

11.0 Cumulative Impacts

11.1 Coolalinga Road Safety Upgrades

The Northern Territory Government aims to improve road safety for all road users, improve accessibility to Stuart Highway and support future planning through the proposal of:

- 2 new signalised intersections on the Stuart Highway
- Multiple road extensions (service roads, roads behind Coolalinga Central, Henning Road)
- New road link between the Stuart Highway and Henning Road
- Reduced posted speed limit to 60km/h on the Stuart Highway

The construction of this project is scheduled for commencement by 2023. At the time of writing this report, the project has completed the first stage of detailed design shown in Figure 11-1.

Figure 11-1: Coolalinga Road Safety Upgrades Plan

Figure source: Northern Territory Government, 2022

Assuming the construction of the Coolalinga Road Project begins in January 2023, this construction period may overlap with the timings of the Barossa Darwin Pipeline Duplication Project (Figure 7-1). The Coolalinga signalisation project may result in the full or partial closure of Stuart Highway; a key road along the rock haulage route. If these closures coincide with the Project's rock delivery schedule, there is a potential that an alternate route may need to be considered.

11.2 Tiger Brenan Drive / Berrimah Road overpass works

Figure 11-2 Tiger Brennan Drive / Berrimah Road Overpass Plan

Figure source: Northern Territory Government, 2022

The Northern Territory Government is in partnership with the Australian Government to improve road safety at the Tiger Brennan Drive and Berrimah Road intersection through the construction of a new overpass (Northern Territory Government, 2022). This will separate the major traffic flow on Tiger Brennan Drive from those on Berrimah Road.

The project will enhance safety, reduce traffic delays during peak hours and improve connectivity for freight transport to East Arm Wharf through the proposal of:

- An overpass with Berrimah Road passing over Tiger Brennan Drive
- Realignment of Tiger Brennan Drive
- Improvements to Berrimah Road catering to requirement for road trains
- On and off ramps
- Earthworks, drainage works, pavement construction, asphalt works, line marking and road safety barriers
- Street lighting, traffic lights, improved pedestrian and cyclist accessibility
- Landscaping and urban design

The construction of the Tiger Brennan Overpass Project has commenced, with site and early works being undertaken at the time of writing this report. While these early works should not impact of traffic movements, construction is likely to extend through to mid 2024 there will likely be a cumulative traffic impact should construction be staged as described in the Traffic Impact Assessment AECOM prepared for Sitzler Pty Ltd (Figure 11-3). Potential detours may occur during the detailed design stage predicted to occur in early 2023.

Figure 11-3: Potential construction staging for Tiger Brennan Drive and Berrimah Road overpass

Figure source: AECOM 2022

11.3 Darwin Ship Lift

The Northern Territory Government is delivering the Darwin Ship Lift Project to establish Darwin as a thriving maritime services industry hub. The Darwin Ship Lift facility will be designed to meet the needs of the general maritime sector, current long-term needs of the Department of Defence and the Australian Border Force, while supporting local jobs and economic growth in the Territory.

In reference to the indicative concept design construction schedule in the Darwin Ship Lift Project draft preliminary documentation (Figure 11-4), construction work is planned to begin in quarter 3 of 2022.

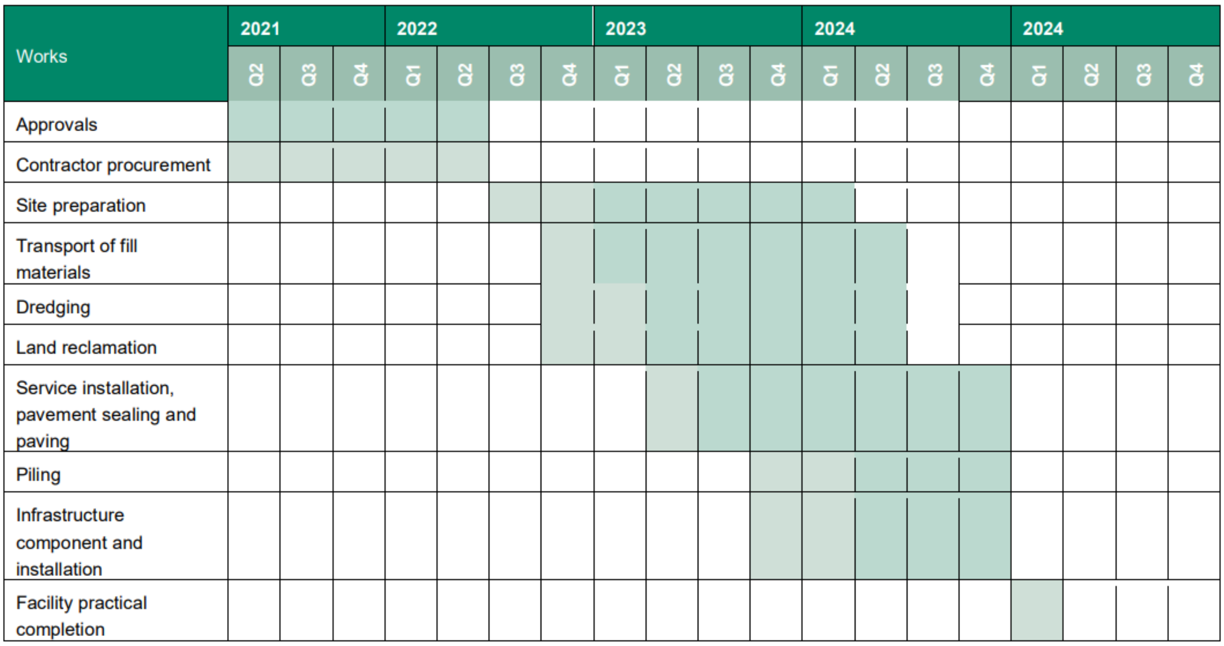

Figure 11-4: Darwin Ship Lift indicative construction schedule

Figure source: AECOM 2021

In reference to the traffic impact assessment AECOM completed for the Darwin Ship Lift Project in 2021, during the 24 months of project construction there will be heavy vehicle traffic generated on the last 20km section of the Barossa project's haulage route outlined in Section 8.0 (Figure 11-5). Whilst the additional heavy vehicle traffic has the potential to create additional trips on the network at the same time as the Project, the approximate traffic generation at peak would be approximately 10 heavy vehicle trips per hour. If the additional heavy vehicle trips occur during the off peak period as per the recommendations made in the report, there is likely to be a negligible cumulative impact on traffic.

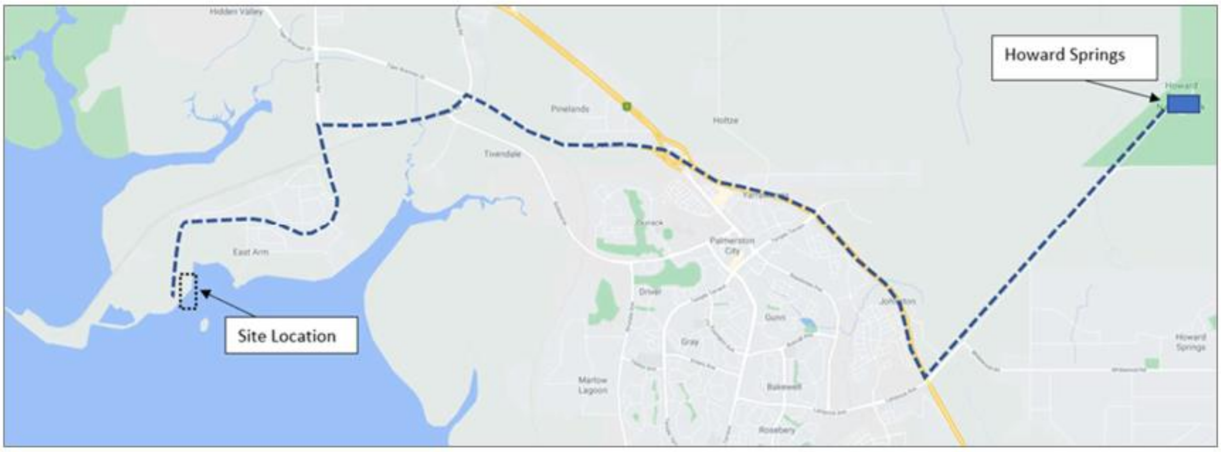

Figure 11-5: Darwin Ship Lift Project haulage route

11.4 Recommended mitigation measures

To mitigate the potential cumulative impacts of the Project and other concurrent projects, the following mitigation measures are recommended:

- Coordination and consultation with key stakeholders to manage the interface of projects occurring at the same time. This may include the coordination of traffic management arrangements between projects and the provision of regular project updates.
- Investigation of potential alternative haulage routes in the event that road closures or access restrictions are required to facilitate other projects.

12.0 Other Impacts and Mitigation Measures

12.1 Pedestrians and cyclists

As shown in section 6.5.1, there are a number of shared footpath and on-road bicycle paths on and around the project haulage routes. In addition, ad-hoc movements of recreational cyclists using highways and pedestrians through local roads can be expected.

Therefore, the Project should consider appropriate traffic management measures to ensure safe pedestrian (including school children in vicinity of school bus stops) and cyclist passage on nominated routes during construction (and if deemed required operation stage), in accordance with relevant road design standards and in consultation with relevant road authorities. The local community and road users should be notified in advance of any changes in transport conditions including details of any proposed road and traffic lane closures.

12.2 Public transport

As shown in section 6.5.2, multiple regular public bus routes operate on the proposed haulage route, notably between Darwin, Palmerston and Humpty Doo. Heavy vehicle movements associated with the Project would likely operate during bus operating times. Therefore, the Project must consider reducing potential impact if conflicts are unable to be suitably managed.

Consultation with local councils and bus operators during the development of the TMP to ensure any affected school routes have appropriate diversions in place that still service necessary stakeholders and deliver acceptable travel time changes should be considered. It is recommended that ongoing consultation with relevant stakeholders would be undertaken to manage the potential disruptions on bus services.

12.3 Road maintenance

This Project is expected to increase the number of axle repetitions the road pavement is exposed to, particularly during the construction period. It is assumed that the road pavements in the study area have been designed to withstand a certain number of axle repetitions which are forecast during the design life of the road due to the existing demand of heavy vehicles on the network.

However, the additional number of heavy vehicles forecast to be generated by the Project is expected to increase the wear on the pavement and increase the likelihood that minor maintenance might be required. With no assessment of the roads in the study areas outlining the current condition or age of the pavement, it is not possible at this time to quantify the impact the Project might have on the road surfaces. It is recommended that a pavement condition program be implemented to monitor the impact and identify any deterioration to the road pavement over the duration of construction. In order to do this a baseline study must be completed to identify the existing conditions of the existing public routes, which are to become part of the haulage routes.

All loads being transported to and from the site will be secured in accordance with the relevant legislation. All vehicles must be correctly licenced and compliant with relevant up to date legislation. Legislation: NT Traffic Regulations 1999.

12.4 Driver fatigue

During the construction there is the potential risk of driver fatigue due to the volume of materials required for completion of the works. This risk will be managed through the appropriate implementation of a Fatigue Management System (FMS) in accordance with the Northern Territory Road Transport Fatigue Management Code of Practice.

This code of practice, this has been developed “to assist transport operators to implement management systems which meet occupational health and safety obligations under the Work Health Act in relation to driver fatigue”.

12.5 Incident management

Due to the nature of the Project, it is expected that relevant guidelines will be adhered to. It is expected that an Incident Management Plan will be utilised in order to set out processes and response measures that are to be implemented in case of a non-compliance to relevant guidelines or should an emergency situation arise.

13.0 Summary and Conclusions

This report details the traffic and transport impact assessment for the Barossa Darwin Pipeline Duplication Project. The report findings are summarised below.

Existing conditions

An existing transport conditions review was undertaken, which was informed via a combination of desktop reviews, site visit, crash/traffic data analysis and review of relevant policies and legislation. The key existing condition findings are summarised below:

- The road network within the study area is comprised of several State roads including Arnhem Highway and Stuart Highway. The Stuart Highway is the most heavily trafficked road in the area, with up to 27,800 vehicles travelling on the road on an average day.
- Stuart Highway, Tiger Brennan Drive and Berrimah Road all form part of the National Land Transport Network. Heavy vehicles (>3 axles) account for between 3.6% and 27.4% of traffic volumes on these roads.
- Traffic volumes on key roads in the study area generally peak during the month of September. Reduced levels of traffic are observed during the wet season (November to April).
- Arnhem Highway, Stuart Highway, Tiger Brennan Drive, Berrimah Road, Kirkland Road, Elrundie Avenue, Jenkins Road, Channel Island Road and Wickham Point Road all form part of the approved network for 53.5 m Road Train vehicles.
- Dedicated cyclist infrastructure in the study area is limited to an on-road bicycle lane on the eastern side of Berrimah Road between Marlow Road and Wishart Road. Several shared footpaths are provided adjacent to key roads in the study area including Berrimah Road, Tiger Brennan Drive, Stuart Highway and Arnhem Highway.
- There are no existing or proposed public bus services within 400 m of the DLNG facility or the intermediate stockpile site at Darwin Port, however CDC Northern Territory operates seven regular public bus services on roads forming part of the proposed Project haulage routes.
- The Adelaide-Darwin railway alignment is located approximately 750 m north-west of the intermediate stockpile site at Darwin Port. This railway line is grade separated from Berrimah Road at East Arm. However, two level railway crossings are located on Kirkland Road and one is located on Channel Island Road.
- In the five-year period from 2015 to 2019, a total of seven fatalities occurred on key roads in the study area. Five of these fatalities occurred on Tiger Brennan Drive.

Impact assessment

The key findings of the construction phase impact assessment are as follows:

- Mid-block capacity: a mid-block capacity assessment was undertaken for key roads in the study area to assess the impact of the Project on road capacity. The results indicate that all roads would operate under capacity in 2024 with the exception of Stuart Highway (between Temple Terrace and Howard Springs Road) and Wishart Road during the AM peak hour. Project-generated traffic would account for a very minor proportion of traffic on the local road network in 2024 and where the available capacity of a road has been exceeded, it is not a result of Project traffic.
- Intersection capacity and performance: traffic modelling using SIDRA Intersection (version 9.0) was performed to assess the impacts of the Project on the capacity and performance of three critical intersections. The modelling results indicate additional traffic movements generated by the construction of the Project in 2024 would result in negligible impacts.
- Preliminary haulage route assessment: routes have been established based on the approved road network for 53.3 metre Road Train vehicles. No road upgrades are anticipated to be required to accommodate Project traffic.

Overall, impacts to the local transport network during Project construction are expected to be negligible given the very low proportion of Project-generated traffic on the local road network.

Mitigation measures

To mitigate the potential impacts of the Project, the following mitigation measures have been recommended:

- All vehicle movements associated with the Project should be planned to occur outside of the identified AM and PM peak hours
- Group transport, such as shuttle buses and car-pooling schemes, should be implemented where practical to reduce the number of light vehicle movements on the local road network
- Heavy vehicle movements should be scheduled to minimise traffic disruption to the road network. This may include:
  - Scheduling of the movement of rock, equipment and other materials to occur outside of the identified AM and PM peak hours
  - Scheduling heavy vehicle movements to be evenly dispersed as far as practical to minimise the potential of convoying or platoons on the road network.
- The loading and unloading of heavy vehicles should be planned so that the capacity of each individual vehicle is fully utilised to reduce the total number of movements on the local road network
- A separate Traffic Management Plan (TMP) should be prepared, approved and implemented during the construction phase of the Project. The TMP will confirm final haulage routes and provide the necessary mitigation measures to ensure that construction vehicle movements can be accommodated on the local road network with minimal impacts.
- Coordination and consultation with key stakeholders to manage the interface of other projects occurring in the study area at the same time. This may include the coordination of traffic management arrangements between projects and the provision of regular project updates.
- Investigation of potential alternative haulage routes in the event that road closures or access restrictions are required to facilitate other projects in the study area.

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Appendix A

Mid-block capacity assessment

Appendix A Mid-block capacity assessment

Table 0-1 Mid-block capacity results for the AM peak

Road	Location	Peak period	Direction of travel	Number of lanes	Capacity (pcu/h/direction)	2024 without construction of Project				2024 with construction of Project			
						LV	HV	PCU	V/C	LV	HV	PCU	V/C
Arnhem Highway	East of Stuart Highway	AM	Eastbound	1	1700	382	14	409	0.24	402	15	431	0.25
			Westbound	1	1700	532	20	572	0.34	532	21	574	0.34
	West of Adelaide River Bridge[1]	AM	Eastbound	1	1700	51	10	72	0.04	71	8	87	0.05
			Westbound	1	1700	45	9	64	0.04	72	10	92	0.05
Berrimah Road	Between Tiger Brennan Drive and Wishart Road	AM	Northbound	2	1800	622	235	1092	0.61	622	240	1102	0.61
			Southbound	2	1800	213	80	373	0.21	213	85	383	0.21
	Between Wishart Road and Cochran Road	AM	Northbound	2	1800	145	55	255	0.14	145	56	257	0.14
			Southbound	2	1800	152	58	268	0.15	170	59	287	0.16
	West of Casey Street[1]	AM	Northbound	1	900	47	18	82	0.09	47	19	84	0.09
			Southbound	1	900	27	10	48	0.05	45	11	68	0.08
Channel Island Road	South of Elizabeth River Bridge[1]	AM	Northbound	1	900	89	2	93	0.10	106	6	119	0.13
			Southbound	1	900	52	1	55	0.06	52	5	63	0.07
Elrundie Avenue	North of Chung Wah Terrace[1]	AM	Northbound	1	900	319	10	339	0.38	336	14	364	0.40
			Southbound	1	900	187	1	190	0.21	187	5	198	0.22
Jenkins Road	West of Stuart Highway	AM	Eastbound	1	900	18	0	18	0.02	38	1	40	0.04
			Westbound	1	900	25	1	26	0.03	25	2	28	0.03
Kirkland Avenue	East of Wishart Road[1]	AM	Northbound	1	900	603	2	607	0.67	621	6	633	0.70
			Southbound	1	900	355	1	357	0.40	355	5	365	0.41
Stuart Highway	Between Tiger Brennan Drive and Temple Terrace	AM	Eastbound	2	3400	709	26	761	0.22	709	27	763	0.22
			Westbound	2	3400	2375	86	2547	0.75	2375	86	2547	0.75
	Between Temple Terrace and Howard Springs Road	AM	Eastbound	2	3400	744	26	796	0.23	744	27	798	0.23
			Westbound	2	3400	4094	148	4391	1.29	4094	149	4393	1.29
	Between Howard Springs Road and Girraween Road	AM	Eastbound	2	3400	587	21	630	0.19	587	22	632	0.19
			Westbound	2	3400	1255	46	1346	0.40	1255	47	1348	0.40
	North of Arnhem Highway	AM	Eastbound	2	3400	544	20	583	0.17	544	21	585	0.17

Road	Location	Peak period	Direction of travel	Number of lanes	Capacity (pcu/h/direction)	2024 without construction of Project				2024 with construction of Project			
						LV	HV	PCU	V/C	LV	HV	PCU	V/C
			Westbound	2	3400	884	33	949	0.28	884	34	951	0.28
	South of Arnhem Highway	AM	Eastbound	2	3400	236	9	254	0.07	236	10	256	0.08
			Westbound	2	3400	415	15	445	0.13	435	16	467	0.14
	North of Jenkins Road	AM	Eastbound	2	3400	245	9	263	0.08	245	10	265	0.08
			Westbound	2	3400	77	2	81	0.02	97	3	103	0.03
Tiger Brennan Drive	West of Berrimah	AM	Eastbound	2	2400	854	1	856	0.36	854	5	864	0.36
			Westbound	2	2400	2008	31	2070	0.86	2008	35	2078	0.87
	Between Berrimah Road and Wishart Road	AM	Eastbound	2	2400	651	10	670	0.28	651	11	672	0.28
			Westbound	2	2400	1931	2	1935	0.81	1931	3	1937	0.81
	Between Wishart Road and Stuart Highway	AM	Eastbound	2	2400	529	54	637	0.27	529	55	639	0.27
			Westbound	2	2400	1002	111	1225	0.51	1002	112	1227	0.51
Wishart Road	East of Berrimah Road	AM	Eastbound	1	900	109	41	192	0.21	109	45	200	0.22
			Westbound	1	900	536	202	940	1.04	553	206	965	1.07

Table notes:

[1] Peak hour traffic volumes have been estimated from AADT data

Table 0-2 Mid-block capacity results for the midday peak

Road	Location	Peak period	Direction of travel	Number of lanes	Capacity (pcu/h/direction)	2024 without construction of Project				2024 with construction of Project			
						LV	HV	PCU	V/C	LV	HV	PCU	V/C
Arnhem Highway	East of Stuart Highway	Midday	Eastbound	1	1700	36	1	39	0.02	36	2	41	0.02
			Westbound	1	1700	279	10	300	0.18	279	11	302	0.18
	West of Adelaide River Bridge[1]	Midday	Eastbound	1	1700	26	6	38	0.02	26	7	40	0.02
			Westbound	1	1700	44	10	64	0.04	44	11	66	0.04
Berrimah Road	Between Tiger Brennan Drive and Wishart Road	Midday	Northbound	2	1800	230	87	404	0.22	230	92	414	0.23
			Southbound	2	1800	161	61	283	0.16	161	66	293	0.16
	Between Wishart Road and Cochran Road	Midday	Northbound	2	1800	239	90	419	0.23	239	91	421	0.23
			Southbound	2	1800	84	32	148	0.08	84	33	150	0.08
	West of Casey Street[1]	Midday	Northbound	1	900	38	14	66	0.07	38	15	68	0.08
			Southbound	1	900	36	14	64	0.07	36	15	66	0.07
Channel Island Road	South of Elizabeth River Bridge[1]	Midday	Northbound	1	900	72	2	76	0.08	72	6	84	0.09
			Southbound	1	900	69	2	73	0.08	69	6	81	0.09
Elrundie Avenue	North of Chung Wah Terrace[1]	Midday	Northbound	1	900	258	8	274	0.30	258	12	282	0.31
			Southbound	1	900	248	8	264	0.29	248	12	272	0.30
Jenkins Road	West of Stuart Highway	Midday	Eastbound	1	900	20	0	20	0.02	20	1	22	0.02
			Westbound	1	900	18	1	19	0.02	18	2	21	0.02
Kirkland Avenue	East of Wishart Road[1]	Midday	Northbound	1	900	488	2	491	0.55	488	6	499	0.55
			Southbound	1	900	470	1	473	0.53	470	5	481	0.53
Stuart Highway	Between Tiger Brennan Drive and Temple Terrace	Midday	Eastbound	2	3400	945	34	1014	0.30	945	35	1016	0.30
			Westbound	2	3400	939	34	1007	0.30	939	35	1009	0.30
	Between Temple Terrace and Howard Springs Road	Midday	Eastbound	2	3400	1055	37	1130	0.33	1055	38	1132	0.33
			Westbound	2	3400	1491	54	1599	0.47	1491	55	1601	0.47
	Between Howard Springs Road and Girraween Road	Midday	Eastbound	2	3400	887	31	950	0.28	887	32	952	0.28
			Westbound	2	3400	883	24	931	0.27	883	33	949	0.28
	North of Arnhem Highway	Midday	Eastbound	2	3400	264	10	283	0.08	264	11	285	0.08
			Westbound	2	3400	531	20	570	0.17	531	21	572	0.17

Road	Location	Peak period	Direction of travel	Number of lanes	Capacity (pcu/h/direction)	2024 without construction of Project				2024 with construction of Project			
						LV	HV	PCU	V/C	LV	HV	PCU	V/C
	South of Arnhem Highway	Midday	Eastbound	2	3400	301	11	323	0.09	301	12	325	0.10
			Westbound	2	3400	306	11	328	0.10	306	12	330	0.10
	North of Jenkins Road	Midday	Eastbound	2	3400	94	3	101	0.03	94	4	103	0.03
			Westbound	2	3400	64	2	67	0.02	64	3	69	0.02
Tiger Brennan Drive	West of Berrimah	Midday	Eastbound	2	2400	610	1	611	0.25	610	5	619	0.26
			Westbound	2	2400	567	8	582	0.24	567	12	590	0.25
	Between Berrimah Road and Wishart Road	Midday	Eastbound	2	2400	588	13	614	0.26	588	14	616	0.26
			Westbound	2	2400	574	1	575	0.24	574	2	577	0.24
	Between Wishart Road and Stuart Highway	Midday	Eastbound	2	2400	1499	152	1802	0.75	1499	153	1804	0.75
			Westbound	2	2400	333	37	407	0.17	333	38	409	0.17
Wishart Road	East of Berrimah Road	Midday	Eastbound	1	900	169	64	297	0.33	169	68	305	0.34
			Westbound	1	900	82	31	143	0.16	82	35	151	0.17

Table notes:

[1] *Peak hour traffic volumes have been estimated from AADT data*

Table 0-3 Mid-block capacity results for the PM peak

Road	Location	Peak period	Direction of travel	Number of lanes	Capacity (pcu/h/direction)	2024 without construction of Project				2024 with construction of Project			
						LV	HV	PCU	V/C	LV	HV	PCU	V/C
Arnhem Highway	East of Stuart Highway	PM	Eastbound	1	1700	271	10	291	0.17	291	11	313	0.18
			Westbound	1	1700	77	10	97	0.06	77	11	99	0.06
	West of Adelaide River Bridge[1]	PM	Eastbound	1	1700	45	6	57	0.03	65	7	79	0.05
			Westbound	1	1700	421	159	739	0.41	421	164	749	0.42
Berrimah Road	Between Tiger Brennan Drive and Wishart Road	PM	Northbound	2	1800	273	103	479	0.27	273	108	489	0.27
			Southbound	2	1800	516	195	906	0.50	534	196	925	0.51
	Between Wishart Road and Cochran Road	PM	Northbound	2	1800	39	15	69	0.04	39	16	71	0.04
			Southbound	2	1800	28	11	50	0.06	46	12	69	0.08
	West of Casey Street[1]	PM	Northbound	1	900	27	10	48	0.05	27	11	50	0.06
			Southbound	1	900	54	1	57	0.06	54	5	65	0.07
Channel Island Road	South of Elizabeth River Bridge[1]	PM	Northbound	1	900	52	1	55	0.06	69	5	80	0.09
			Southbound	1	900	193	6	206	0.23	193	10	214	0.24
Elrundie Avenue	North of Chung Wah Terrace[1]	PM	Northbound	1	900	186	6	198	0.22	204	10	224	0.25
			Southbound	1	900	46	0	46	0.05	46	1	48	0.05
Jenkins Road	West of Stuart Highway	PM	Eastbound	1	900	31	1	33	0.04	51	2	55	0.06
			Westbound	1	900	366	1	368	0.41	366	5	376	0.42
Kirkland Avenue	East of Wishart Road[1]	PM	Northbound	1	900	353	1	355	0.39	370	5	380	0.42
			Southbound	1	900	1819	66	1950	0.57	1819	67	1952	0.57
Stuart Highway	Between Tiger Brennan Drive and Temple Terrace	PM	Eastbound	2	3400	1020	37	1094	0.32	1020	37	1094	0.32
			Westbound	2	3400	2038	72	2182	0.64	2038	73	2184	0.64
	Between Temple Terrace and Howard Springs Road	PM	Eastbound	2	3400	1638	59	1756	0.52	1638	60	1758	0.52
			Westbound	2	3400	987	36	1058	0.31	987	37	1060	0.31
	Between Howard Springs Road and Girraween Road	PM	Eastbound	2	3400	728	26	781	0.23	728	27	783	0.23
			Westbound	2	3400	894	32	959	0.28	894	33	961	0.28
	North of Arnhem Highway	PM	Eastbound	2	3400	558	21	599	0.18	558	22	601	0.18
			Westbound	2	3400	473	17	507	0.15	493	18	529	0.16

Road	Location	Peak period	Direction of travel	Number of lanes	Capacity (pcu/h/direction)	2024 without construction of Project				2024 with construction of Project			
						LV	HV	PCU	V/C	LV	HV	PCU	V/C
	South of Arnhem Highway	PM	Eastbound	2	3400	340	12	365	0.11	340	13	367	0.11
			Westbound	2	3400	232	8	249	0.07	252	9	271	0.08
	North of Jenkins Road	PM	Eastbound	2	3400	115	3	121	0.04	115	4	123	0.04
			Westbound	2	3400	1855	2	1858	0.77	1855	6	1866	0.78
Tiger Brennan Drive	West of Berrimah	PM	Eastbound	2	2400	872	11	895	0.37	872	15	903	0.38
			Westbound	2	2400	1828	23	1873	0.78	1828	24	1875	0.78
	Between Berrimah Road and Wishart Road	PM	Eastbound	2	2400	819	1	821	0.34	819	2	823	0.34
			Westbound	2	2400	1499	152	1802	0.75	1499	153	1804	0.75
	Between Wishart Road and Stuart Highway	PM	Eastbound	2	2400	333	37	407	0.17	333	38	409	0.17
			Westbound	2	2400	478	181	840	0.93	496	185	865	0.96
Wishart Road	East of Berrimah Road	PM	Eastbound	1	900	142	54	249	0.28	142	58	257	0.29
			Westbound	1	900	271	10	291	0.17	291	11	313	0.18

Table notes:

[1] Peak hour traffic volumes have been estimated from AADT data

Appendix B

SIDRA Intersection results

Appendix B SIDRA Intersection results

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: Without Project 2024 - AM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 140 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
1	L2	290	24	305	8.3	0.659	56.9	LOS E	18.6	139.6	0.95	0.85	0.95	35.2
2	T1	232	19	244	8.2	* 0.839	78.3	LOS E	9.1	68.0	1.00	0.90	1.29	28.9
3	R2	11	1	12	9.1	0.155	81.1	LOS F	0.8	6.1	0.99	0.68	0.99	28.5
Approach		533	44	561	8.3	0.839	66.7	LOS E	18.6	139.6	0.97	0.87	1.10	32.0
East: Tiger Brennan Drive														
4	L2	24	0	25	0.0	0.018	12.0	LOS B	0.4	2.6	0.27	0.67	0.27	65.7
5	T1	1687	2	1776	0.1	* 0.868	31.1	LOS C	55.5	389.1	0.90	0.86	0.93	54.2
6	R2	223	0	235	0.0	* 0.885	83.6	LOS F	17.8	124.9	1.00	0.92	1.28	28.3
Approach		1934	2	2036	0.1	0.885	36.9	LOS D	55.5	389.1	0.90	0.86	0.97	49.1
North: Berrimah Road														
7	L2	105	8	111	7.6	0.106	8.2	LOS A	1.0	7.8	0.21	0.63	0.21	62.2
8	T1	225	17	237	7.6	0.811	75.6	LOS E	8.7	64.7	1.00	0.89	1.24	29.7
9	R2	67	5	71	7.5	* 0.933	97.4	LOS F	5.7	42.6	1.00	0.96	1.61	24.8
Approach		397	30	418	7.6	0.933	61.5	LOS E	8.7	64.7	0.79	0.84	1.03	33.2
West: Tiger Brennan Drive														
10	L2	115	0	121	0.0	0.090	13.1	LOS B	2.2	15.2	0.31	0.69	0.31	61.8
11	T1	552	1	581	0.2	0.271	17.5	LOS B	10.3	71.9	0.57	0.49	0.57	67.8
12	R2	188	0	198	0.0	0.746	73.4	LOS E	13.6	95.0	1.00	0.85	1.08	31.3
Approach		855	1	900	0.1	0.746	29.2	LOS C	13.6	95.0	0.63	0.60	0.65	53.4
All Vehicles		3719	77	3915	2.1	0.933	42.0	LOS D	55.5	389.1	0.84	0.80	0.92	44.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

Pedestrian Movement Performance

Mov ID	Crossing	Input Vol. ped/h	Dem. Flow ped/h	Aver. Delay sec	Level of Service	AVERAGE BACK OF QUEUE [Ped ped	Dist] m	Prop. Que	Effective Stop Rate	Travel Time sec	Travel Dist. m	Aver. Speed m/sec
South: Berrimah Road												
P1	Full	5	5	64.1	LOS F	0.0	0.0	0.96	0.96	238.4	226.5	0.95
West: Tiger Brennan Drive												
P4	Full	5	5	64.1	LOS F	0.0	0.0	0.96	0.96	236.8	224.5	0.95
All		10	11	64.1	LOS F	0.0	0.0	0.96	0.96	237.6	225.5	0.95

Pedestrians

Level of Service (LOS) Method: SIDRA Pedestrian LOS Method (Based on Average Delay)
Pedestrian movement LOS values are based on average delay per pedestrian movement.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

PHASING SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: Without Project 2024 - AM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Cycle Time)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, D, E, F, G
Output Phase Sequence: A, D, E, F, G

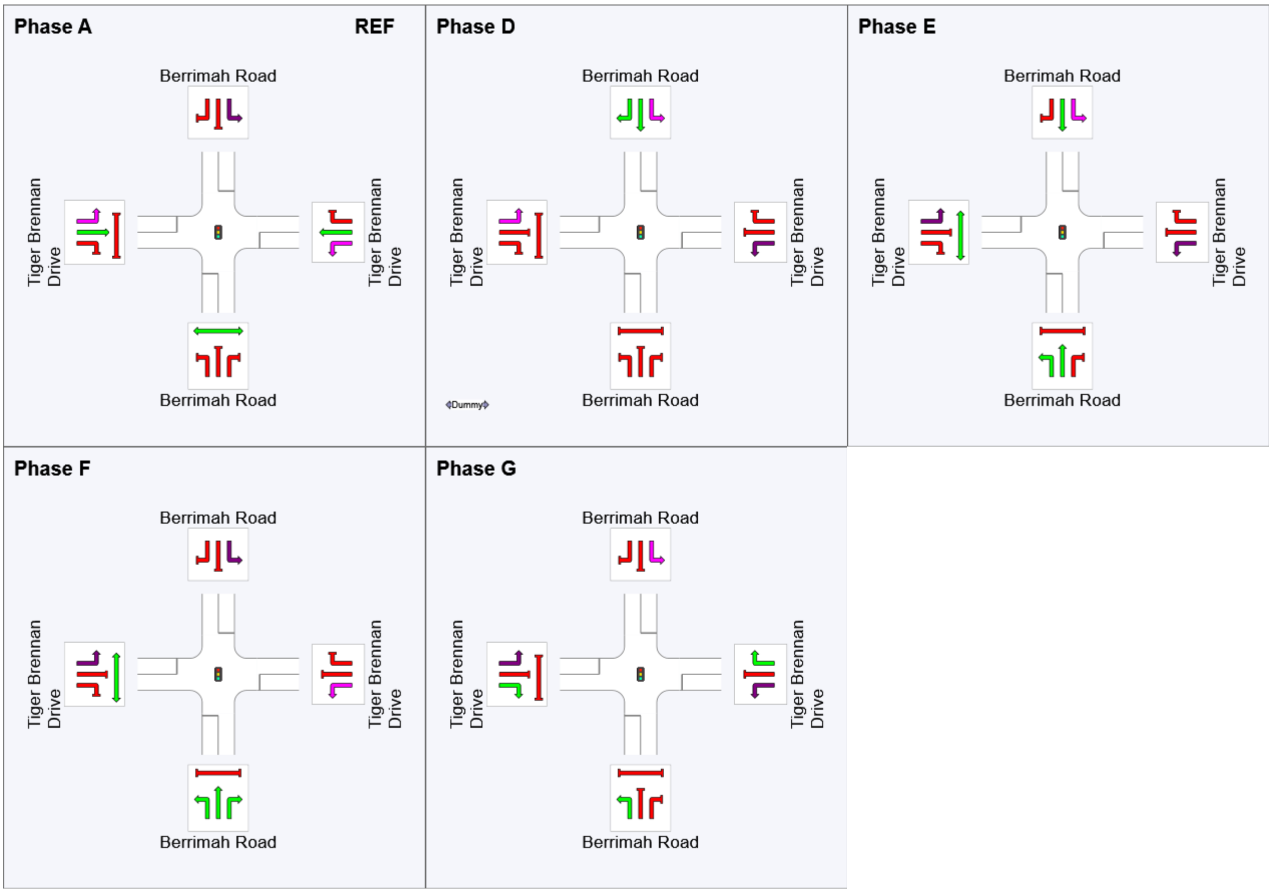
Phase Timing Summary

Phase	A	D	E	F	G
Phase Change Time (sec)	0	83	96	101	114
Green Time (sec)	77	6	***	6	20
Phase Time (sec)	84	13	5	12	26
Phase Split	60%	9%	4%	9%	19%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

*** No green time has been calculated for this phase because the next phase starts during its intergreen time.
This occurs with overlap phasing where there is no single movement connecting this phase to the next, or where the only such movement is a dummy movement with zero minimum green time specified.
If a green time is required for this phase, specify a dummy movement with a non-zero minimum green time.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase

	Normal Movement		Permitted/Opposed
	Slip/Bypass-Lane Movement		Opposed Slip/Bypass-Lane
	Stopped Movement		Turn On Red
	Other Movement Class (MC) Running		Undetected Movement
	Mixed Running & Stopped MCs		Continuous Movement
	Other Movement Class (MC) Stopped		Phase Transition Applied

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Wishart Drive / Tivendale Road (Site Folder: Without Project 2024 - AM Peak)]

Tiger Brennan Drive / Wishart Road / Tivendale Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated Cycle Time = 140 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Wishart Road														
1	L2	327	33	344	10.1	0.506	41.8	LOS D	17.6	134.2	0.81	0.82	0.81	38.9
2	T1	184	18	194	9.8	* 0.592	59.8	LOS E	12.3	93.3	0.97	0.81	0.97	30.5
3	R2	50	5	53	10.0	* 0.531	80.7	LOS F	3.7	28.2	1.00	0.75	1.01	26.6
Approach		561	56	591	10.0	0.592	51.2	LOS D	17.6	134.2	0.88	0.81	0.88	34.4
East: Tiger Brennan Drive														
4	L2	172	17	181	9.9	0.141	11.7	LOS B	2.6	19.9	0.27	0.70	0.27	62.3
5	T1	867	87	913	10.0	* 0.591	33.2	LOS C	23.7	180.5	0.83	0.73	0.83	52.4
6	R2	52	7	55	13.5	0.188	62.2	LOS E	3.2	25.2	0.89	0.76	0.89	32.5
Approach		1091	111	1148	10.2	0.591	31.2	LOS C	23.7	180.5	0.74	0.73	0.74	52.1
North: Tivendale Road														
7	L2	39	4	41	10.3	0.138	58.9	LOS E	2.4	18.2	0.88	0.73	0.88	32.0
8	T1	109	11	115	10.1	0.351	54.7	LOS D	6.9	52.7	0.92	0.74	0.92	31.6
9	R2	10	1	11	10.0	0.106	76.0	LOS E	0.7	5.4	0.98	0.68	0.98	27.8
Approach		158	16	166	10.1	0.351	57.1	LOS E	6.9	52.7	0.92	0.73	0.92	31.4
West: Tiger Brennan Drive														
10	L2	32	3	34	9.4	0.025	10.8	LOS B	0.4	2.9	0.22	0.67	0.22	60.6
11	T1	450	45	474	10.0	0.307	28.5	LOS C	10.6	80.4	0.71	0.60	0.71	56.2
12	R2	166	17	175	10.2	* 0.589	66.7	LOS E	11.2	85.1	0.97	0.82	0.97	30.4
Approach		648	65	682	10.0	0.589	37.4	LOS D	11.2	85.1	0.75	0.66	0.75	47.0
All Vehicles		2458	248	2587	10.1	0.592	39.1	LOS D	23.7	180.5	0.79	0.73	0.79	44.1

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

PHASING SUMMARY

Site: [Tiger Brennan Drive / Wishart Drive / Tivendale Road (Site Folder: Without Project 2024 - AM Peak)]

Tiger Brennan Drive / Wishart Road / Tivendale Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Cycle Time)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, D, E, G
Output Phase Sequence: A, D, E, G

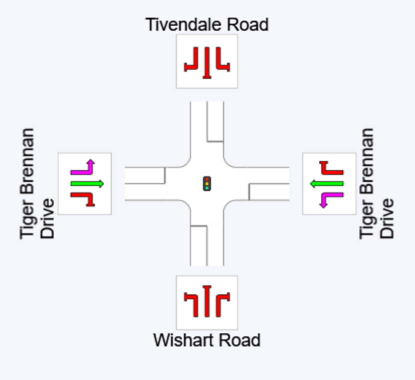
Phase Timing Summary

Phase	A	D	E	G
Phase Change Time (sec)	0	65	79	110
Green Time (sec)	59	8	25	24
Phase Time (sec)	65	14	31	30
Phase Split	46%	10%	22%	21%

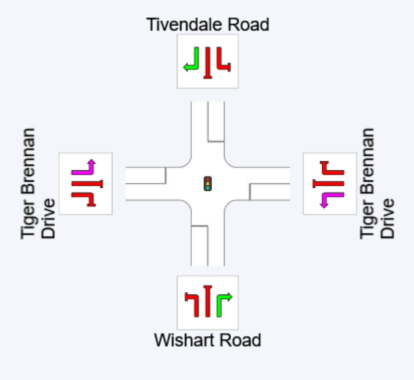
See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

Output Phase Sequence

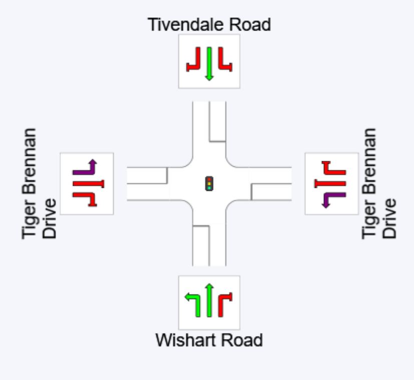
Phase A **REF**



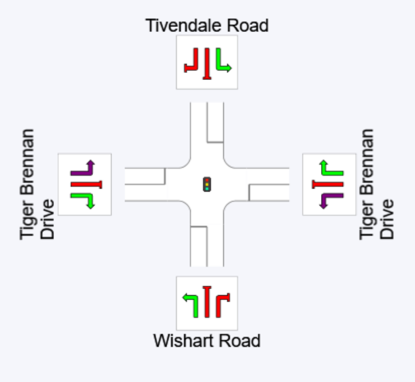
Phase D



Phase E



Phase G



REF: Reference Phase
VAR: Variable Phase

Normal Movement	Permitted/Opposed
Slip/Bypass-Lane Movement	Opposed Slip/Bypass-Lane
Stopped Movement	Turn On Red
Other Movement Class (MC) Running	Undetected Movement
Mixed Running & Stopped MCs	Continuous Movement
Other Movement Class (MC) Stopped	Phase Transition Applied

MOVEMENT SUMMARY

Site: [Berrimah Road / Wishart Road (Site Folder: Without Project 2024 - AM Peak)]

Berrimah Road / Wishart Road
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 60 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance														
Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
2	T1	136	37	143	27.2	0.130	15.3	LOS B	1.5	12.8	0.73	0.57	0.73	60.0
3	R2	64	18	67	28.1	* 0.435	37.6	LOS D	2.0	17.7	0.98	0.76	0.98	38.9
Approach		200	55	211	27.5	0.435	22.4	LOS C	2.0	17.7	0.81	0.63	0.81	51.2
East: Wishart Road														
4	L2	1	0	1	0.0	0.001	8.3	LOS A	0.0	0.0	0.26	0.61	0.26	64.3
6	R2	721	198	759	27.5	* 0.524	20.0	LOS B	8.0	69.3	0.75	0.81	0.75	48.0
Approach		722	198	760	27.4	0.524	20.0	LOS B	8.0	69.3	0.75	0.81	0.75	48.0
North: Berrimah Road														
7	L2	83	23	87	27.7	0.080	8.7	LOS A	0.4	3.2	0.26	0.65	0.26	56.6
8	T1	210	58	221	27.6	* 0.501	28.0	LOS C	3.2	28.0	0.97	0.76	0.97	49.7
Approach		293	81	308	27.6	0.501	22.5	LOS C	3.2	28.0	0.77	0.73	0.77	51.5
All Vehicles		1215	334	1279	27.5	0.524	21.0	LOS C	8.0	69.3	0.77	0.76	0.77	49.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

PHASING SUMMARY

Site: [Berrimah Road / Wishart Road (Site Folder: Without Project 2024 - AM Peak)]

Berrimah Road / Wishart Road
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 60 seconds (Site User-Given Cycle Time)

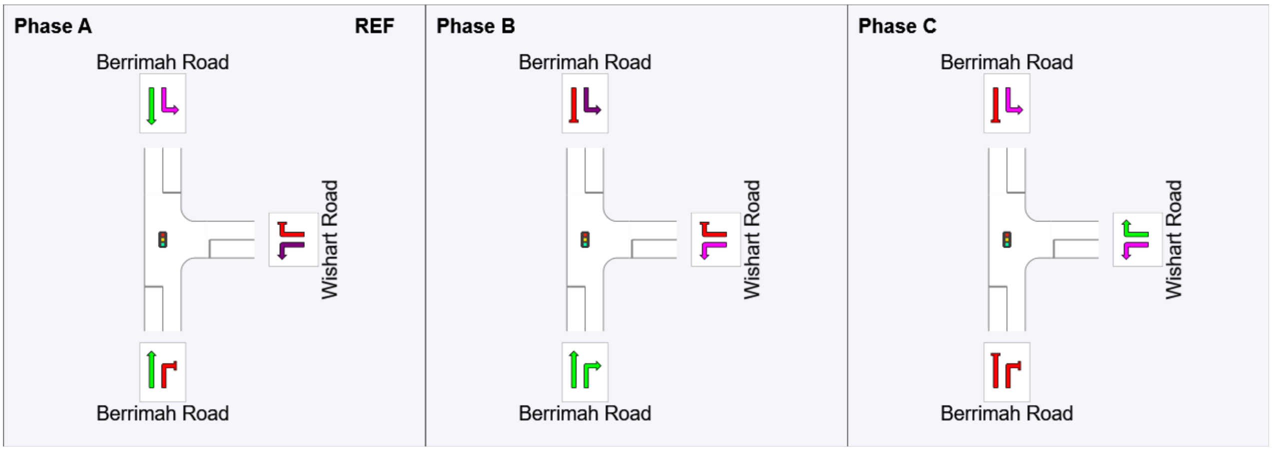
Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, B, C
Output Phase Sequence: A, B, C

Phase Timing Summary

Phase	A	B	C
Phase Change Time (sec)	0	14	26
Green Time (sec)	8	6	28
Phase Time (sec)	14	12	34
Phase Split	23%	20%	57%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase

Normal Movement	Permitted/Opposed
Slip/Bypass-Lane Movement	Opposed Slip/Bypass-Lane
Stopped Movement	Turn On Red
Other Movement Class (MC) Running	Undetected Movement
Mixed Running & Stopped MCs	Continuous Movement
Other Movement Class (MC) Stopped	Phase Transition Applied

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: Without Project 2024 - PM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
1	L2	76	6	80	7.9	0.185	49.0	LOS D	4.0	29.9	0.83	0.76	0.83	38.1
2	T1	182	15	192	8.2	* 0.841	75.2	LOS E	6.7	50.3	1.00	0.89	1.35	29.6
3	R2	28	2	29	7.1	0.361	76.8	LOS E	1.9	14.5	1.00	0.72	1.00	29.6
Approach		286	23	301	8.0	0.841	68.4	LOS E	6.7	50.3	0.95	0.84	1.17	31.5
East: Tiger Brennan Drive														
4	L2	8	0	8	0.0	0.006	11.3	LOS B	0.1	0.7	0.26	0.66	0.26	66.5
5	T1	756	1	796	0.1	0.369	17.1	LOS B	13.9	97.2	0.60	0.53	0.60	68.2
6	R2	56	0	59	0.0	0.229	62.7	LOS E	3.4	23.6	0.93	0.76	0.93	33.7
Approach		820	1	863	0.1	0.369	20.2	LOS C	13.9	97.2	0.62	0.55	0.62	63.8
North: Berrimah Road														
7	L2	225	19	237	8.4	0.379	24.9	LOS C	8.5	63.9	0.67	0.77	0.67	48.4
8	T1	136	11	143	8.1	0.628	68.5	LOS E	4.7	35.5	1.00	0.79	1.07	31.5
9	R2	51	4	54	7.8	* 0.661	78.5	LOS E	3.7	27.3	1.00	0.79	1.14	28.4
Approach		412	34	434	8.3	0.661	46.0	LOS D	8.5	63.9	0.82	0.78	0.86	38.3
West: Tiger Brennan Drive														
10	L2	52	0	55	0.0	0.036	9.7	LOS A	0.5	3.3	0.19	0.67	0.19	65.6
11	T1	1597	2	1681	0.1	* 0.857	28.1	LOS C	49.3	345.5	0.86	0.82	0.90	56.7
12	R2	208	0	219	0.0	* 0.851	75.7	LOS E	15.1	105.4	1.00	0.90	1.24	30.7
Approach		1857	2	1955	0.1	0.857	32.9	LOS C	49.3	345.5	0.86	0.82	0.92	52.0
All Vehicles		3375	60	3553	1.8	0.857	34.4	LOS C	49.3	345.5	0.80	0.75	0.86	49.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

Pedestrian Movement Performance

Mov ID	Crossing	Input Vol. ped/h	Dem. Flow ped/h	Aver. Delay sec	Level of Service	AVERAGE BACK OF QUEUE [Ped ped	Dist] m	Prop. Que	Effective Stop Rate	Travel Time sec	Travel Dist. m	Aver. Speed m/sec
South: Berrimah Road												
P1	Full	5	5	59.2	LOS E	0.0	0.0	0.95	0.95	233.4	226.5	0.97
West: Tiger Brennan Drive												
P4	Full	5	5	59.2	LOS E	0.0	0.0	0.95	0.95	231.8	224.5	0.97
All		10	11	59.2	LOS E	0.0	0.0	0.95	0.95	232.6	225.5	0.97

Pedestrians

Level of Service (LOS) Method: SIDRA Pedestrian LOS Method (Based on Average Delay)
Pedestrian movement LOS values are based on average delay per pedestrian movement.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

PHASING SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: Without Project 2024 - PM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, D, E, F, G
Output Phase Sequence: A, D, E, F, G

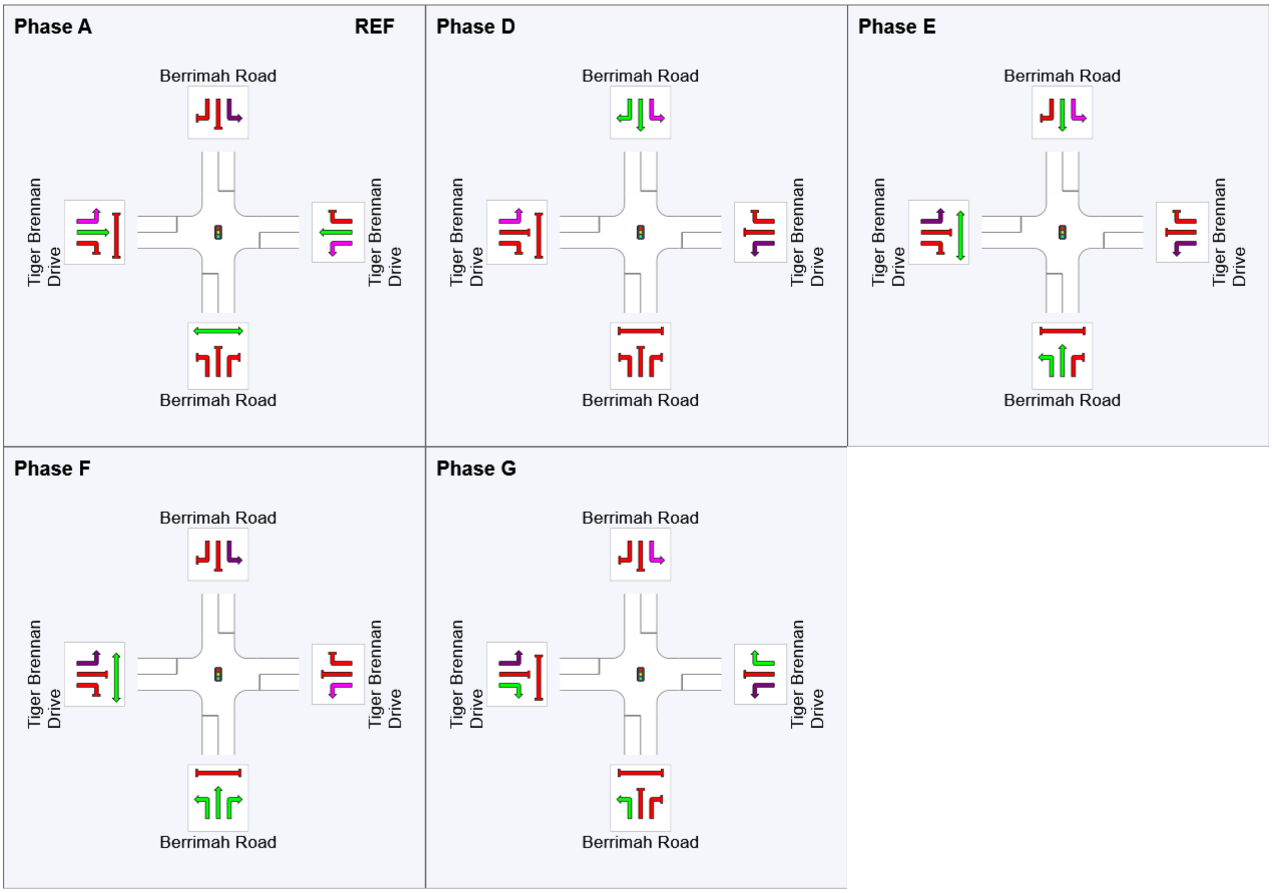
Phase Timing Summary

Phase	A	D	E	F	G
Phase Change Time (sec)	0	78	91	93	106
Green Time (sec)	72	6	***	6	18
Phase Time (sec)	79	13	2	12	24
Phase Split	61%	10%	2%	9%	18%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

*** No green time has been calculated for this phase because the next phase starts during its intergreen time. This occurs with overlap phasing where there is no single movement connecting this phase to the next, or where the only such movement is a dummy movement with zero minimum green time specified.
If a green time is required for this phase, specify a dummy movement with a non-zero minimum green time.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase

Normal Movement	Permitted/Opposed
Slip/Bypass-Lane Movement	Opposed Slip/Bypass-Lane
Stopped Movement	Turn On Red
Other Movement Class (MC) Running	Undetected Movement
Mixed Running & Stopped MCs	Continuous Movement
Other Movement Class (MC) Stopped	Phase Transition Applied

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Wishart Drive / Tivendale Road (Site Folder: Without Project 2024 - PM Peak)]

Tiger Brennan Drive / Wishart Road / Tivendale Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Wishart Road														
1	L2	153	15	161	9.8	0.159	14.3	LOS B	2.8	21.0	0.48	0.72	0.48	57.4
2	T1	116	12	122	10.3	0.414	55.8	LOS E	7.1	53.9	0.94	0.77	0.94	31.7
3	R2	96	10	101	10.4	* 0.760	76.7	LOS E	6.8	52.1	1.00	0.85	1.19	27.5
Approach		365	37	384	10.1	0.760	43.9	LOS D	7.1	53.9	0.77	0.77	0.82	37.2
East: Tiger Brennan Drive														
4	L2	26	3	27	11.5	0.034	21.4	LOS C	0.7	5.7	0.50	0.70	0.50	52.5
5	T1	300	30	316	10.0	0.561	55.9	LOS E	9.5	71.9	0.98	0.79	0.98	39.6
6	R2	44	4	46	9.1	0.288	69.6	LOS E	2.8	21.4	0.97	0.75	0.97	30.6
Approach		370	37	389	10.0	0.561	55.1	LOS E	9.5	71.9	0.94	0.78	0.94	38.8
North: Tivendale Road														
7	L2	72	7	76	9.7	0.473	68.5	LOS E	4.8	36.1	0.99	0.77	0.99	29.6
8	T1	216	22	227	10.2	* 0.770	60.1	LOS E	14.6	111.2	1.00	0.90	1.10	30.0
9	R2	8	1	8	12.5	0.064	67.4	LOS E	0.5	4.0	0.95	0.67	0.95	29.6
Approach		296	30	312	10.1	0.770	62.3	LOS E	14.6	111.2	1.00	0.86	1.07	29.9
West: Tiger Brennan Drive														
10	L2	14	1	15	7.1	0.010	9.8	LOS A	0.1	0.9	0.18	0.66	0.18	61.6
11	T1	1348	135	1419	10.0	* 0.801	30.1	LOS C	37.6	286.0	0.91	0.83	0.91	54.9
12	R2	491	49	517	10.0	* 0.791	39.0	LOS D	19.9	151.3	0.95	0.92	0.98	40.9
Approach		1853	185	1951	10.0	0.801	32.3	LOS C	37.6	286.0	0.92	0.85	0.92	50.7
All Vehicles		2884	289	3036	10.0	0.801	39.8	LOS D	37.6	286.0	0.91	0.83	0.93	44.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

PHASING SUMMARY

Site: [Tiger Brennan Drive / Wishart Drive / Tivendale Road (Site Folder: Without Project 2024 - PM Peak)]

Tiger Brennan Drive / Wishart Road / Tivendale Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

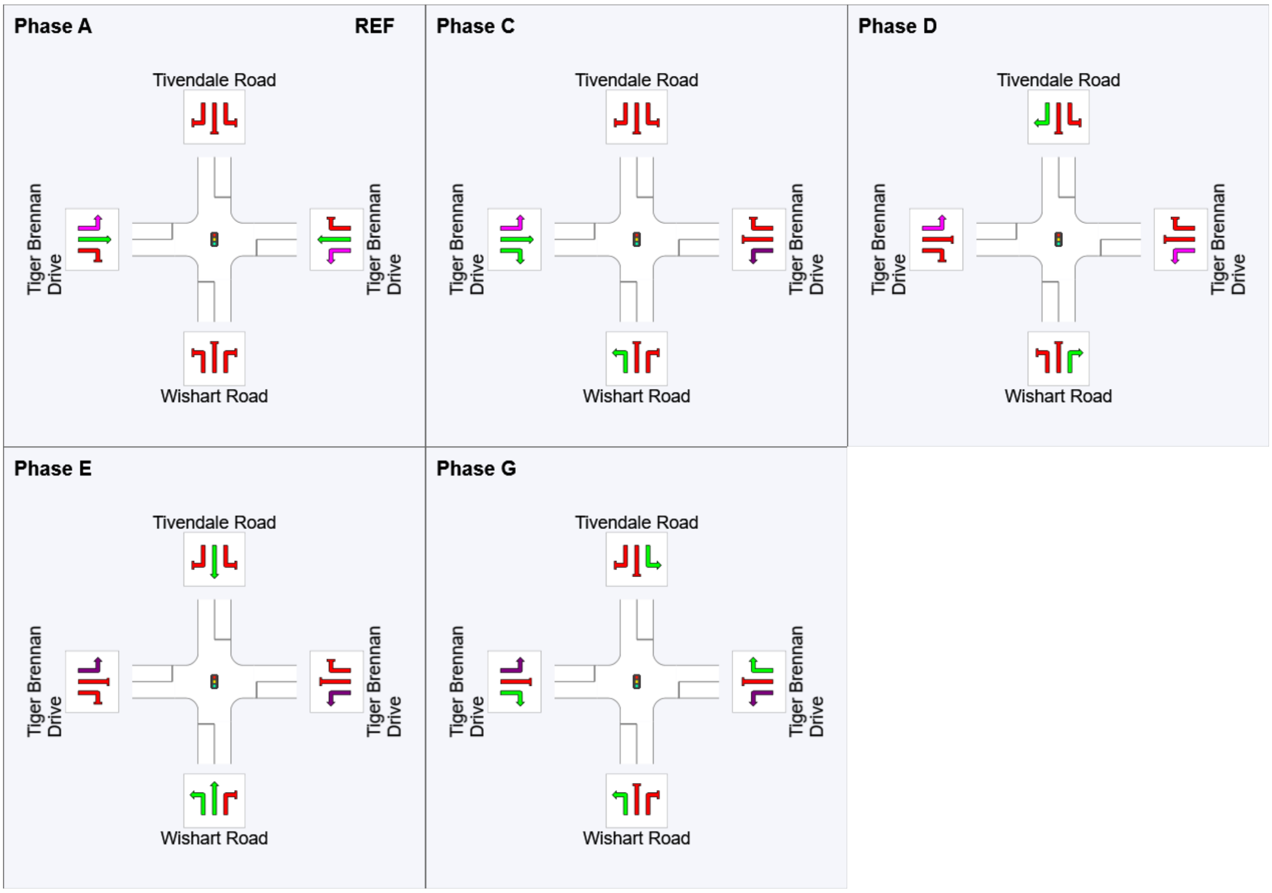
Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, C, D, E, G
Output Phase Sequence: A, C, D, E, G

Phase Timing Summary

Phase	A	C	D	E	G
Phase Change Time (sec)	0	26	69	85	112
Green Time (sec)	20	37	10	21	12
Phase Time (sec)	26	43	16	27	18
Phase Split	20%	33%	12%	21%	14%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase

Normal Movement	Permitted/Opposed
Slip/Bypass-Lane Movement	Opposed Slip/Bypass-Lane
Stopped Movement	Turn On Red
Other Movement Class (MC) Running	Undetected Movement
Mixed Running & Stopped MCs	Continuous Movement
Other Movement Class (MC) Stopped	Phase Transition Applied

MOVEMENT SUMMARY

Site: [Berrimah Road / Wishart Road (Site Folder: Without Project 2024 - PM Peak)]

Berrimah Road / Wishart Road
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 120 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
2	T1	389	107	409	27.5	0.171	5.4	LOS A	3.7	31.8	0.33	0.29	0.33	71.5
3	R2	322	88	339	27.3	* 0.374	21.7	LOS C	10.4	90.2	0.57	0.77	0.57	47.0
Approach		711	195	748	27.4	0.374	12.8	LOS B	10.4	90.2	0.44	0.50	0.44	57.8
East: Wishart Road														
4	L2	1	0	1	0.0	0.001	7.7	LOS A	0.0	0.0	0.11	0.61	0.11	65.1
6	R2	191	52	201	27.2	* 0.369	55.6	LOS E	5.3	45.8	0.93	0.78	0.93	32.7
Approach		192	52	202	27.1	0.369	55.4	LOS E	5.3	45.8	0.92	0.78	0.92	32.8
North: Berrimah Road														
7	L2	322	88	339	27.3	0.379	10.3	LOS B	4.6	39.5	0.32	0.69	0.32	55.5
8	T1	54	15	57	27.8	* 0.188	56.3	LOS E	1.6	13.9	0.96	0.70	0.96	35.9
Approach		376	103	396	27.4	0.379	16.9	LOS B	4.6	39.5	0.41	0.69	0.41	51.4
All Vehicles		1279	350	1346	27.4	0.379	20.4	LOS C	10.4	90.2	0.50	0.60	0.50	50.3

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

PHASING SUMMARY

Site: [Berrimah Road / Wishart Road (Site Folder: Without Project 2024 - PM Peak)]

Berrimah Road / Wishart Road
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 120 seconds (Site User-Given Cycle Time)

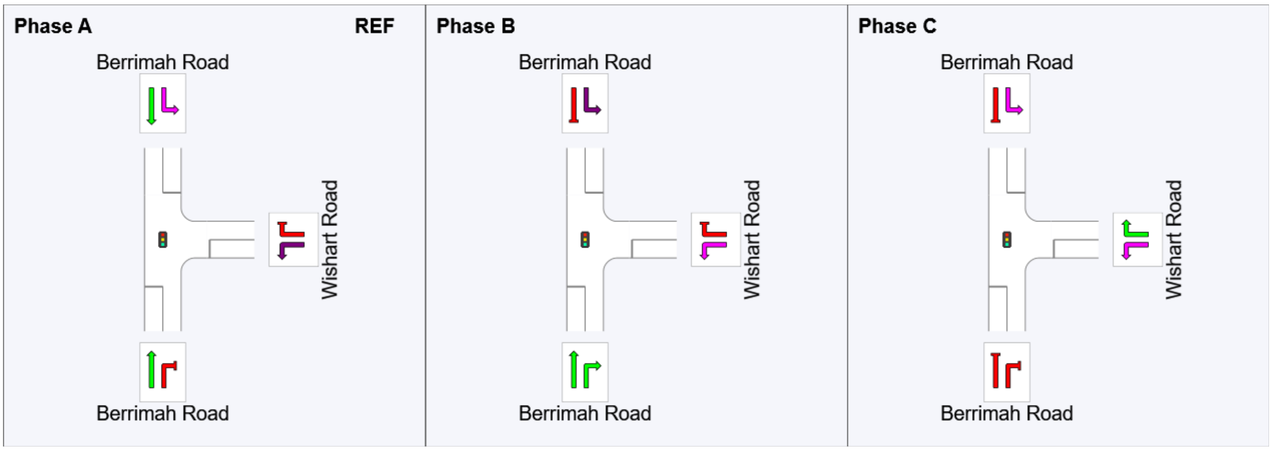
Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, B, C
Output Phase Sequence: A, B, C

Phase Timing Summary

Phase	A	B	C
Phase Change Time (sec)	0	17	93
Green Time (sec)	11	70	21
Phase Time (sec)	17	76	27
Phase Split	14%	63%	23%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: With Project 2024 - AM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 140 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
1	L2	294	28	309	9.5	0.673	57.2	LOS E	19.0	143.7	0.95	0.85	0.95	35.0
2	T1	232	19	244	8.2	* 0.839	78.3	LOS E	9.1	68.0	1.00	0.90	1.29	28.9
3	R2	12	2	13	16.7	0.178	81.7	LOS F	0.9	7.1	0.99	0.68	0.99	28.0
Approach		538	49	566	9.1	0.839	66.8	LOS E	19.0	143.7	0.97	0.87	1.10	31.9
East: Tiger Brennan Drive														
4	L2	25	1	26	4.0	0.020	12.1	LOS B	0.4	2.8	0.27	0.67	0.27	64.4
5	T1	1687	2	1776	0.1	* 0.868	31.1	LOS C	55.5	389.1	0.90	0.86	0.93	54.2
6	R2	223	0	235	0.0	* 0.885	83.6	LOS F	17.8	124.9	1.00	0.92	1.28	28.3
Approach		1935	3	2037	0.2	0.885	36.9	LOS D	55.5	389.1	0.90	0.86	0.97	49.1
North: Berrimah Road														
7	L2	105	8	111	7.6	0.107	8.4	LOS A	1.1	8.2	0.21	0.64	0.21	62.0
8	T1	225	17	237	7.6	0.811	75.6	LOS E	8.7	64.7	1.00	0.89	1.24	29.7
9	R2	67	5	71	7.5	* 0.933	97.4	LOS F	5.7	42.6	1.00	0.96	1.61	24.8
Approach		397	30	418	7.6	0.933	61.5	LOS E	8.7	64.7	0.79	0.84	1.03	33.1
West: Tiger Brennan Drive														
10	L2	115	0	121	0.0	0.090	13.1	LOS B	2.2	15.2	0.31	0.69	0.31	61.8
11	T1	552	1	581	0.2	0.271	17.5	LOS B	10.3	71.9	0.57	0.49	0.57	67.8
12	R2	192	4	202	2.1	0.773	74.7	LOS E	14.1	100.3	1.00	0.86	1.11	30.8
Approach		859	5	904	0.6	0.773	29.7	LOS C	14.1	100.3	0.63	0.60	0.65	52.9
All Vehicles		3729	87	3925	2.3	0.933	42.2	LOS D	55.5	389.1	0.84	0.80	0.92	44.1

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

Pedestrian Movement Performance

Mov ID	Crossing	Input Vol. ped/h	Dem. Flow ped/h	Aver. Delay sec	Level of Service	AVERAGE BACK OF QUEUE [Ped ped	Dist] m	Prop. Que	Effective Stop Rate	Travel Time sec	Travel Dist. m	Aver. Speed m/sec
South: Berrimah Road												
P1	Full	5	5	64.1	LOS F	0.0	0.0	0.96	0.96	238.4	226.5	0.95
West: Tiger Brennan Drive												
P4	Full	5	5	64.1	LOS F	0.0	0.0	0.96	0.96	236.8	224.5	0.95
All		10	11	64.1	LOS F	0.0	0.0	0.96	0.96	237.6	225.5	0.95

Pedestrians

Level of Service (LOS) Method: SIDRA Pedestrian LOS Method (Based on Average Delay)
Pedestrian movement LOS values are based on average delay per pedestrian movement.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: With Project 2024 - PM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
1	L2	80	10	84	12.5	0.201	49.3	LOS D	4.2	32.8	0.83	0.76	0.83	37.6
2	T1	182	15	192	8.2	* 0.841	75.2	LOS E	6.7	50.3	1.00	0.89	1.35	29.6
3	R2	29	3	31	10.3	0.382	77.1	LOS E	2.0	15.4	1.00	0.72	1.00	29.4
Approach		291	28	306	9.6	0.841	68.3	LOS E	6.7	50.3	0.95	0.84	1.17	31.4
East: Tiger Brennan Drive														
4	L2	9	1	9	11.1	0.007	11.8	LOS B	0.1	1.0	0.26	0.66	0.26	62.7
5	T1	756	1	796	0.1	0.369	17.1	LOS B	13.9	97.2	0.60	0.53	0.60	68.2
6	R2	56	0	59	0.0	0.229	62.7	LOS E	3.4	23.6	0.93	0.76	0.93	33.7
Approach		821	2	864	0.2	0.369	20.2	LOS C	13.9	97.2	0.62	0.55	0.62	63.7
North: Berrimah Road														
7	L2	225	19	237	8.4	0.380	24.9	LOS C	8.5	64.0	0.67	0.77	0.67	48.4
8	T1	136	11	143	8.1	0.628	68.5	LOS E	4.7	35.5	1.00	0.79	1.07	31.5
9	R2	51	4	54	7.8	* 0.661	78.5	LOS E	3.7	27.3	1.00	0.79	1.14	28.4
Approach		412	34	434	8.3	0.661	46.0	LOS D	8.5	64.0	0.82	0.78	0.86	38.3
West: Tiger Brennan Drive														
10	L2	52	0	55	0.0	0.036	9.7	LOS A	0.5	3.3	0.19	0.67	0.19	65.6
11	T1	1597	2	1681	0.1	* 0.859	28.4	LOS C	49.7	348.3	0.86	0.82	0.90	56.5
12	R2	212	4	223	1.9	* 0.880	78.8	LOS E	15.8	112.4	1.00	0.92	1.30	29.8
Approach		1861	6	1959	0.3	0.880	33.6	LOS C	49.7	348.3	0.86	0.83	0.93	51.4
All Vehicles		3385	70	3563	2.1	0.880	34.9	LOS C	49.7	348.3	0.80	0.75	0.87	49.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

Pedestrian Movement Performance

Mov ID	Crossing	Input Vol. ped/h	Dem. Flow ped/h	Aver. Delay sec	Level of Service	AVERAGE BACK OF QUEUE [Ped ped	Dist] m	Prop. Que	Effective Stop Rate	Travel Time sec	Travel Dist. m	Aver. Speed m/sec
South: Berrimah Road												
P1	Full	5	5	59.2	LOS E	0.0	0.0	0.95	0.95	233.4	226.5	0.97
West: Tiger Brennan Drive												
P4	Full	5	5	59.2	LOS E	0.0	0.0	0.95	0.95	231.8	224.5	0.97
All		10	11	59.2	LOS E	0.0	0.0	0.95	0.95	232.6	225.5	0.97

Pedestrians

Level of Service (LOS) Method: SIDRA Pedestrian LOS Method (Based on Average Delay)
Pedestrian movement LOS values are based on average delay per pedestrian movement.
Intersection LOS value for Pedestrians is based on average delay for all pedestrian movements.

PHASING SUMMARY

Site: [Tiger Brennan Drive / Berrimah Road (Site Folder: With Project 2024 - PM Peak)]

Tiger Brennan Drive / Berrimah Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, D, E, F, G
Output Phase Sequence: A, D, E, F, G

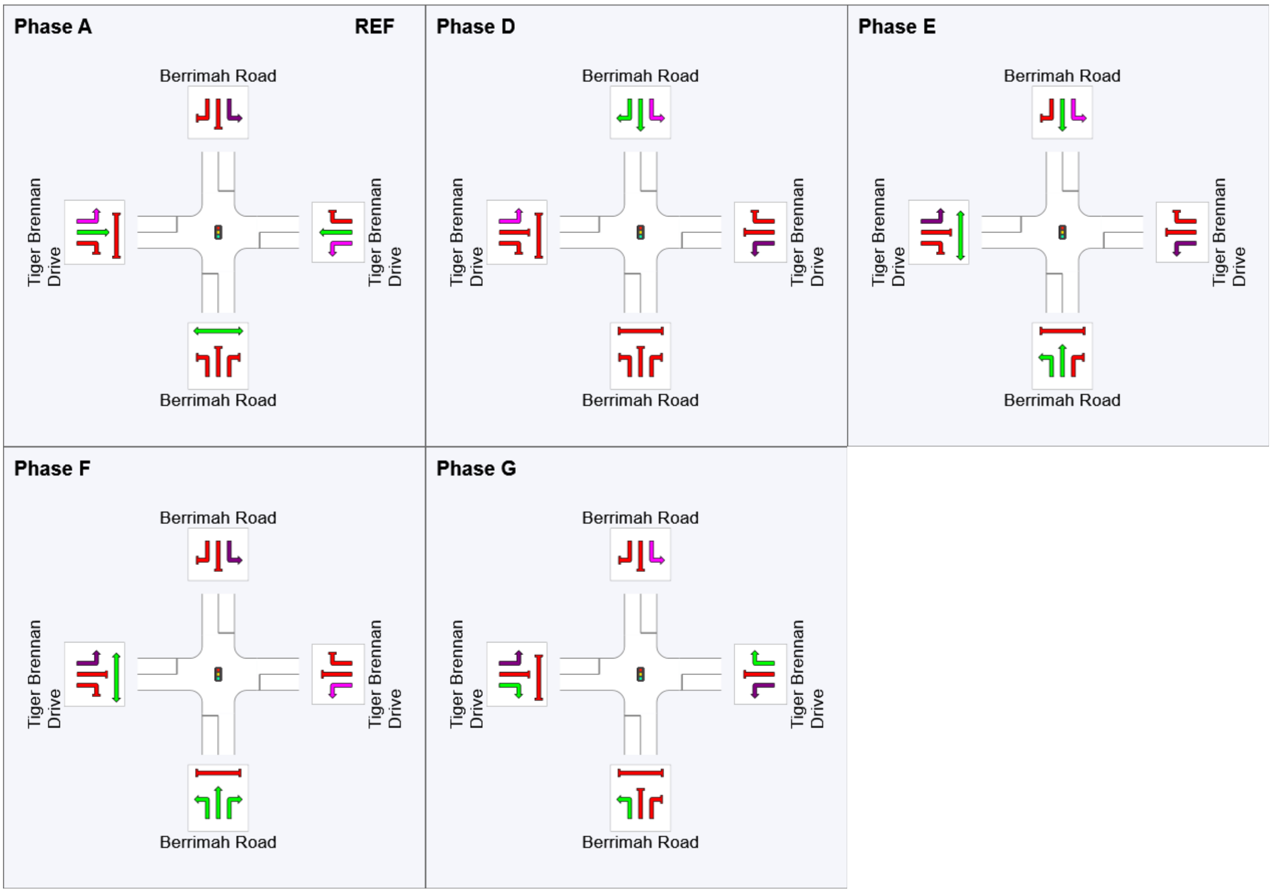
Phase Timing Summary

Phase	A	D	E	F	G
Phase Change Time (sec)	0	78	91	93	106
Green Time (sec)	72	6	***	6	18
Phase Time (sec)	79	13	2	12	24
Phase Split	61%	10%	2%	9%	18%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

*** No green time has been calculated for this phase because the next phase starts during its intergreen time. This occurs with overlap phasing where there is no single movement connecting this phase to the next, or where the only such movement is a dummy movement with zero minimum green time specified.
If a green time is required for this phase, specify a dummy movement with a non-zero minimum green time.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase

	Normal Movement		Permitted/Opposed
	Slip/Bypass-Lane Movement		Opposed Slip/Bypass-Lane
	Stopped Movement		Turn On Red
	Other Movement Class (MC) Running		Undetected Movement
	Mixed Running & Stopped MCs		Continuous Movement
	Other Movement Class (MC) Stopped		Phase Transition Applied

MOVEMENT SUMMARY

Site: [Tiger Brennan Drive / Wishart Drive / Tivendale Road (Site Folder: With Project 2024 - PM Peak)]

Tiger Brennan Drive / Wishart Road / Tivendale Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Wishart Road														
1	L2	153	15	161	9.8	0.161	14.8	LOS B	3.0	22.4	0.49	0.72	0.49	57.0
2	T1	116	12	122	10.3	0.434	56.9	LOS E	7.1	54.5	0.95	0.78	0.95	31.4
3	R2	96	10	101	10.4	* 0.844	81.3	LOS F	7.1	54.2	1.00	0.90	1.35	26.5
Approach		365	37	384	10.1	0.844	45.7	LOS D	7.1	54.5	0.77	0.79	0.86	36.5
East: Tiger Brennan Drive														
4	L2	26	3	27	11.5	0.034	21.8	LOS C	0.8	5.8	0.51	0.70	0.51	52.1
5	T1	301	31	317	10.3	0.512	53.7	LOS D	9.3	70.8	0.96	0.78	0.96	40.5
6	R2	44	4	46	9.1	0.203	63.6	LOS E	2.7	20.2	0.93	0.75	0.93	32.2
Approach		371	38	391	10.2	0.512	52.7	LOS D	9.3	70.8	0.92	0.77	0.92	39.9
North: Tivendale Road														
7	L2	72	7	76	9.7	0.334	62.3	LOS E	4.5	33.9	0.95	0.77	0.95	31.2
8	T1	216	22	227	10.2	* 0.808	62.9	LOS E	15.0	114.5	1.00	0.93	1.16	29.3
9	R2	8	1	8	12.5	0.071	68.8	LOS E	0.5	4.0	0.96	0.67	0.96	29.3
Approach		296	30	312	10.1	0.808	62.9	LOS E	15.0	114.5	0.99	0.88	1.10	29.8
West: Tiger Brennan Drive														
10	L2	14	1	15	7.1	0.010	9.7	LOS A	0.1	0.9	0.18	0.66	0.18	61.8
11	T1	1349	136	1420	10.1	* 0.843	36.6	LOS D	41.7	317.4	0.95	0.90	1.00	50.0
12	R2	491	49	517	10.0	* 0.791	33.4	LOS C	17.7	134.3	0.95	0.89	0.98	44.0
Approach		1854	186	1952	10.0	0.843	35.5	LOS D	41.7	317.4	0.95	0.89	0.99	48.5
All Vehicles		2886	291	3038	10.1	0.844	41.8	LOS D	41.7	317.4	0.92	0.86	0.98	42.9

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

PHASING SUMMARY

Site: [Tiger Brennan Drive / Wishart Drive / Tivendale Road (Site Folder: With Project 2024 - PM Peak)]

Tiger Brennan Drive / Wishart Road / Tivendale Road
Site Category: Base Year
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 130 seconds (Site User-Given Cycle Time)

Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, C, D, E, G
Output Phase Sequence: A, C, D, E, G

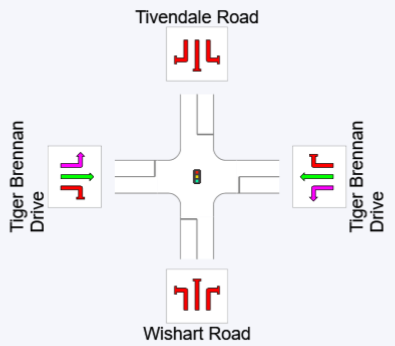
Phase Timing Summary

Phase	A	C	D	E	G
Phase Change Time (sec)	0	28	66	81	107
Green Time (sec)	22	32	9	20	17
Phase Time (sec)	28	38	15	26	23
Phase Split	22%	29%	12%	20%	18%

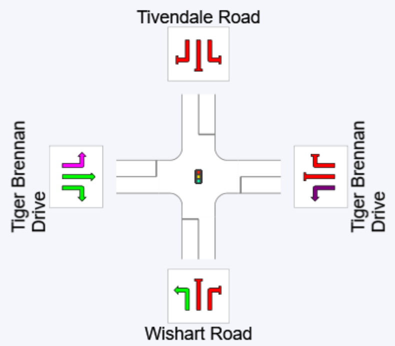
See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

Output Phase Sequence

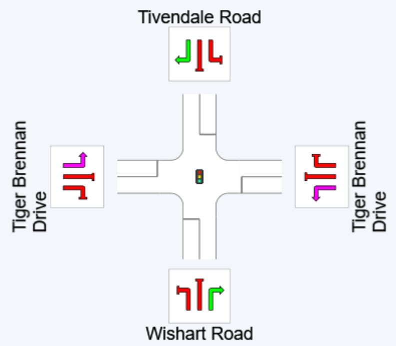
Phase A **REF**



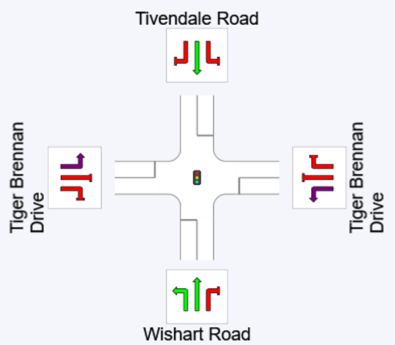
Phase C



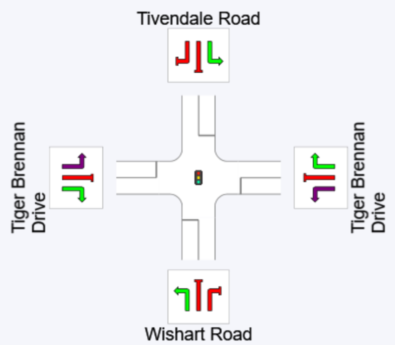
Phase D



Phase E



Phase G



REF: Reference Phase
VAR: Variable Phase

Normal Movement		Permitted/Opposed	
Slip/Bypass-Lane Movement		Opposed Slip/Bypass-Lane	
Stopped Movement		Turn On Red	
Other Movement Class (MC) Running		Undetected Movement	
Mixed Running & Stopped MCs		Continuous Movement	
Other Movement Class (MC) Stopped		Phase Transition Applied	

MOVEMENT SUMMARY

Site: [Berrimah Road / Wishart Road (Site Folder: With Project 2024 - PM Peak)]

Berrimah Road / Wishart Road
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 50 seconds (Site User-Given Cycle Time)

Vehicle Movement Performance

Mov ID	Turn	INPUT VOLUMES [Total veh/h	HV] veh/h	DEMAND FLOWS [Total veh/h	HV] %	Deg. Satn v/c	Aver. Delay sec	Level of Service	95% BACK OF QUEUE [Veh. veh	Dist] m	Prop. Que	Effective Stop Rate	Aver. No. Cycles	Aver. Speed km/h
South: Berrimah Road														
2	T1	394	112	415	28.4	0.197	4.0	LOS A	2.1	18.3	0.44	0.37	0.44	73.6
3	R2	343	92	361	26.8	* 0.579	20.6	LOS C	7.1	61.5	0.83	0.82	0.83	47.7
Approach		737	204	776	27.7	0.579	11.8	LOS B	7.1	61.5	0.62	0.58	0.62	58.8
East: Wishart Road														
4	L2	5	4	5	80.0	0.006	9.4	LOS A	0.0	0.2	0.25	0.61	0.25	46.2
6	R2	191	52	201	27.2	* 0.539	32.3	LOS C	2.6	22.1	0.98	0.79	1.03	41.4
Approach		196	56	206	28.6	0.539	31.7	LOS C	2.6	22.1	0.96	0.79	1.01	41.5
North: Berrimah Road														
7	L2	322	88	339	27.3	0.430	11.7	LOS B	3.5	30.1	0.59	0.76	0.59	54.2
8	T1	59	20	62	33.9	* 0.162	23.0	LOS C	0.7	6.6	0.93	0.67	0.93	53.3
Approach		381	108	401	28.3	0.430	13.5	LOS B	3.5	30.1	0.65	0.74	0.65	54.1
All Vehicles		1314	368	1383	28.0	0.579	15.2	LOS B	7.1	61.5	0.68	0.66	0.69	54.0

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Vehicle movement LOS values are based on average delay per movement.
Intersection and Approach LOS values are based on average delay for all vehicle movements.
Delay Model: SIDRA Standard (Geometric Delay is included).
Queue Model: SIDRA Standard.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

* Critical Movement (Signal Timing)

PHASING SUMMARY

Site: [Berrimah Road / Wishart Road (Site Folder: With Project 2024 - PM Peak)]

Berrimah Road / Wishart Road
Site Category: (None)
Signals - EQUISAT (Fixed-Time/SCATS) Isolated   Cycle Time = 50 seconds (Site User-Given Cycle Time)

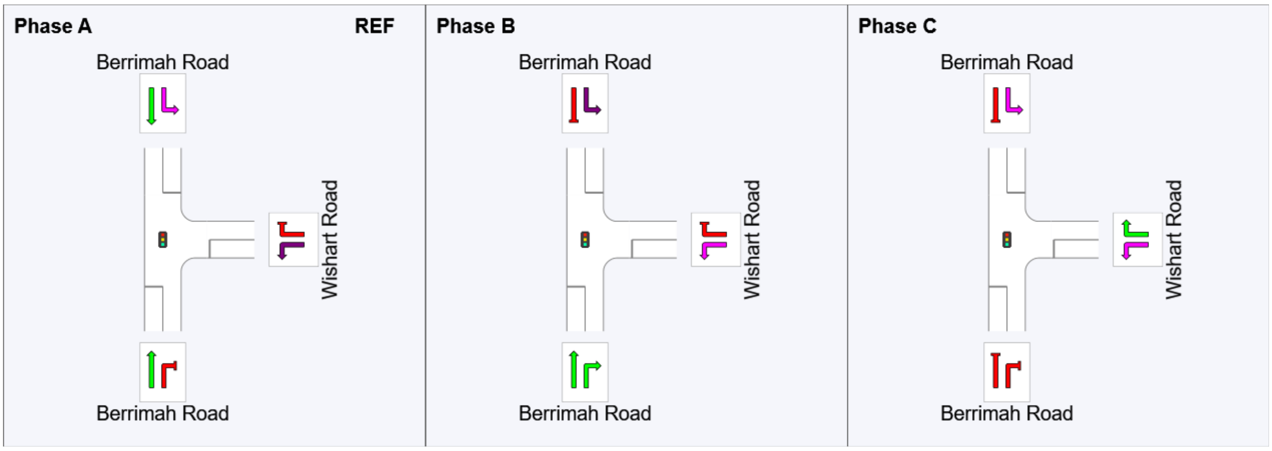
Timings based on settings in the Site Phasing & Timing dialog
Phase Times determined by the program
Phase Sequence: SCATS 2022
Reference Phase: Phase A
Input Phase Sequence: A, B, C
Output Phase Sequence: A, B, C

Phase Timing Summary

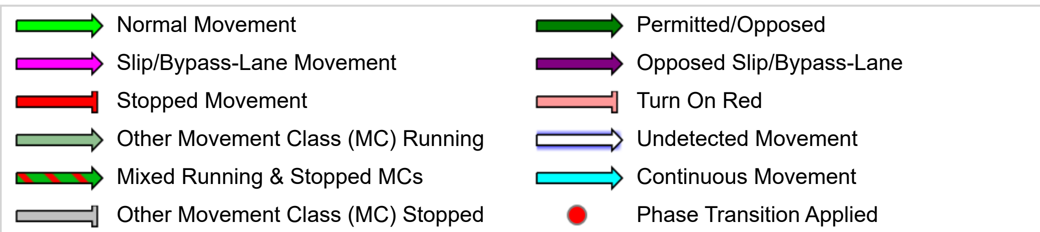
Phase	**A**	**B**	**C**
Phase Change Time (sec)	0	12	38
Green Time (sec)	6	20	6
Phase Time (sec)	12	26	12
Phase Split	24%	52%	24%

See the Timing Analysis report for more detailed information including input values of Yellow Time and All-Red Time, and information on any adjustments to Intergreen Time, Phase Time and Green Time values in cases of Pedestrian Actuation, Minor Phase Actuation and Phase Frequency values (user-specified or implied) less than 100%.

Output Phase Sequence



REF: Reference Phase
VAR: Variable Phase



Appendix 11: Onshore Construction Environmental Management Plan (CEMP)

BAS-210 0025

Santos

Darwin Pipeline Duplication (DPD) Project – Onshore Construction Environmental Management Plan (CEMP)

PROJECT / FACILITY	Barossa DPD Project
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	**Owner**	**Reviewer/s** *Managerial / Technical / Site*	**Approver**
	Project Environmental Lead	Project HSE Manager	Project Director
E			

Any hard copy of this document, other than those identified above, are uncontrolled. Please refer to the Barossa Document Management System for the latest revision.

Rev	Rev Date	Author / Editor	Amendment
A	5/09/2022	RPS	Issued for Santos review
B	14/11/2022	RPS	Issued for Santos review
C	08/02/2023	RPS	Issued for Santos review
D	09/03/2023	RPS	Issued for Santos review
E	26/04/2023	RPS	Issued for NT EPA review

Contents

Acronyms, Terms, Definitions and Units of Measurement		**8**
1	**Introduction**	**12**
1.1	Project overview	12
1.2	Purpose	14
1.3	Scope	14
1.4	Plan structure	18
1.5	Proponent	19
1.5.1	Details of the proponent	19
1.5.2	Details of nominated liaison person	19
1.5.3	Notification procedure in the event of changed details	20
1.6	Document review, revision and availability	20
2	**Detailed Activity Description**	**21**
2.1	Overview	21
2.2	Onshore project area	22
2.3	Onshore construction	24
2.3.1	Onshore pre-lay works	24
2.3.2	Onshore pipeline installation	25
2.3.3	Pre-commissioning	27
2.3.4	Trench backfill and demobilisation at shore crossing	27
2.3.5	Resource requirements and access	27
2.3.6	Fuels and chemicals	28
2.3.7	Atmospheric Emissions	28
2.3.8	Wastes	28
2.4	Indicative construction schedule	28
3	**Legal and Other Obligations**	**29**
3.1	Barossa DPD project approvals	29
3.1.1	Commonwealth environmental approvals	29
3.1.2	Northern Territory environmental approvals	29
3.1.3	Aboriginal Areas Protection Authority certificates	29
3.2	Legislative framework	30
3.2.1	Key legislation	30
3.2.2	Other relevant legislation	31
3.2.3	International conventions and agreements	33
3.3	Standards, codes and guidelines	34

4	**Environmental Management Framework**	**35**
4.1	Santos management system	35
4.2	Santos' Environment, Health, and Safety Policy	35
4.3	DPD Project environmental management plans	35
4.4	Supporting management processes and procedures	35
4.4.1	Contractor Health, Safety and Environment requirements	35
4.4.2	Chemical selection and assessment procedure	36
4.4.3	Santos waste management process	36
5	**Existing Environment**	**37**
5.1	Information sources	37
5.2	Key environmental factors	37
5.2.1	Terrestrial environmental quality	37
5.2.2	Terrestrial ecosystems	39
5.2.3	Inland and intertidal water quality	44
5.2.4	Climate and air quality	47
5.2.5	Community and economy	47
5.2.6	Culture and heritage	47
5.2.7	Recovery plans	48
6	**Impact and risk Assessment**	**50**
6.1	Conceptual Site Model	50
6.2	Impact and risk assessment methods	50
6.2.1	Identification of environmental hazard	50
6.2.2	Standard controls	50
6.2.3	Impact and risk assessment	50
6.3	Residual consequences and risks	54
6.3.1	Planned events	54
6.3.2	Unplanned events	55
6.4	Impact/risk assessment summary	55
6.5	Assessment of potential for cumulative impacts	60
6.5.1	Cumulative assessment methodology	60
6.5.2	Cumulative impacts to atmospheric processes	60
6.5.3	Cumulative impacts to community and economy	60
7	**Environmental management strategies**	**61**
7.1	NT EPA hierarchy	61
7.2	Environmental performance objectives	61
7.3	Performance criteria	62
7.4	Management actions	62
7.5	Adaptive management mechanism	62

7.6 Planned events impact management strategies 62
7.6.1 Ground disturbance and clearing – physical presence 62
7.6.2 Ground disturbance and clearing – acid sulfate soils 65
7.6.3 Light emissions 67
7.6.4 Noise emissions 69
7.6.5 Atmospheric emissions 71
7.7 Unplanned events risk management strategies 73
7.7.1 Interaction with terrestrial fauna 73
7.7.2 Introduction and spread of invasive species 75
7.7.3 Release of non-hazardous and hazardous materials 77
7.7.4 Spread of fire to surrounding bushland 79
7.8 Summary of management actions 81

8 Implementation Strategy 82

8.1 Leadership, accountability and responsibility 82
8.2 Workforce training and competency 85
8.2.1 Inductions 85
8.2.2 Training and competency 86
8.2.3 Workforce involvement and communication 86
8.3 Audits and inspections 86
8.4 Environmental Incident Reporting 87
8.4.1 Internal incident reporting 87
8.4.2 External incident reporting 87
8.5 Corrective actions 88
8.6 Continuous improvement 88
8.7 Emergency preparedness and response 88
8.7.1 Contractor Emergency Plans 89
8.7.2 Santos Incident Management and Oil Spill Response Arrangements 89
8.8 Reporting and notifications 89
8.9 Document management 92
8.9.1 Information management and document control 92
8.9.2 Management of change 92
8.9.3 Reviews 92

9 Stakeholder Consultation 93

10 References 94

Figures

Figure 1-1: DPD Project Location 13

Figure 1-2: Conceptual model of management plan geographical scopes 18
Figure 2-1: Onshore Project Area 23
Figure 2-2: Onshore site layout and Santos Barossa DPD Project teams shore crossing at the intertidal area 26
Figure 2-3: Nominal construction sequence and durations for the DPD Project 28
Figure 5-1: Wetlands of national significance - Darwin Harbour wetlands 46

Tables

Table 1-1: DPD Project Activities within the Project Area covered by the CEMPs 16
Table 1-2: Construction Environmental Management Plan Structure 18
Table 1-3: Proponent details for Barossa DPD Project's future Inland Waters Licence 19
Table 2-1: Attributes of the Activity 21
Table 2-2: Onshore pipeline start and end locations. 21
Table 3-1: Commonwealth legislation relevant to the activity 31
Table 3-2: Northern Territory legislation relevant to the activity 32
Table 3-3: International agreements and conventions relevant to the activity 33
Table 5-1: Introduced species potentially found within and proximate to the onshore Project Area 40
Table 5-2: Conservation significant terrestrial fauna species potentially found within and proximate to the onshore Project Area 42
Table 5-3: Threats and strategies from relevant recovery plans, conservation advice and management plans 49
Table 6-1: NT EPA consequence descriptor 52
Table 6-2: Environmental consequence level descriptions 54
Table 6-3: Likelihood descriptions 54
Table 6-4: Risk assessment matrix 54
Table 6-5: Summary of the residual consequence levels associated with planned events 55
Table 6-6: Summary of the residual risk levels associated with unplanned events 55
Table 6-7: Summary of onshore construction impact and risk assessment outcomes 56
Table 7-1: Environmental management strategies template 61
Table 7-2: Ground disturbance and clearing – physical presence EPOs and associated performance criteria 62
Table 7-3: Management actions for ground disturbance and clearing – physical presence during onshore DPD construction activities 64
Table 7-4: Ground disturbance and clearing – acid sulfate soils EPO and associated performance criteria 65
Table 7-5: Management actions for ground disturbance and clearing – Acid Sulfate Soils during onshore DPD construction activities 66
Table 7-6: Light emissions EPOs and associated performance criteria 67
Table 7-7: Management actions for light emissions during onshore DPD construction activities 68
Table 7-8: Noise emissions EPO and associated performance criteria 69
Table 7-9: Management actions for noise emissions during onshore DPD construction activities 70
Table 7-10: Atmospheric emissions EPOs and associated performance criteria 71
Table 7-11: Management actions for atmospheric emissions during onshore DPD construction activities 72
Table 7-12: Interaction with terrestrial fauna EPOs and associated performance criteria 73
Table 7-13: Management actions for interaction with terrestrial fauna during onshore DPD construction activities 74

Table 7-14: Introduction and spread of invasive species EPOs and associated performance criteria 75

Table 7-15: Management actions for introduction and spread of invasive species during onshore DPD construction activities 76

Table 7-16: Release of non-hazardous and hazardous materials EPOs and associated performance criteria 77

Table 7-17: Management actions for release of non-hazardous and hazardous material 78

Table 7-18: Spread of fire to surrounding bushland EPOs and associated performance criteria 79

Table 7-19: Management actions for spread of fire to surrounding bushland 80

Table 8-1: Chain of command and key roles and responsibilities 83

Table 8-2: Summary of key environmental reporting requirements. 90

Appendices

Appendix 1 Santos Environment, Health and Safety Policies

Appendix 2 Summary of management actions and associated performance criteria for the proposed activity

Acronyms, Terms, Definitions and Units of Measurement

Term	Definition
Acronyms	
AAPA	Aboriginal Areas Protection Authority
ALARP	As low as reasonably practicable
AMSA	Australian Maritime Safety Authority
AQIS	Australia Quarantine and Inspection Service
ASS	Acid sulfate soils
ASSDMP	Acid Sulfate Soils and Dewatering Management Plan
BOM	Bureau of Meteorology
CAMBA	China-Australia Migratory Bird Agreement
DAWE	Commonwealth Department of the Agriculture, Water and the Environment
DEPWS	Norther Territory Department of Environment, Parks and Water Security
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DITT	Northern Territory Department of Industry, Tourism and Trade
DLNG	Darwin Liquefied Natural Gas
DoE	Commonwealth Department of the Environment
DoEE	Commonwealth Department of the Environment and Energy
DIPL	Northern Territory Department of Infrastructure, Planning and Logistics
DPD	Darwin Pipeline Duplication
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities
EDP	Exceptional Development Permit
ENVID	Environmental impact identification
EP Act	*Environment Protection Act 2019*
EP Regulations	Environment Protection Regulations 2020
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
EPL	Environmental Protection Licence
EPO	Environmental performance objectives
EPS	Environmental performance standard
FCGT	Flood / clean / gauge / testing
GEP	Gas export pipeline
GHG	Greenhouse gas

Term	Definition
HAT	Highest astronomical tide
HSE	Health, safety and environment
JAMBA	Japan-Australia Migratory Bird Agreement
KP	Kilometre point
LNG	Liquid natural gas
LOR	Limit of reporting
MARPOL	The International Convention for the Prevention of Pollution from Ships
MMNMP	Marine Megafauna Noise Management Plan
MNES	Matters of National Environmental Significance
MoC	Management of change
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NR	Natural resource
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
ODS	Ozone depleting substances
OEMP	Operations Environmental Management Plan
PASS	Potential acid sulfate soils
PLET	Pipeline end termination
PMP	Pipeline management plan
PMST	Protected Matters Search Tool
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
Santos	Santos NA Barossa Pty Ltd
SER	Supplementary Environmental Report
SMS	Santos Management System
TPWC Act	*Territory Parks and Wildlife Conservation Act 1976*
TSDMMP	Trenching and Spoil Disposal Management and Monitoring Plan
WONS	Weeds of National Significance
Legislation terms	
Licence	A licence granted under Part III or section 43 of the *Energy Pipelines Act 1981* (NT)
Licensee	The registered holder of a licence
Non-Indigenous	Refers to heritage artefacts or sites that are not deemed “sacred sites” per the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT) or deemed Aboriginal or Macassan archaeological sites or artefacts per the *Heritage Act 2011* (NT).

Term	Definition
Pipeline	A pipe or system of pipes that has or have a maximum allowable operating pressure greater than 1050 kilopascals or a hoop stress (being a circumferential stress arising from internal pressure) that is, at one or more positions, greater than 20% of the specified minimum yield stress specified in the manufacturing standard with which the pipe complies and that are used or intended to be used for the conveyance of an energy-producing hydro-carbon, and includes: (a) all structures for protecting or supporting a pipeline; and (b) all loading terminals, works and buildings and all fittings, pumps, tanks, appurtenances and appliances, used in connection with a pipeline, but does not include: (c) a pipeline as defined in the *Petroleum (Submerged Lands) Act 1981*; (e) a pipeline constructed or to be constructed on land used for residential, business, agricultural, commercial or industrial purposes, designed for use solely for the residential, business, agricultural, commercial or industrial purposes carried on that land and situated wholly within the boundaries of that land; or (f) a pipeline or a pipeline of a class declared under section 4(2) to be a pipeline in respect of which a licence is not required
Pipeline management plan	Pipeline management plan in force, in relation to a pipeline, means: (a) a pipeline management plan for the pipeline submitted by or for the pipeline licensee and accepted under these Regulations; or (b) if the pipeline management plan is accepted in part – that part of the pipeline management plan that is accepted, as revised from time to time under these Regulations, but does not include a pipeline management plan for which the acceptance has been withdrawn.
Definitions	
DLNG team	The DLNG contractors
Environmental Performance Standard	A statement of performance required of a management action.
Environmental Performance Objective	Measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks are of an acceptable level.
Measurement Criteria	A system of measurements that define whether a project is successful.
Onshore Project Area	Onshore Project Area is the same area as the Project Area, except it extends between the onshore termination point and the upstream weld of the beach valve.
Onshore termination point	The point (KP122.484; approximately 2 m above highest astronomical tide) to which the pipeline will be pulled ashore to by the shore-pull activity.
Performance Criteria	The standards by which success of management actions is evaluated.
Project Area	Project Area extends between the 3 nautical mile boundary and the upstream weld of the beach valve. Refer to
Target	Specific and measurable performance requirements to achieve EPOs.
Units of measurement	

Term	Definition
°	degrees
µS	microSiemens
cm	centimetre
dB	decibels
dB(A)	a-weighted sound pressure level in decibels
kHz	kilohertz
km	kilometre
km^2	square kilometre
m	metre
m^2	square metre
m AHD	metres Australian Height Datum
mg/L	milligrams per litre
nm	nautical mile

1 Introduction

1.1 Project overview

Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the existing Bayu-Undan to Darwin Gas Export Pipeline (GEP). The Bayu-Undan to Darwin GEP is a dry natural gas export pipeline transporting gas from the Bayu-Undan field located in Timor-Leste waters to the Darwin Liquefied Natural Gas (DLNG) facility at Wickham Point peninsula near Darwin, Northern Territory (NT), Australia. The Bayu-Undan to Darwin GEP has been operational since 2005. In anticipation of the end of the Bayu-Undan field's commercial production in 2022 / 2023, the Barossa Field is being developed to supply gas to the DLNG facility. The supply of backfill gas to the DLNG facility was originally planned to be achieved through the installation of a 262 kilometre (km) Barossa GEP to a tie-in point on the existing Bayu-Undan to Darwin GEP.

In recognition of potential Carbon Capture and Storage opportunities at the Bayu-Undan, Santos has approved an alternative solution to transport backfill gas to the DLNG facility through the construction of an additional segment of pipeline to extend the Barossa GEP to the DLNG facility, instead of tying into the Bayu-Undan to Darwin GEP. Construction of this segment of pipeline is referred to as the Darwin Pipeline Duplication (DPD) Project, as it will be installed, parallel to the existing Bayu-Undan to Darwin GEP. The effective 'duplication' of the existing Bayu-Undan to Darwin GEP is considered the optimal route to minimise potential environmental and social impacts.

The pipeline will run from a location where the Barossa GEP approaches the existing Bayu-Undan pipeline and continue through Darwin Harbour into the DLNG facility (**Figure 1-1**). Santos' DPD Project includes a ~23 km segment in Commonwealth waters and a ~100 km segment in NT waters and lands adjacent to the existing Bayu-Undan to Darwin GEP. The DPD Project pipeline will be located for the most part approximately 50 – 100 m from the existing Bayu-Undan to Darwin pipeline, to minimise potential environmental and social impacts. The Project Area for the DPD Project includes a 2 km buffer around the pipeline route in NT waters, the onshore construction area at the DLNG facility and an offshore spoil disposal ground, and buffer, for the trench spoil disposal (**Figure 1-1**). The construction of the pipeline onshore is covered under this Construction Environmental Management Plan (CEMP) (**Figure 2-2**).

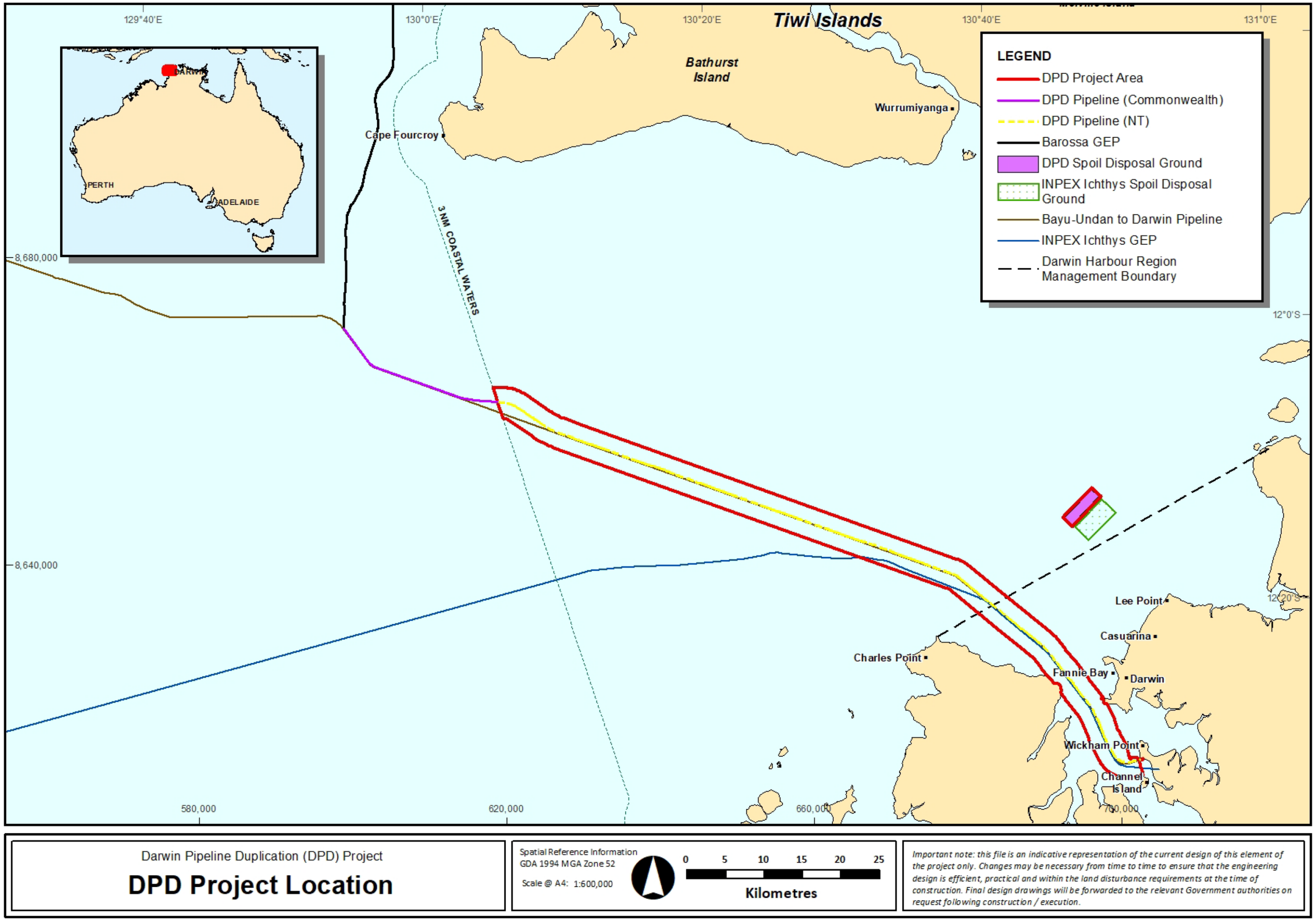


Figure 1-1: DPD Project Location

1.2 Purpose

This CEMP has been prepared to detail and provide guidance on environmental management requirements, to ensure the DPD Project pipeline construction activities on NT land are undertaken in an environmentally responsible manner and in line with regulatory requirements.

This CEMP will be submitted with the DPD Project Supplementary Environmental Report (BAS-210 0020) (SER) under the NT *Environment Protection Act 2019* and supporting regulations. This CEMP will be provided to the relevant Minister in support of the Pipeline Management Plan (PMP) required to construct a pipeline under the *Energy Pipelines Act 1981* (NT) and supporting regulations.

The purpose of this onshore CEMP is to meet the relevant requirements of the:

+ *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) as administered by Department of Climate Change, Energy, the Environment and Water (DCCEEW), including relevant management and recovery plans and conservation advice for Matters of National Environmental Significance (MNES).
+ The EP Act and Environment Protection Regulations 2020 (EP Regulations), as administered by the NT EPA.
+ NT Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015)
+ NT Energy Pipelines Act 1981, and Energy Pipelines Regulations 2001 as administered by the NT Department of Industry, Tourism and Trade (DITT).

This CEMP details the environmental impacts and risks associated with the onshore activities and demonstrates how these will be reduced to an acceptable level. This CEMP provides an implementation strategy that will be used to measure and report on environmental performance during planned activities and unplanned events, to ensure impacts and risks are continuously reduced and are maintained at an acceptable level. The environmental management of the activity described in this CEMP complies with the Santos Environment, Health and Safety Policy (**Appendix 1**) and with all relevant legislation (**Section 3**). All relevant stakeholder consultation performed has been considered in the development of this CEMP (**Section 9**).

1.3 Scope

This CEMP is relevant to the onshore section of the DPD pipeline only, which is approximately 200 metres (m) in length between the onshore termination point (kilometre point (KP) 122.484) which is approximately 2 m above highest astronomical tide [HAT]) to which the pipeline will be pulled ashore by the shore-pull activity) and the upstream weld of the beach valve (KP 122.692). This onshore section of the DPD pipeline will be designed and constructed by the Santos DLNG team and contractors. This CEMP is therefore termed the DPD Project Onshore Pipeline CEMP (Onshore CEMP). The construction of the remainder of the DPD pipeline, from the onshore termination point to the 3 nautical mile (nm) Commonwealth/NT waters boundary, will be designed and constructed by the Santos Barossa DPD Project team (and contractors) (referred to in this document as the Barossa team) and subject to another CEMP termed the DPD Project Offshore Pipeline CEMP (BAS-210 0024).

A summary of activities relevant to each CEMP is provided in **Table 1-1**.

This CEMP forms part of a suite of environmental management plans which collectively cover all activities from the 3 nm Commonwealth/NT waters boundary to the upstream weld of the beach valve. (**Figure 1-2**).

There are three additional management plans that address specific activities during construction (**Figure 1-2**). These are the:

+ Trenching and Spoil Disposal Monitoring and Management Plan (TSDMMP) (BAS-210 0023) that addresses all trenching and spoil disposal activities from the 3 nm Commonwealth/NT waters boundary to the onshore termination point.
+ Marine Megafauna Noise Management Plan (MMNMP) (BAS-210 0045) that addresses all activities associated with underwater noise impacts to marine megafauna from the 3 nm Commonwealth/NT waters boundary to the onshore termination point.
+ Acid Sulfate Soil and Dewatering Management Plan (ASSDMP) (BAS-210 0049) that addresses all activities associated with acid sulfate soils (ASS) from lowest astronomical tide (LAT) to the upstream weld of the beach valve.

Table 1-1: DPD Project Activities within the Project Area covered by the CEMPs

Phases	Activities		
	Offshore CEMP	**Onshore CEMP**	**Outside scope of CEMPs**
Surveys	+ Offshore Surveying during construction + Environmental surveys during construction	Onshore surveying during construction	+ Low impact pre-construction surveys required to gather information for Project planning and approvals are out of scope for the CEMPs. These surveys include, but are not limited to, environment, heritage, geotechnical, geophysical and unexploded ordinance (UXO) surveys + Any surveys in Commonwealth waters
Pre-lay works	+ Installation of offshore pipeline from the onshore termination point to the 3 nm Commonwealth/NT waters boundary + Trenching and spoil disposal from the onshore termination point to the 3 nm Commonwealth/NT waters boundary + Spoil disposal at nominated spoil disposal grounds and in situ + Pre-lay span rectification + Cable crossings along the Pipeline pathway + Installation of site buildings and generators + Construction of the site access road + Installation of traffic plates over the existing Bayu-Undan pipeline + Preparation of the site pad, including installation of geotextile and site hard stand areas, installation of holdback	Onshore trenching of the onshore pipeline from the upstream weld of the beach valve to the onshore termination point and onshore stockpile of trench material for use as trench backfill. This will involve: + Excavation of trench from the upstream weld of the beach valve to site pad + Extension of trench to the onshore termination point through the site pad once no longer in use + Storage of any identified ASS / PASS on limestone pads and treated with lime prior to reuse or disposal to landfill	Any pre-lay works within Commonwealth waters

Phases	Activities		
	Offshore CEMP	**Onshore CEMP**	**Outside scope of CEMPs**
	anchor, linear winch, trench and shore pull wire.		
Pipeline installation and pre-commissioning	+ Pipelay activities + In-line tee installation + Pipeline shore pull + Rock backfill + Post-lay span rectification + Testing and pre-commissioning the offshore pipeline + Post-lay trenching + Pipelay contingencies	+ Installation of the onshore pipeline from the upstream weld of the beach valve to the onshore termination point + Testing and pre-commissioning the onshore pipeline + Tie-in onshore pipeline to the offshore pipeline at the onshore termination point	+ Any installation or pre-commissioning within Commonwealth waters, including: – DPD Project Pipeline end termination (PLET) installation – Spool installation (between DPD Project PLET and Offshore Barossa GEP PLET) + Installation of the beach valve and the pipeline between the beach valve and the DLNG facility + Installation of the shore crossing CP monitoring system
Demobilisation	+ Removal of the pre-commissioning spread + Removal of the hard stand and geotextile + Re-contouring of the site as applicable + Removal of causeway/s	+ Backfilling onshore pipeline trench + Site returned to pre-construction condition	
Operations	N/A	N/A	+ Operations + Inspection maintenance and repair
Decommissioning	N/A	N/A	+ Decommission pipeline + Removal of subsea infrastructure + Onshore decommissioning and rehabilitation + As-left/ post-surveys

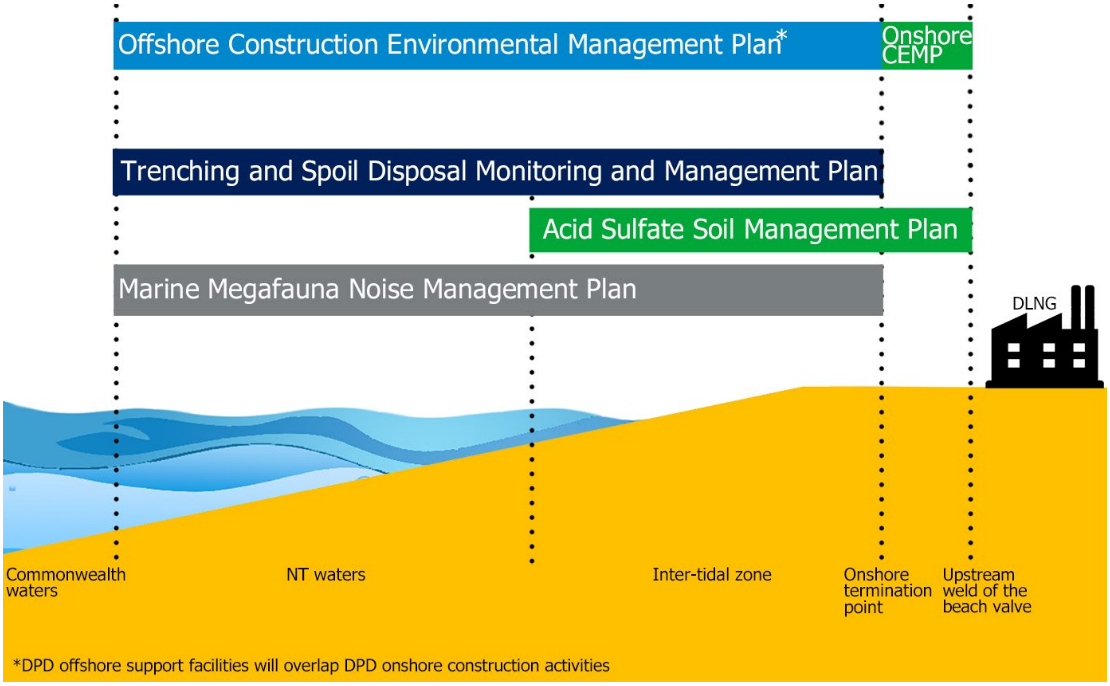


Figure 1-2: Conceptual model of management plan geographical scopes

1.4 Plan structure

This CEMP has been prepared and structured in accordance with the Guideline for the Preparation of an Environmental Management Plan (in draft) (NT EPA, 2015). The guideline requirements and where they have been addressed within the CEMP are detailed in **Table 1-2**.

Table 1-2: Construction Environmental Management Plan Structure

Regulatory requirement Guideline for the Preparation of an Environmental Management Plan	Relevant CEMP section
+ Project overview + Proponent details + Key contacts	**Section 1:** **Introduction**
Clear and comprehensive project description	**Section 2:** **Detailed Activity Description**
Legal and other obligations	**Section 3:** **Legal and Other Obligations**
Environmental management framework	**Section 4: Environmental Management Framework**
Existing environment	**Section 5:** **Existing Environment**

Regulatory requirement Guideline for the Preparation of an Environmental Management Plan	Relevant CEMP section
+ Conceptual site model + Environmental risk assessment	**Section 6:** **Risk Assessment** The requirement for a Conceptual Site Model is addressed within the risk assessment.
Environmental management strategies	**Section 7:** **Environmental management strategies**
+ Corrective actions and contingencies + Audit, reporting and review + Training and awareness	**Section 8:** **Implementation Strategy**
Communication	**Section 9:** **Stakeholder Consultation**

1.5 Proponent

1.5.1 Details of the proponent

Santos, as the operator of the Barossa Joint Venture, has applied to the DITT for two pipeline licences for the nearshore section of the DPD pipeline:

+ Coastal and Territorial Waters Licence for the section of the pipeline under the jurisdiction of the *Petroleum (Submerged Lands) Act 1981* (NT) (i.e. between the NT Coastal Waters Limit and the Territorial Sea Baseline)
+ Inland Waters Licence for the section of pipeline under the jurisdiction of the *Energy Pipelines Act 1981* (NT) (i.e. between the Territorial Sea Baseline and the upstream weld of the beach valve at the DLNG Facility).

The Inland Waters Licence is applicable to the section of pipeline within the scope of this CEMP. The proposed proponent details are provided in **Table 1-3**, with the nominated operator shown in bold.

Table 1-3: Proponent details for Barossa DPD Project's future Inland Waters Licence

Title	Proponent (nominated operator in bold)	ABN	Interest	Contact details
Inland Waters License	**Santos NA Barossa Pty Ltd**	44 109 974 932	25.0%	Business Address: Level 7, 100 St Georges Terrace, Perth, Western Australia, 6000 Telephone number: (08) 6218 7100 Fax number: (08) 6218 7200 Email address: barossa.regulatory@santos.com
	Santos Offshore Pty Ltd	38 005 475 589	25.0%	
	SK E&S Australia Pty Ltd	55 158 702 071	37.5%	Business Address: Level 6, 60 Martin Place, Sydney NSW 2000, Australia Telephone number: (02) 21213304 Fax number: None Email address: hyunjoon-kim@sk.com
	JERA	18 654 004 387	12.5%	Business Address: Level 9 Brookfield Place, 125 St Georges Tce, PERTH, WA, 6000

1.5.2 Details of nominated liaison person

Details for Santos's nominated liaison person for the activity are as follows:

Name Dr Lachlan MacArthur

Title: Environmental Approvals Adviser

Business address: Level 7, 100 St Georges Terrace, Perth, WA 6000

Telephone number: (08) 6218 7100

Email address: Barossa.regulatory@santos.com

1.5.3 Notification procedure in the event of changed details

If there is a change in the nominated operator, or a change in the contact details for the operator or liaison person, Santos will notify the DITT and provide the updated details.

1.6 Document review, revision and availability

This CEMP has been prepared for submission with the SER (BAS-210 0020) and other supporting documents to the NT EPA, under the EP Act, and will be updated to reflect any relevant regulatory conditions associated with the DPD Project approvals.

This CEMP will be provided to the relevant Minister in support of the PMP required to construct a pipeline under the *Energy Pipelines Act 1981* (NT) and Energy Pipelines Regulations 2001. A pipeline licensee for a pipeline for which a PMP is in force must submit to the Minister a proposed revision of the PMP in the event of a change, or proposed change, of circumstances or operations under Regulation 33, when requested by the Minister under Regulation 34 or at the end of each five-year period under Regulation 35.

Santos will review and update the document as required based on regulatory feedback and any regulatory conditions on DPD Project approval as applicable. The final CEMP will be made publicly available on an Australian website.

2 Detailed Activity Description

2.1 Overview

Table 2-1 provides the key attributes of the construction activity covered by this CEMP. A detailed activity description is provided in **Sections 2.3.1** and **2.3.8**.

Table 2-1: Attributes of the Activity

Attribute	Summary
Activity location	The relevant onshore section of the DPD pipeline extends from the onshore termination point (KP 122.484) to the upstream weld of the beach valve. The beach value is located at KP122.692. It is located at the shore crossing of the DLNG Facility on the Wickham Point peninsula, near Darwin (**Figure 2-1**). The onshore termination point is two metres above HAT. The nominal coordinates of the KPs are provided in **Table 2-2**. The onshore section of the Project Area is located within the existing DLNG disturbance footprint.
Pipeline installation	Approximately 200 m of 34-inch diameter carbon steel pipe. Pre-lay works phase: + Onshore trenching from the upstream weld of the beach valve to onshore termination point Pipeline installation and pre-commissioning phase: + Installation of the onshore pipeline from the upstream weld of the beach valve to the onshore termination point + Testing and pre-commissioning the onshore pipeline + Tie-in (welding) of the onshore pipeline to the offshore pipeline at the onshore termination point Demobilisation phase: + Backfilling onshore pipeline trench + Undertaking site remediation Refer to further detail in **Table 1-1**.
Machinery and vehicles	+ Light vehicles + Mobile equipment such as excavators, graders, trucks, fuel trucks + Heavy equipment such as cranes + Water cart
Proposed schedule	Work is scheduled to be performed in early 2024 and take up to 1 months

The locations for activities along the DPD Project pipeline are described using 'kilometre points' (KP), where KP 0 is the beginning of the DPD Project pipeline from the "pipeline end termination point C" (PLET C) in Commonwealth waters and KP 122.692 is the end of the onshore section of the DPD Project Pipeline.

Table 2-2: Onshore pipeline start and end locations.

Location	Kilometre Point	MGA Zone *	Easting*	Northing*
Onshore termination point	KP122.484	52	702272.73 E	8614606.40 S
Upstream weld of the beach valve	KP122.692	52	702,472.29 E	8,614,655.73 S

*Coordinates in GDA 94, MGA zone 52

2.2 Onshore project area

The Onshore Project Area is defined as the area within which the construction activity will take place and extends between the onshore termination point and the upstream weld of the beach valve (**Figure 2-1**). The onshore Project Area is contained within the existing DLNG disturbance envelope, which was previously subject to vegetation clearing. Areas within the DLNG disturbance envelope outside of the onshore Project Area may be used by the DLNG team for equipment laydown or trench material stockpiling.

The Project Area is shown in **Figure 2-1** with the DPD offshore support facilities shown in **Figure 2-2**.

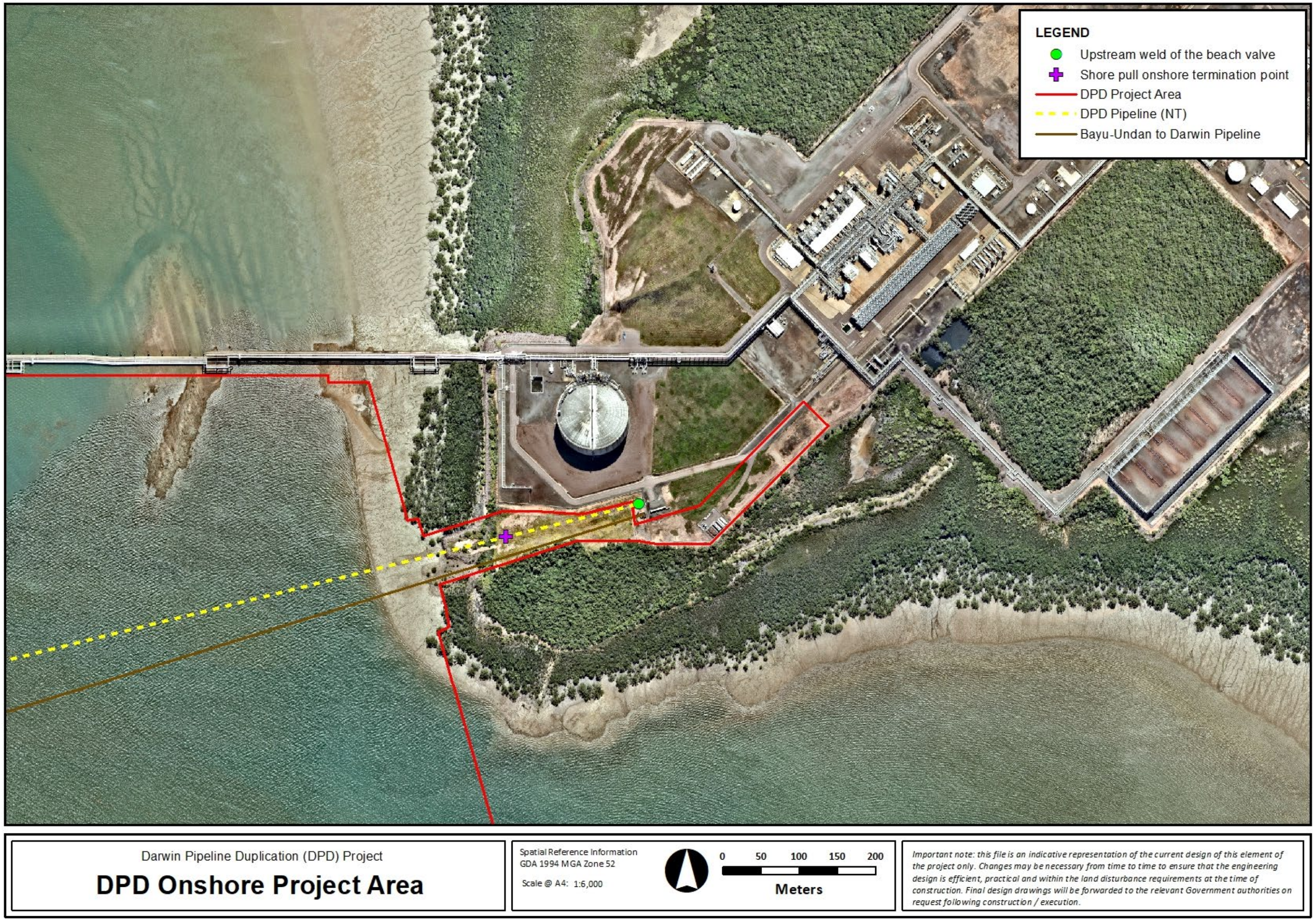


Figure 2-1: Onshore Project Area

2.3 Onshore construction

2.3.1 Onshore pre-lay works

2.3.1.1 Site establishment

The onshore construction site layout for the Barossa team is illustrated in **Figure 2-2.** The DLNG team's support facilities (i.e. site office, spoil stockpile, laydown areas) will be located within the existing DLNG disturbance envelope. Primary site access for both the Barossa and DLNG teams will be via the site access road shown in **Figure 2-2**.

2.3.1.2 Onshore trenching

Geophysical and/or geotechnical surveys will be undertaken before the commencement of construction of the onshore site, which will involve digging test pits and sampling extending down to the anticipated depth of the trench of ~2.5 m.

The construction works will be undertaken simultaneously with the Santos Barossa DPD Project team's onshore and intertidal construction works. Therefore, trenching will initially be completed from the upstream weld of the beach valve location to the extent of the DPD site pad (which will be used by the Barossa team). This section will be approximately 130 m in length. Once the shore crossing facilities have been removed by the Barossa team, the DLNG team will extend the trench from the extent of the DPD site pad down to the onshore termination point. This trench will be approximately 70 m in length and up to a maximum of 40 m wide. The onshore construction site layout is shown in **Figure 2-2.**

Trenching works may be scheduled either during or after the offshore pipeline's pre-commissioning works have been completed. Timing will be detailed through simultaneous operations (SIMOPS) once a detailed schedule of all onshore activities is developed.

The onshore trenching works will be undertaken during wet and/or dry seasons. Dewatering due to rainwater will be primarily managed by a diesel-powered suction pump combined with a silt separator, where the water that has been separated from solids is then discharged to grade (Downer, 2022). Additional sparges and hoses may be used to manage removal of water. While unlikely, dewatering of groundwater may be required, and is included in the Acid Sulfate Soils Management Plan (ASSDMP [BAS-210 0049]) to ensure management of any acidic groundwater.

Excavation will be completed by a 35-tonne excavator, articulated dump trucks and a water truck for dust suppression (Downer, 2022). The area of the onshore pipeline has been previously disturbed and was cleared of native vegetation during construction of the Bayu-Undan to Darwin Gas Export Pipeline. It is currently covered with naturally regrown native grasses and weeds. The grasses and topsoil will be stripped, and the trench will be excavated to ~2.5 m deep and will be ~3m wide at the base. At each welded pipeline connection, a wider excavation will be completed to provide suitable access and working area for the piping and welding crew (Downer, 2022). When trenching, all sides will be adequately supported by either shoring, benching or battering.

The trenched material will be placed on the non-working side of the trench (Downer, 2022) or stockpiled within the onshore Project Area or the DLNG disturbance envelope for future reuse as backfill. Surplus material will be removed offsite. The trenched material will be stockpiled onsite for testing and will be removed offsite to an appropriately licensed landfill as required.

While considered highly unlikely, if ASS or Potential ASS (PASS) are identified during trenching works the ASS / PASS material will be stored on limestone pads within the onshore Project Area or the DLNG disturbance envelope and treated with lime prior to reuse or disposal to an appropriately licensed landfill. Further context on ASS/PASS is provided in the ASSDMP (BAS-210 0049).

2.3.2 Onshore pipeline installation

The DLNG team are responsible for the fabrication of the structural steel and pipework, which will occur offsite at the nominated subcontractor's fabrication workshop (Downer, 2022). The pipe spool configuration will require field welding; therefore surface treatment and non-destructive examination (NDE) will be completed offsite and final weld testing, surface treatment and hydrostatic testing will be completed onsite. Structural steel will be fabricated by either welded assembly or stick build. Standalone pipe supports will be fabricated as one item and will require no assembly. The piping and structural steel will be transported to site by road and unloaded by a site-based crane at a laydown area onto timbers or dunnage (Downer, 2022). Lay-down areas will be defined by the installation contractor during detailed design (**Figure 2-2**).

The onshore pipeline will be approximately 200 m length of 34-inch diameter carbon steel with an external anti-corrosion coating to maintain the pipeline integrity. The pipeline assembly configurations between the upstream weld of the beach valve and the onshore termination point are outlined in the Barossa Onshore Tie-In Project Delivery Management Plan (Downer, 2022). Pipe will be strung out alongside the trench, lifted onto temporary pipe supports and cut to length, subjected to end preparation works and aligned for welding. This will be followed by butt welding of the joint and NDE until the sub-assembly is completed. The sub-assemblies will be lifted onto temporary pipe supports in the trench, aligned for welding and butt welding of the joint. The final NDE and coating will be completed prior to the hydrotesting. A 25-tonne Franna crane will be available for minor lifts and pipe placement and two 55-tonne rough terrain cranes will be used for placement of the welded pipes into the trench.

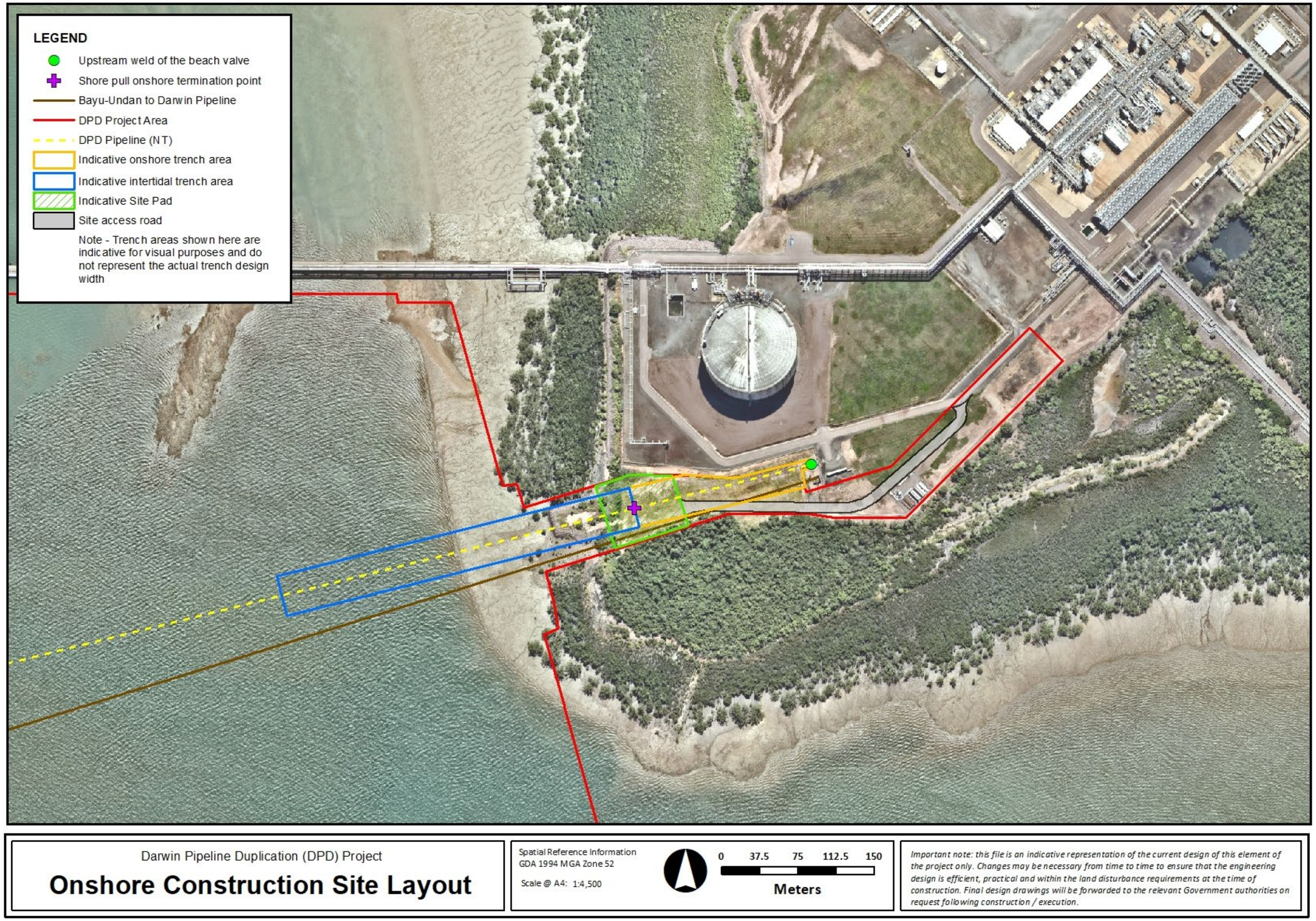


Figure 2-2: Onshore site layout and Santos Barossa DPD Project teams shore crossing at the intertidal area

2.3.3 Pre-commissioning

Once the DLNG team has installed the onshore pipeline, it will be subjected to a hydrostatic pressure test (hydrotest). Hydrotesting will be completed in line with Santos' specification, Pressure Testing of Process and Utility Piping (1540-120-SPC-0018), and Downer standard, Hydrostatic Testing (SM-QA-ST014) (Downer, 2022). The Barossa team will source hydrotesting water for pre-commissioning the offshore pipeline by water extraction from Darwin Harbour. The water will be filtered to remove particulates and then chemically treated. The DLNG team will use this treated seawater for their hydrotesting activities of the onshore pipeline. As water extraction from Darwin Harbour and filter backflushing is managed by the Barossa team and is described and assessed in the Offshore CEMP (BAS-210 0024) it is not described or assessed further within this CEMP.

A volume of chemically treated seawater will be pushed into the pipeline to raise its pressure. This hydrotest pressure will be held for a period of time as per the relevant standard to test the pipeline integrity. The discharged hydrotest water will be temporarily stored in an enclosed bladder for offsite disposal (enclosed bladder within steel retaining wall). This bladder will be installed in the onshore Project Area, potentially on the DPD site pad, where bulk chemical storage will also be located.

In the event of a pipeline issue that requires remedial construction work, contingency plans will be implemented and the onshore pipeline's hydrotest section will be emptied to the bladder to facilitate these repairs. Once the onshore pipeline is successfully tested and pre-commissioned, the DLNG team will complete the tie-in with a golden weld to the offshore pipeline at the onshore termination point.

Alternatively, the onshore pipeline may be connected to the offshore pipeline at the onshore termination point (KP122.484) before the offshore pipeline is pre-commissioned so that FCGT can be undertaken by the Barossa team for the entire DPD pipeline (onshore and offshore sections).

2.3.4 Trench backfill and demobilisation at shore crossing

At the completion of the pipeline installation and pre-commissioning activities, the onshore trench will be backfilled with soil and topsoil from trenching and additional fill of specific parameters should engineering backfill be required. The disturbed onshore area relevant to the DLNG team will be returned to natural grade to match existing topography. Revegetation works are not proposed in this CEMP.

The Barossa team will be responsible for removal of the-onshore support facilities shown in **Figure 2-2**. The DLNG team will be responsible for the removal of equipment and demobilisation as relevant to their scope.

2.3.5 Resource requirements and access

Other requirements of the onshore construction activity include the following:

+ Personnel will be required during the construction period. Labour will be recruited from the domestic and local labour market where possible; this is subject to the contractors' resourcing requirements at the time. Accommodation will be provided for the workforce within the Darwin area.
+ Power will likely be supplied by onsite generators to support construction amenities and operation of equipment.
+ Water usage including for dust suppression, washdown facilities and ablutions supply will likely be sourced from mains water supply within the DLNG Facility, or provided as self-sufficient water through containerised water trucks; and

+ Access to the onshore site will be via the existing DLNG access at the end of Middle Arm Peninsula into Wickham Point.

2.3.6 Fuels and chemicals

Chemical and fuel storage will be stored onsite within self-bunded fuel storage/tanks. Fuel trucks will likely be used to supply fuel to construction equipment, including excavators, graders, cranes, and generators, in accordance with standard refuelling procedures. Hydrotest chemicals will also be stored onshore within a bunded hydrotest spread (i.e. biocides, oxygen scavenger and dye).

2.3.7 Atmospheric Emissions

A GHG emissions study was conducted to determine the scope 1, 2 and 3 emissions from the DPD Project. The scope 1 emissions, within NT jurisdiction, are emissions that result directly from the construction DPD Project and include those from:

+ Vessel-based construction activities (offshore activities only)
+ Onshore power generating equipment (i.e. engines and generators)

Scope 2 and Scope 3 emissions are associated with the broader Barossa project and comprise emissions related to electricity use, transport and construction of materials and consumption of Barossa products by customers.

The total scope 1 emissions for the DPD offshore and onshore Project construction activities in the NT are approximately 50,000 tCo2-e

2.3.8 Wastes

Construction of the pipeline will produce the following wastes:

+ Onshore wastes including water from dewatering and general rubbish / food waste.
+ Trench spoil

Section 4.4.3 outlines waste management for the DPD project in more detail.

2.4 Indicative construction schedule

The indicative schedule to complete construction works is shown in **Figure 2-3**.

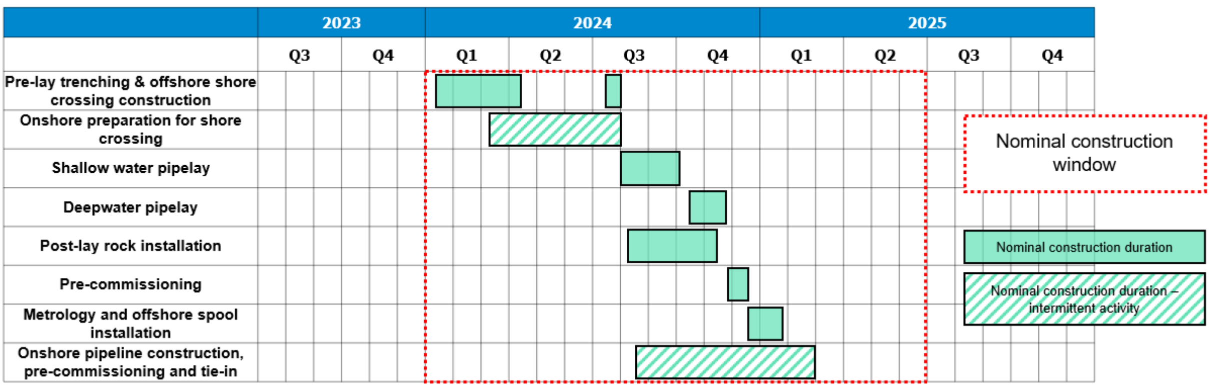


Figure 2-3: Nominal construction sequence and durations for the DPD Project

Santos

3 Legal and Other Obligations

The following sections describe the legislative framework governing the impacts from the construction of the DPD Pipeline (NT).

3.1 Barossa DPD project approvals

3.1.1 Commonwealth environmental approvals

The DPD Project including the DPD Pipeline section in Commonwealth waters was referred to the DCCEEW under the EPBC Act on 7 October 2022 (EPBC 2022/9372). On 6 December 2022 the DPD Project was determined to be a Controlled Action requiring further assessment based on Preliminary Documentation. Further information was requested under section 95A(2) of the EPBC Act on 23 December 2022.

It was determined that the Project may have a significant impact on the following controlling provisions under the EPBC Act:

+ Listed threatened species and communities (sections 18 & 18A)
+ Listed migratory species (sections 20 & 20A)
+ Commonwealth marine areas (sections 23 and 24A)

The Preliminary documentation is currently being prepared for submission to DCCEEW.

This CEMP will be updated to reflect any relevant regulatory conditions associated with this approval.

3.1.2 Northern Territory environmental approvals

The DPD Project was referred to the NT EPA on 14 January 2022 under Section 55 of the EP Act. The NT EPA determined the DPD proposal required assessment by SER (Tier 2) in accordance with the EP Regulations. The SER is required to address public submissions and include information additional to the referral document in relation to specific aspects of potential significance. T

The following approvals are also required for construction of the DPD Project under NT legislation:

+ Department of Infrastructure, Planning and Logistics (DIPL) – Development Permit (*Planning Act 1999)* and Occupational Licence (*Crown Lands Act (1992)*)
+ DITT – Energy Division Consent to construct and Consent to Test (*Energy Pipeline Act 1981* and *Petroleum (Submerged Lands) Act 1981*) Pipeline Licence *(Energy Pipeline Act 1981*)

Conditions within these permits, where they are relevant to the environmental management of works will be incorporated into future revisions of the CEMP.

Native vegetation clearing in the NT requires a permit issued under either the *Planning Act 1999* (NT) or the *Pastoral Land Act 1992* (NT). The onshore Project Area is within freehold land, therefore any native vegetation clearing for the activity will be controlled, as required, by the *Planning Act 1999* (NT) through a Development Permit.

3.1.3 Aboriginal Areas Protection Authority certificates

Aboriginal Areas Protection Authority (AAPA) certificates aim to protect indigenous sacred sites preventing damage from nearby works and outlines conditions to be followed when carrying out works on land and sea near to sacred sites across NT. The AAPA administer these certificates under the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT).

Santos has received an AAPA Authority Certificate (C2022-098) from AAPA on 23 December 2022 and will ensure the requirements of the certificate (including avoidance of restricted work areas) and the *Northern Territory Aboriginal Sacred Sites Act 1989* are met.

3.2 Legislative framework

Environmental legislative requirements governing DPD project are described in the following sections. All activities will comply with legislative requirements established under relevant Commonwealth and NT legislation. Key legislation is described below in **Sections 3.2.1.1**, **3.2.1.2** and **3.2.1.3**. Other relevant legislation is described in **Table 3-1** and **Table 3-2**.

3.2.1 Key legislation

3.2.1.1 Environment Protection and Biodiversity Conservation Act 1999 (Cth)

The EPBC Act is administered by DCCEEW. The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities, and heritage places, which are defined in the EPBC Act as matters of national environmental significance. There are nine matters of national environmental significance to which the EPBC Act applies these are: world heritage properties, national heritage places, wetlands of international importance, nationally threatened species and ecological communities, migratory species, Commonwealth marine areas, the Great Barrier Reef Marine Park, nuclear actions, and water resources (in relation to coal seam gas development and large coal mining development) (DCCEEW, 2022a). When a person proposes to take an action that they consider may need approval under the EPBC Act, they must refer the proposal to the Commonwealth Minister for Environment.

Section 3A of the EPBC Act sets out the principles of ecologically sustainable development, which are:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- The principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.
- The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; and
- Improved valuation, pricing and incentive mechanisms should be promoted.

The construction and operation of the DPD Project (including the Commonwealth waters section) has been referred to DCCEEW under the EPBC Act and assessed to be a Controlled Action (referral number EPBC 2022/9372) requiring further assessment based on Preliminary Documentation (in progress).

3.2.1.2 *Environment Protection Act 2019* (NT)

The EP Act and associated EP Regulations are administered by DEPWS. The EP Act protects the environment and related purposes of the NT. The Act also:

- Promotes ecologically sustainable development
- Recognises the role of environmental impact assessment and environmental approval in promoting the protection and management of the environment of the Territory

+ Provides for broad community involvement during the process of environmental impact assessment and environmental approval
+ Recognises the role that Aboriginal people have as stewards of their country as conferred under their traditions and recognised in law, and the importance of participation by Promotion of ecologically sustainable development.

This CEMP has been developed under the guidance of this Act and the NT EPA Draft Guidelines for an Environmental Management Plan (NT EPA, 2015), and will be submitted to NT EPA with the DPD SER (BAS-210 0020) for assessment.

3.2.1.3 Energy Pipelines Act 1981 (NT)

The *Energy Pipelines Act 1981* (NT) allows for the creation of provisions for the construction, operation, maintenance and cessation of use or abandonment of pipelines for the conveyance of energy-producing hydrocarbons, and for related purposes. The *Energy Pipelines Act* applies to the DPD pipeline inshore from the NT Territorial Sea Baseline to the Onshore termination point.

The *Energy Pipelines Act 1981* (NT) and subsidiary Energy Pipelines Regulations require the proponent to operate licensed pipelines in accordance with an accepted Pipeline Management Plan (PMP). The Energy Pipelines Regulations do not require the PMP to explicitly consider environmental impacts and risks, however it is DITT- Energy Division policy that an environmental management plan (EMP), is submitted to, with the PMP for approval. This CEMP and supporting plans will constitute the EMP to be provided with the PMP for approval under the *Energy Pipelines Act 1981.*

3.2.2 Other relevant legislation

3.2.2.1 Commonwealth legislation

Commonwealth legislative requirements relevant to the DPD Project onshore construction activities are outlined in **Table 3-1**.

Table 3-1: Commonwealth legislation relevant to the activity

Commonwealth	
Title	**Description**
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	The purpose of this act is to preserve and protect places and objects in Australia and in Australian waters from injury or desecration; places or objects in question must be of particular significance to Aboriginal people with Aboriginal tradition.
Biosecurity Act 2015	The Act describes how to manage biosecurity threats to plant, animal and human health in Australia and its external territories, ensuring a very low level of risk.
Industrial Chemicals (Notification and Assessment) Regulations 1990 (Cth) National Industrial Chemicals Notification and Assessment Scheme (NICNAS)	Industrial chemicals are regulated by the Australian Government and administered by NICNAS. NICNAS provides a national notification and assessment scheme to protect the health of the public, workers and the environment from the harmful effect of industrial chemicals. NICNAS also assess all chemicals new to Australia and existing chemicals on a priority basis, in response to concerns about their safety on health and environmental grounds.
National Greenhouse and Energy Reporting Act 2007	Introduces a single national reporting framework for the reporting and dissemination of information about GHG emissions, GHG projects and energy use and production of corporations.

Commonwealth	
Title	**Description**
Native Title Act 1993	This Act provides for the recognition and protection of native title and provides or permits for the validation of past acts and intermediate period acts, invalidated because of the existence of native title. It additionally establishes ways in which future dealings affecting native title may proceed and sets standards for those dealings and establishes mechanisms for determining claims to native title. There is a Native Title Determination (Tribunal ID DCD2006/001) over the onshore Project Area, Larrakia (Part A – consolidated proceeding). The outcome of the determination found that Native Title does not exist (National Native Title Tribunal, 2022).
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	This Act, and associated regulations, implements the requirements of the Vienna Convention and Montreal Protocol to avoid using ozone depleting substances.

3.2.2.2 Northern Territory legislation

NT legislative requirements relevant to the DPD Project onshore construction activities are outlined in **Table 3-2.**

Table 3-2: Northern Territory legislation relevant to the activity

Northern Territory	
Title	**Description**
Aboriginal Land Rights (Northern Territory) Act 1976	The Act provides the basis upon which Aboriginal Australian people in the Northern Territory can claim rights to land based on traditional occupation
Aboriginal Land Act 1978	This Act provides for the access to Aboriginal land, certain roads bordered by Aboriginal land and the seas adjacent to Aboriginal land.
Bushfires Management Act 2016 Bushfires Management (General) Regulations 2017	The Act establishes the Bushfires Council and provides for the prevention and control of bushfires in the NT.
Dangerous Goods Act 1998 and *Dangerous Goods Regulations 2017*	This Act provides for the safe storage, handling, and transport of certain dangerous goods. These being explosives (including fireworks) and fuel gas (including Autogas) (NT WorkSafe, 2020).
Environmental Offences and Penalties Act 2011	This Act defines levels and penalties for environmental offences
Fire and Emergency Act 1996 Fire and Emergency Regulations 1996	This Act provides for the establishment and operation of the NT Fire and Rescue Service and their operational and emergency response activities. The Regulations outline general requirements under the Act, such as storing flammable or combustible material and using cutting, heating and welding equipment.

Northern Territory	
Title	**Description**
Northern Territory Environment Protection Authority Act 2012	This act aims to: a) promote ecology sustainable development; b) to protect the environment, having regard to the need to enable ecologically sustainable development; (c) to promote effective waste management and waste minimisation strategies; and (d) to enhance community and business confidence in the environmental protection regime of the Territory.
Planning Act 1999 Planning Regulation 2000	The Act provides framework of controls for the orderly use and development of land. The objective of the Act includes ensuring that strategic planning is applied to planning schemes and implemented in individual planning decisions, promotion of sustainable development of land and promotion of the responsible use of land and water resources to limit the adverse effects on development of ecological processes. Division 2 of the Act provides the planning basis for the submission, review and authorisation of Exceptional development permits (EDPs), and related EDP variations. An EDP has been issued for the DLNG Facility. Approval for the DPD Project will be obtained under the *Planning Act 1999* (NT), Santos is consulting with DIPL regarding the pathway for this approval.
Territory Parks and Wildlife Conservation Act 1976	This Act provides for the establishment of Territory Parks and other parks and reserves and for the study, protection, and conservation of wildlife in NT. This includes provisions on changes and revocation of parks, reserves and sanctuaries, the preparation and implementation of plans of management, the creation and management of sanctuaries and on the management of wildlife, flora, and fauna.
Waste Management and Pollution Control Act 1998 Waste Management and Pollution Control (Administration) Regulations 1998	This Act provides for the protection of the environment through encouragement of effective waste management and pollution prevention and control practices and for related purposes.
Weeds Management Act 2001	This Act allows for the classification of declared weeds or potential weeds, requirements for managing declared weeds or potential weeds and preparing management plans.

3.2.3 International conventions and agreements

Australia is signatory to numerous international conventions and agreements that obligate the Commonwealth government to prevent pollution and protect specified habitats for flora and fauna. Those which are relevant to the activity are outlined in **Table 3-3**.

Table 3-3: International agreements and conventions relevant to the activity

International agreements and conventions	
Title	**Description**
China-Australia Migratory Bird Agreement (CAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China. Implemented in the EPBC Act.

International agreements and conventions	
Title	**Description**
Japan-Australia Migratory Bird Agreement (JAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan. Implemented in the EPBC Act.
Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Korea. Implemented in the EPBC Act.
United Nations Convention on Biological Diversity – 1992	An international treaty to sustain life on earth.
United Nations Framework Convention on Climate Change (1992)	The objective of the convention is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. Australia ratified the convention in December 1992, and it came into force on 21 December 1993.

3.3 Standards, codes and guidelines

There are several Australian Standards, Codes of Practise and Guidelines relevant to this CEMP, which have been identified below.

+ AS2885 Pipelines – Gas and Liquid Petroleum
+ AS/NZS 4801 Occupational Health and Safety Management
+ AS/NZS ISO 9001:2008, Quality management systems – Requirements
+ AS/NZS ISO 14001:2004, Environmental management system – Requirements with guidance for use
+ AS/NZS ISO 31000:2009, Risk management – Principles and guidelines
+ HB 203:2006 Environmental Risk Management – Principles and Process
+ Draft Guidelines for the Preparation of an Environmental Management Plan (NT EPA, 2015)
+ Guideline for Reporting on Environmental Monitoring (NT EPA, 2016)

4 Environmental Management Framework

4.1 Santos management system

Santos's Management System (known as the SMS) exists to support its moral, professional, and legal obligations to undertake work in a manner that does not cause harm to people or the environment. The framework of policies, standards, processes, procedures, tools, and control measures that, when used together by a properly resourced and competent organisation, result in:

+ A common HSE approach is followed across the organisation.
+ HSE is proactively managed and maintained.
+ The mandatory requirements of HSE management are implemented and are auditable.
+ HSE management performance is measured, and corrective actions are taken.
+ Opportunities for improvement are recognised and implemented.
+ Workforce commitments are understood and demonstrated.

The Implementation Strategy and Stakeholder Consultation sections within this CEMP (**Section 8** and **Section 9**) align with the Santos Management System structure and are designed to require that:

+ environmental impacts and risks continue to be identified for the duration of the activity and reduced to ALARP.
+ controls are effective in reducing environmental impacts and risks to ALARP and acceptable levels.
+ environmental performance objectives (EPOs) and environmental performance standards (EPSs) set out in this CEMP are met.
+ consultation with relevant and interested persons is maintained throughout the activity as appropriate.

4.2 Santos' Environment, Health, and Safety Policy

Santos' Environment, Health and Safety Policy (**Appendix 1**) clearly sets out its strategic environmental objectives and the commitment of the management team to continuous environmental performance improvement. This CEMP has been prepared in accordance with the fundamentals of this policy. By accepting employment with Santos, each employee and contractor is made aware during the recruitment process that he or she is responsible for the application of this policy.

4.3 DPD Project environmental management plans

This CEMP is part of a suite of environmental management plans covering all activities from the 3 nm Commonwealth/NT waters boundary to the upstream weld of the beach valve. This Onshore CEMP covers activities between the onshore termination point and the upstream weld of the beach valve and the offshore CEMP (BAS-210 0024) covers activities between the Commonwealth/NT waters boundary and onshore termination point. The TSDMMP (BAS-210 0023), ASSDMP (BAS-210 0049) and MMNMP (BAS-210 0045) sit under the CEMPs addressing specific activities. These activities are described in **Section 1.3**. outlines this management plan hierarchy.

4.4 Supporting management processes and procedures

4.4.1 Contractor Health, Safety and Environment requirements

The HSE requirements for contracts/contractor management during pre-contract planning, contracting, contract execution and contract completion and evaluation are outlined in the HSE Contractor Management Operating Standard (SMS-HSS-OS08) and the Contracting and Procurement Operating Standard (SMS-PRC-OS01). It includes the following minimum requirements:

+ Contractors to comply with all applicable HSE laws and regulations and any additional guidelines, operating standards, policies and management plans provided to the Contractor.
+ A review of the Contractor HSE Management System is completed before being contracted.
+ Provisions for Santos to conduct audits/inspections of the Contractor’s operations, equipment and emergency procedures at any time.

4.4.2 Chemical selection and assessment procedure

All chemicals that are planned to be used on site during the DLNG construction activity will be evaluated using a defined framework and set of tools to ensure potential impacts are acceptable, ALARP and met Santos’ expectation for environmental performance.

DLNG construction personnel and contractors will adhere to the process outlined in the Chemical Management Procedure (ALL/HSE/PRO/044) and approved chemicals and hazardous substances will be recorded on the DLNG Approved Chemicals and Hazardous substances register (DLNG/HSE/REG/001).

4.4.3 Santos waste management process

As per the Santos Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02), Santos requires that for all waste generated at its facilities and by contractors under its influence, the hierarchy of waste management applies whereby wastes are (in order of preference) avoided, reduced, re-used, recycled, treated and/or disposed of at an appropriately licensed facility. A waste inventory must be documented and records of waste disposal from the onshore site are standardised (Waste Monitoring and Reporting Procedure - SMS-EXA-OS01-PD02-PD01) to allow accurate and consistent waste tracking. Contractors under this CEMP will demonstrate waste management processes will be aligned with regulatory and Santos’ requirements through the provision of Waste Management Plan for Santos acceptance.

5 Existing Environment

This section describes the key physical, biological, socio-economic and cultural characteristics of the existing environment that may be impacted by planned and unplanned events associated with the activity.

The description of the environment applies to the terrestrial land within which planned activities will occur (onshore Project Area; see **Figure 2-1**), and the terrestrial land and coastal waters that may be impacted by unplanned events. While highly unlikely, unplanned events could impact marine receptors within a few kilometres of the onshore Project Area.

5.1 Information sources

A summary of information derived from the following documents are provided in this section:

+ Darwin Pipeline Duplication (DPD) Project – EPBC Referral Supporting Information (BAA-201 0004; Santos, 2022a), including a Protected Matters Search Tool (PMST) report undertaken in October 2021 for a 5 km radius from the DPD pipeline
+ DLNG Operations Environmental Management Plan (OEMP) (ConocoPhillips, 2018)
+ Ichthys Gas Field Development Project – Draft Environmental Impact Statement (INPEX Browse Ltd, 2010)
+ Fauna conservation advice and recovery plans relevant to the onshore Project Area and within a few kilometres of it.

5.2 Key environmental factors

5.2.1 Terrestrial environmental quality

5.2.1.1 Bioregion

Based on the Interim Biogeographic Regionalisation for Australia Version 7, the onshore Project Area and surrounding areas are within the Darwin Coastal bioregion (Australian Government, 2022).

The Darwin Coastal bioregion comprises gently undulating plains on lateritised Cretaceous sandstones and siltstones; sandy and loamy red and yellow earths and siliceous sands from near the mouth of the Victoria River to just west of Cobourg Peninsula. The most notable vegetation feature is the extensive and diverse floodplain environment associated with the lower reaches of the many large river systems. There are also substantial areas of mangroves, and rainforest and other riparian vegetation fringing the rivers. Inland from the coast, the dominant vegetation type is eucalypt tall open forest, typically dominated by Darwin woollybutt (*Eucalyptus miniata*) and Darwin stringybark (*E. tetrodont*a) (Baker *et al.*, 2005).

5.2.1.2 Geology, soils and geomorphology

The bedrock of the onshore Project Area is comprised of meta-sediments that have metamorphosed and undergone one major deformation, resulting in steep dips and a north-north-east orientated strike of the strata (BAA-201 0003; Santos, 2021). The shore crossing's Burrell Creek Formation comprises of a sequence of phyllite, siltstone, shale, sandstone and conglomerate (ConocoPhillips, 2019).

The Koolpinyah Surface was developed in the Later Tertiary through an extensive cycle of deep weathering, erosion, re-sorting and lateralisation occurred throughout the Top End of the NT (Dames & Moore Pty Ltd, 1997). Parts of the Koolpinyah Surface are present on the Wickham Point peninsula, forming laterite deposits on the lower slopes' bench areas of the flanks of the ridges and as extensive platforms near sea level. There is a prominent ferricrete pavement near sea level that extends seawards out to the low tide level. It forms a capping on the shallow near shore reefs (ConocoPhillips, 2019).

Tidal mudflats surround the Wickham Point peninsula, which includes mangrove flats or salt flats. The mudflats are composed of Quaternary marine alluvium which consists of clay, silt and some fine sand, commonly with shell and coral fragments and organic matter in the mangrove zone and salt crusting on the salt flats (Dames & Moore Pty Ltd, 1997).

5.2.1.3 Topography and land units

The Darwin Coastal bioregion is characterised by generally flat, low-lying country that is drained by several large rivers (Bastin and the ACRIS Management Committee, 2008). The local topography at 1:2,500 scale of the onshore pipeline area is approximately 8 to 10 metres above Australian Height Datum (m AHD) and the broader onshore Project Area gently slopes to 6 m AHD along its southern boundary (DEPWS, 2022). The majority of the onshore Project Area has a slope of less than 2% (BAA-201 0003; Santos, 2021).

Two land units have been mapped over the onshore Project Area, noting that this area has been highly disturbed due to the DLNG Facility and the Bayu-Undan pipeline. The land units included (DEPWS, 2022; DLRM, 2015):

+ Low Hills – Steeply sloping ridge terrain; gradient 10 – 40%; shallow stony lithosols: Eucalypt Woodland, minor Open Woodland
+ Rises – Low rises (adjacent to estuarine areas); gradient 1 – 2.5%; shallow gravelly lithosols: Variable Tall Shrubland or Eucalypt Open Forest.

Soil orders across Wickham Point vary with the land units, generally Kandosols in the higher landscapes and Hydrosols in the lower landscapes (BAA-201 0003; Santos, 2021). The Keefers Hut and Littoral land systems overlap the onshore Project Area (DEPWS, 2022). The Keefers Hut land system area has largely been disturbed by the DLNG Facility and is described as plains and rises associated with deeply weathered profiles (laterite) including sand sheets and other depositional products and sandy and earth soils. The Littoral land system which encompasses most of Wickham Point, is characterised as tidal mudflats and coastal floodplains with channels and estuaries. It is subject to tidal inundation and has poorly drained clays and muds.

5.2.1.4 Rainfall and cyclone activity

The mean annual rainfall for Darwin is 1723.8 mm with the majority of this (87%) rainfall coming in wet season months between November and March. Mean 9am and 3pm relative humidity is also higher in the wet season following similar trends to rainfall (BOM, 2022).

5.2.1.5 Acid sulfate soils

ASS are formed naturally and often occur in low lying coastal areas (BAA-201 0003; Santos, 2021). Coastal estuarine and mangrove environments develop ASS due to its typical waterlogged nature, saltwater influences and anaerobic soils.

ASS mapping over the Darwin region indicates that the onshore Project Area has a high potential for PASS to occur (BAA-201 0003; Santos, 2021). As a result of the historical earthworks undertaken as part of the development of the DLNG facility, the natural material has been removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m below ground level (Santos, 2022b).

5.2.2 Terrestrial ecosystems

5.2.2.1 Flora, vegetation communities and weeds

5.2.2.1.1 Flora

A search of the DEPWS Natural Resource (NR) Maps database for threatened flora and significant flora within 5 km of the onshore Project Area identified one significant flora species, Byblis (*Byblis aquatica*) (DEPWS, 2022). This species is listed as near threatened under the *Territory Parks and Wildlife Conservation Act 1976* (TPWC Act) and was recorded approximately 5 km to the south-east of the onshore Project Area. It grows in semi-aquatic conditions and is insectivorous to acquire nutrients in nutrient-poor environments (Atlas of Living Australia, 2022). This species is commonly found in areas specifically between Darwin and Berry Springs.

Previous flora surveys of the DLNG Facility disturbance envelope did not identify the presence of any threatened or conservation significant flora species (BAA-201 0003; Santos, 2021). The Byblis is unlikely to occur within the onshore Project Area as it has been previously disturbed and there are no permanent freshwater habitats present (BAA-201 0003; Santos, 2021).

5.2.2.1.2 Vegetation communities

The vegetation on the Middle Arm Peninsula and inland of Darwin is consistent with the Darwin Coastal Bioregion and is classified as various closed forest and woodland communities, that is dominated by *Eucalyptus* woodlands and *Acacia* forest (BAA-201 0003; Santos, 2021).

CDM Smith (2021b) undertook a vegetation assessment of the DPD shore crossing location, inclusive of the approximately 200 m of onshore pipeline. The onshore pipeline alignment is maintained in a cleared state and is currently covered with naturally regrown native grasses and weeds. Visible vegetation along the southern extent of the onshore Project Area is dominated by common and fast growing *Acacia* species (*A. auriculiformis*) (CDM Smith, 2021b). Vegetation mapped outside of the onshore Project Area is described as closed forests, including *Acacia* closed forest, *Rhizophora* mid closed forest and *Sonneratia* low closed forest (DEPWS, 2022). No ecological communities listed under territory or Commonwealth legislation were recorded by CDM Smith (2021b) within the Project Area.

5.2.2.1.3 Mangroves

Monitoring of the mangrove communities surrounding the DLNG Facility has being ongoing since 2006 (CononoPhillips, 2018). They are comprised of predominately *Rhizophora* and *Sonneratia* species and to a lesser extent *Aegialitis*, *Avicennia*, *Osbornia* and *Aegiceras* species. The data collected indicates that the mangrove communities are in good health, with no significant deterioration or stress resulting from DLNG Facility operations.

CDM Smith's (2021b) vegetation assessment of the DPD shore crossing location identified less than five individuals of one mangrove species, *Sonneratia alba*, within 20 m either side of the DPD pipeline alignment. This species of mangrove is a common taxon that is well represented and characterised in the DLNG Facility's mangrove monitoring program. CDM Smith (2021b) concluded that the vegetation in proximity to the DPD pipeline is of low ecological value and well represented in the area.

These mangroves are located outside of the pipeline alignment for the approximately 200 m section of onshore pipeline, therefore are unlikely to be impacted by the onshore works relevant to this CEMP.

5.2.2.1.4 Introduced flora species

A desktop assessment of the NT DEPWS's NR Maps identified 11 introduced species (weeds) within approximately 5 km of the onshore Project Area (DEPWS, 2022) (**Table 5-1**). Three of the weed species are declared under the *Weeds Management Act 2001* (NT) and are Weeds of National Significance (WONS) (Centre for Invasive Species Solutions, 2020).

The DLNG Facility currently manages weeds in accordance with the DLNG OEMP (ConocoPhillips, 2018) which includes annual monitoring of weeds within the DLNG Facility site and lease area, and active weed management through herbicide application by grounds services contractor. Considering the onshore Project Area is entirely within the DLNG disturbance envelope, control measures to limit the introduction or spread of weeds during construction will be in line with the DLNG operational requirements (BAA-201 0003; Santos, 2021).

Table 5-1: Introduced species potentially found within and proximate to the onshore Project Area

Name	Status		Potential for occurrence within the onshore Project Area
	Declared under *Weeds Management Act 2001* (NT)	WONS	
Adenosma indiana	No	No	The closest recording of *Adenosma indiana* is approximately 3 km to the south-east on the Wickham Point peninsula. It is possible that this species could occur within the onshore Project Area.
Gamba Grass *Andropogon gayanus*	Yes	Yes	Gamba Grass may occur within the onshore Project Area as it has been previously identified within the DLNG Facility site (Greening Australia, 2015).
Aristolochia *Aristolochia indica*	No	No	The closest recordings of Aristolochia are on Channel Island, approximately 2.4 km to the south. It is possible that this species could occur within the onshore Project Area.
Rubber Bush *Calotropis procera*	Yes	No	The closest recording of a Rubber Bush is approximately 3.5 km to the south-east on the Wickham Point peninsula. It is possible that this species could occur within the onshore Project Area.
Golden Rain Tree *Cassia fistula*	No	No	The closest recordings of Golden Rain Tree are on Channel Island, approximately 3 km to the south. It is possible that this species could occur within the onshore Project Area.
Couch Grass *Cynodon dactylon*	No	No	The closest recording of Couch Grass is approximately 2 km to the south-east on the Wickham Point peninsula. It is possible that this species could occur within the onshore Project Area.
Bellyache Bush *Jatropha gossypiifolia*	Yes	Yes	The closest recordings of Bellyache Bush are on Channel Island, approximately 3 km to the south. It is possible that this species could occur within the onshore Project Area.

Name	Status		Potential for occurrence within the onshore Project Area
	Declared under *Weeds Management Act 2001* (NT)	WONS	
Lantana *Lantana camara*	Yes	Yes	Lantana may occur within the onshore Project Area as it has been previously identified within the DLNG Facility site (Greening Australia, 2015) and it has been recorded immediately adjacent to the onshore Project Area's southern boundary (DEPWS, 2022).
Coffee Bush *Leucaena leucocephala* subsp. *leucocephala*	No	No	The closest recordings of Coffee Bush are on Channel Island, approximately 3.3 km to the south. It is possible that this species could occur within the onshore Project Area.
Passiflora *Passiflora foetida*	No	No	Passiflora may occur within the onshore Project Area as it has been previously identified within the DLNG Facility site (Greening Australia, 2015).
Flannel Weed *Sida cordifolia*	Yes	No	The closest recording of Flannel Weed is approximately 2 km to the south-east on the Wickham Point peninsula. It is possible that this species could occur within the onshore Project Area.

5.2.2.2 Terrestrial fauna and fauna habitat

5.2.2.2.1 Threatened and migratory terrestrial fauna

A desktop assessment of the NT EPA referral's PMST search results and the NT DEPWS's NR Maps identified a number of threatened and significant fauna species within 5 km of the onshore Project Area (BAA-201 0003; Santos, 2021; DEPWS, 2022). These species may be present proximate to the onshore Project Area. However, given that the onshore Project Area has been previously cleared and is currently comprised of regenerating native grasses and weeds, it is not considered to be representative of habitat where most of the identified fauna species would likely occur (BAA-201 0003; Santos, 2021).

The criteria applied to define the likelihood of occurrence for terrestrial fauna is:

+ Unlikely: the Project Area is not within the species known distribution; and/or suitable habitat is not present within the Project
+ Potential: the Project Area is within the species known distribution, but the species has not been recorded within 5 km of the Project; and the Project Area contains suitable habitat for the species.
+ Likely: the species has been recorded within 5 km of the Project in the past 10 years; and the Project Area contains suitable habitat for the species.
+ Known to occur: the species has been recorded (directly by commissioned surveys or from database records) within the Project Area in the past 10 years.

The likelihood of conservation significant terrestrial fauna species occurring within the onshore Project Area, as determined in the NT EPA referral, is summarised in **Table 5-2**. Note the terrestrial fauna with a likelihood defined as "unlikely" are not listed in **Table 5-2.**

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Table 5-2: Conservation significant terrestrial fauna species potentially found within and proximate to the onshore Project Area

Name	Status		Occurrence likelihood	Potential for occurrence within the onshore Project Area
	EPBC Act	TPWC Act		
Terrestrial mammals				
Migratory Terrestrial / Wetland Species				
Common Sandpiper *Actitis hypoleucos*	Migratory	Not Listed	Potential	In Australia, the common sandpiper is found along all coastlines and in many areas inland, the common sandpiper is widespread in small numbers. The species utilises a wide range of coastal wetlands and some inland wetlands, with varying levels of salinity, and is mostly found around muddy margins or rocky shores and rarely on mudflats (DCCEEW, 2022b. The common sandpiper has been recorded in estuaries and deltas of streams, as well as on banks farther upstream, around lakes, pools, billabongs, reservoirs, dams and claypans, and occasionally piers and jetties. There is no suitable habitat for nesting or roosting within the onshore Project Area. However, there is potential habitat for foraging in the surrounding area, therefore individuals may traverse the onshore Project Area.
Oriental Plover *Charadrius veredus*	Migratory	Not Listed	Potential	This species has not been recorded within a 5 km radius of the onshore Project Area (DEPWS, 2022). The oriental plover is a non-breeding visitor to Australia where it occurs in both coastal and inland areas (DCCEEW, 2022c). In coastal habitats this species is found on estuarine mudflats and sandbanks, sandy or rocky ocean beaches or nearby reefs, or in near-coastal grasslands. In inland regions the oriental plover inhabits flat, open, semi-arid or arid grasslands, where the grass is short and sparse, and interspersed with hard, bare ground, such as claypans, dry paddocks, playing fields, lawns, and cattle camps. There are regrown grasses located near the coastline within the onshore Project Area, which may provide habitat for the oriental plover. Therefore, individuals may occasionally visit the onshore Project Area.

Name	Status		Occurrence likelihood	Potential for occurrence within the onshore Project Area
	EPBC Act	TPWC Act		
Osprey *Pandion haliaetus*	Migratory	Not Listed	Potential	Ospreys occur in littoral and coastal habitats and terrestrial wetlands of tropical and temperate Australia and offshore islands (DCCEEW, 2022d). They are mostly found in coastal areas but occasionally travel inland along major rivers, particularly in northern Australia. They require extensive areas of open fresh, brackish, or saline water for foraging. They frequent a variety of wetland habitats including inshore waters, reefs, bays, coastal cliffs, beaches, estuaries, mangrove swamps, broad rivers, reservoirs and large lakes and waterhole. Nests are usually located near a suitable area of foraging habitat and are a bulky structure made from piled sticks, often positioned in a tall dead tree or artificial structures such as telecommunication towers or poles. There is no suitable habitat for nesting or roosting within the onshore Project Area, however the onshore Project Area and surrounds contain suitable foraging habitat for the species. There is an osprey nest on the DLNG Facility site (BAA-201 0003; Santos, 2021).
Grey Plover *Pluvialis squatarola*	Migratory	Not Listed	Potential	Non-breeding birds occur around coastal Australia, with approximately 12,000 annually migrating to Australia (DCCEEW, 2022e). They inhabit intertidal mud flats, salt marshes, sand flats and beaches and feed on polyochaete worms, molluscs and crustaceans. There is no suitable habitat for nesting or roosting within the onshore Project Area. However, there is suitable habitat for foraging in the surrounding area, therefore individuals may traverse the onshore Project Area.

5.2.2.2.2 Introduced terrestrial fauna species

There are six introduced species that have been recorded within 5 km of the onshore Project Area (DEPWS, 2022). This included Rock Dove (*Columba livia*), Cane Toad (*Rhinella marina*), Asian House Gecko (*Hemidactylus frenatus*), Cat (*Felis catus*), Pig (*Sus scrofa*) and Black Rat (*Rattus rattus*).

Cats are established at Wickham Point, likely prior to the DLNG Facility was constructed, and are currently present in relatively low numbers (ConocoPhillips, 2018). Wild dogs are also present in low numbers, according to the presence of scats and tracks and observations by the DLNG Facility staff. There are no cat or dog control programs in place as there is no reason to implement one at this time. Cane toads are established at Wickham Point and may pose a threat to native predator populations (ConocoPhillips, 2018). Browsing ants (*Lepisiota frauenfeldi*) have been recorded at Darwin Port region in 2015, with known infestations found at Wickham Point, East Arm, Frances Bay and Berrimah (NT Government, 2022). Browsing ants can cause native species decline and alter ecosystem function by forming large colonies that displace native ants and invertebrates and strip native vegetation.

5.2.2.2.3 Biting pests

The Middle Arm Peninsula is known to have large populations of biting insects (i.e. mosquitos and midges) due to nearby mudflats and mangroves breeding sites along the peninsula shoreline, Hudson Creek and Bleesers Creek (Department of Health, 2011). There are also a number of breeding sites within constructed surfaces, including large mud ponds, shallow depressions on reclaimed land and on a site used for borrowing material, drainage lines and small sediment traps (BAA-201 0003; Santos, 2021).

Two mosquito species, northern salt marsh mosquito (*Aedes vigilax*) and common banded mosquito (*Culex annulirostris*), have been recorded in high numbers during the wet season at Middle Arm (Warchot and Whelan, 2010). They can occupy the same breeding sites, with breeding occurring when flooding lasts over seven days (BAA-201 0003; Santos, 2021). The northern salt marsh mosquito is recorded in high numbers from December to January, while the common banded mosquito is recorded in high numbers from January to April.

5.2.3 Inland and intertidal water quality

5.2.3.1 Groundwater and surface water

There are no permanent surface water features located in the onshore Project Area or its surrounds, however there are several minor creek lines that flow from high areas into Darwin Harbour during the wet season (ConocoPhillips, 2019). Surface water runoff can erode sediments and transport them into the harbour due to intense rainfall causing strong surface water flows and the structureless and sodic nature of soils in the Darwin regions (BAA-201 0003; Santos, 2021).

There are currently six groundwater bores located at the DLNG Facility and one offsite reference bore that have been monitored biannually since 2015 (DEPWS, 2022 and BAA-201 0003; Santos, 2021). Groundwater levels vary seasonally, with higher levels during the wet season and lower levels during the dry season. Groundwater levels averaged 5.43 mAHD in the wet season and 2.45 mAHD in the dry season in 2021 (CDM Smith, 2021a). Field measurements of groundwater from March 2015 to August 2021 found that pH was mostly acidic, ranging from 4.1 to 7.7 with an average of 6 pH units, and conductivity ranged from 98 microSiemens per centimetre (µS/cm) to 91,800 µS/cm with an average of 16,994 µS/cm. Conductivity varies subject to the seasons and bore proximity to the saline Darwin Harbour. Heavy metals are naturally elevated in all bores, which reflects the geology of the area (ConocoPhillips, 2019). The onshore Project Area overlaps the DLNG Facility's Irrigation Area, which is irrigated with wastewater from the DLNG wastewater treatment plant. All average metal concentrations, except arsenic, iron and manganese, are higher at the reference bore than the onsite bores which is likely a result from the irrigation water diluting natural concentrations (ConocoPhillips, 2019). Total nitrogen concentrations range from below the limit of reporting (LOR) to 66 mg/L and total phosphorus concentrations range from below the LOR to 1.76 mg/L (CDM Smith, 2021a). In comparison to the reference bore, some of the onsite bores have recorded elevated nutrient concentrations (ConocoPhillips, 2019).

5.2.3.2 Wetlands

The Port Darwin wetlands (NT029 Port Darwin) are listed as a Nationally Important Wetland under the Directory of Important Wetlands in Australia (Australian Government, 2022). The wetlands are located on the inner shores of the entire embayment of Port Darwin and includes 48,000 hectares (BAA-201 0003; Santos, 2021). The onshore Project Area is adjacent to a mangrove wetland to the south which is of low ecological value (BAA-201 0003; Santos, 2021; Australian Government, 2022).

5.2.3.3 Intertidal area

Part of the DPD Project Area is situated in a low-lying intertidal area. The clayey nature of the underlying soils and the surrounding area results in localised pooling of rainfall and limited/low infiltration rates. The site is largely cleared of large vegetation due to historical earthworks associated with the installation of the existing Bayu-Undan to Darwin GEP.

The coastline of the site is fringed by mangroves and clayey tidal flats to the north and south of the site.

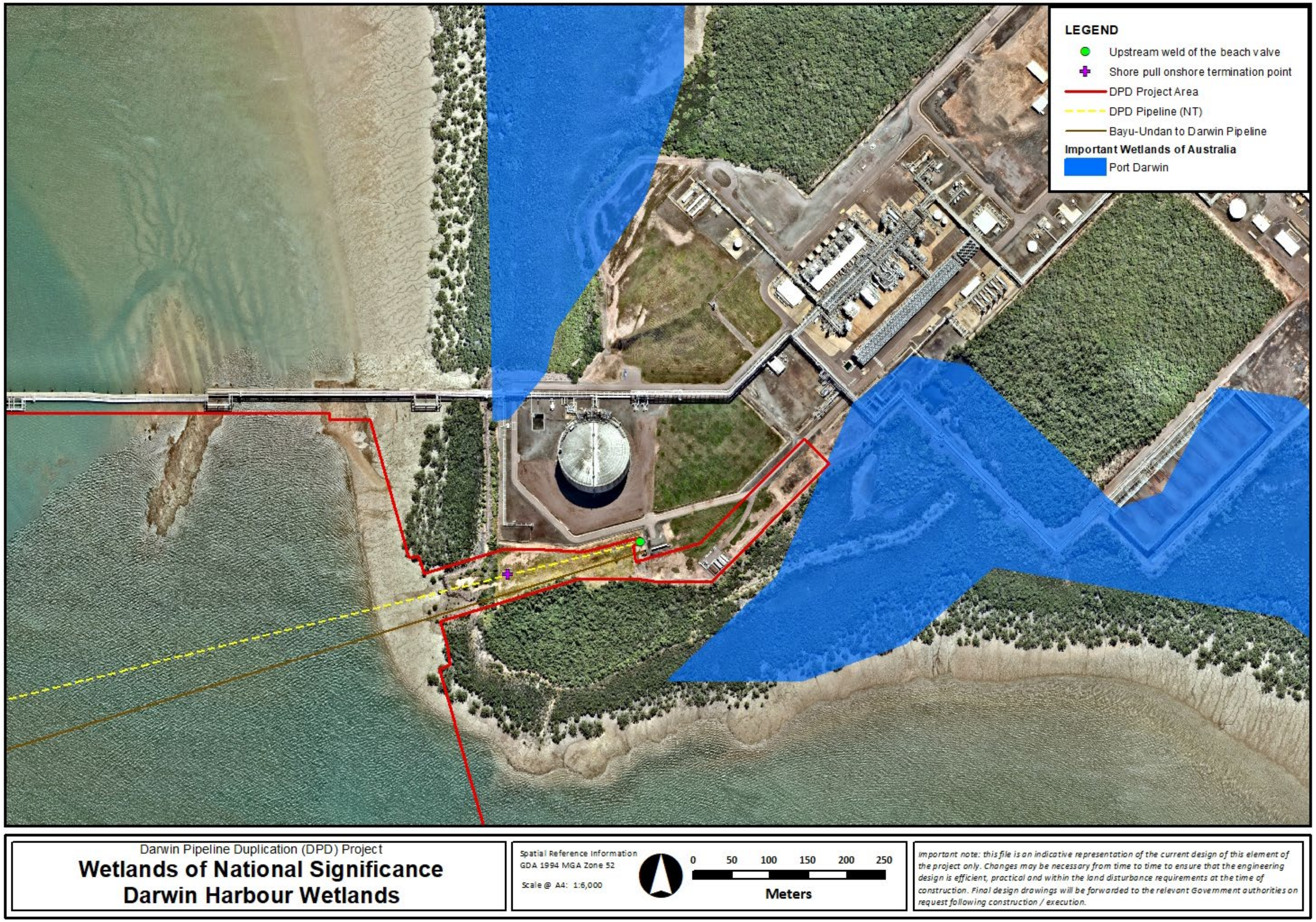

Figure 5-1: Wetlands of national significance - Darwin Harbour wetlands

5.2.4 Climate and air quality

5.2.4.1 Climate

The climate of the onshore Project Area is characterised by a tropical monsoonal climate with a distinct dry season (June to September) and wet season (October to April) (BOM, 2019). As described at the Darwin Airport weather station (BOM, 2022), the dry season is dominated by cooler temperatures, low humidity and minimal rainfall, whereas the wet season is dominated by warmer temperatures, high humidity and high rainfall, with high rainfall rates usually occurring during storm events.

Wind speeds are generally stronger in the dry season, generally coming from a south-easterly direction in the morning and from an easterly or north-westerly direction in the afternoons (BOM, 2022). Winds generally come from a westerly direction in the morning and from a north-westerly direction in the afternoon during the wet season.

Tropical cyclones occur on average once every four years (BOM, 2018). Storm surges often result in flooding, raised tidal levels and increased wave heights resulting in damage. These impacts are mostly felt within 50km of the coastline.

5.2.4.2 Air quality

Within nearshore NT coastal waters, particularly within Darwin Harbour, local and regional air quality is impacted by several anthropogenic influences, such as local industry, shipping and urban traffic and bushfires on a seasonal basis (BAA-201 0003; Santos, 2021). Air quality monitored by the NT EPA monitoring network in Darwin and its surrounds, including particular matter, carbon monoxide, sulphur dioxide, nitrogen dioxide, nitrogen oxide and ozone, found that Darwin has good air quality (Katestone, 2016).

5.2.5 Community and economy

5.2.5.1 Baseline noise

Noise modelling for the DLNG Facility by Bechtel Australia Pty Ltd (2001) predicted that the operational facility would not exceed 70 decibels A-weighted (dB (A)) at the property boundary with levels at Darwin predicted to be well below 45 dB (A) during normal atmospheric conditions. Noise monitoring that was undertaken in 2006 (SVT, 2007) to measure ambient background and construction noise for the DLNG Facility validated these findings, as the results indicated typical minimum noise levels at commercial or residential areas ranged from 34.2 dB (A) to 41.0 dB (A).

5.2.5.2 Petroleum industry

The onshore Project Area is entirely within the DLNG disturbance envelope. Gas produced offshore is conveyed via the Bayu-Undan to Darwin GEP to be converted into LNG at the DLNG Facility. The LNG is then transported to international markets (BAA-201 0003; Santos, 2021).

There is another LNG facility on Middle Arm, which is operated by INPEX, called the Ichthys LNG Project and is located approximately 5.5 km to the east of the DLNG.

5.2.6 Culture and heritage

There are no World Heritage properties and no heritage places on the National Heritage List or the Register of the National Estate within the onshore Project Area (DCCEEW, 2022f). No European heritage sites are currently listed at Wickham Point, with the remnants of artefacts documented and removed prior to the construction of the DLNG Facility (BAA-201 0003; Santos, 2021).

There are no Aboriginal sacred sites identified by the Aboriginal Areas Protection Authority under the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT) within the onshore Project Area (BAA-201 0003; Santos, 2021). There are no known Aboriginal burial grounds on Wickham Point, and possible burial grounds located at the northern extremity of Wickham Peninsula are well separated from the onshore Project Area (ConocoPhillips, 2018). A number of middens within and adjacent to the DLNG Facility disturbance envelope were subject to investigation with the former Heritage Branch of Department of Infrastructure, Planning and Environment. Shell middens are the most commonly recorded type of archaeological site within the Darwin region.

5.2.7 Recovery plans

Recovery Plans set out the research and management actions necessary to stop the decline of and support the recovery of listed Threatened species under the EPBC Act. **Table 5-3** summarises the current threats relevant to the activity, with more information about the specific requirements of the relevant management plans (including Conservation Advice and Conservation Management Plans) that would be applicable to the activity and demonstrates where current management requirements have been considered.

Table 5-3: Threats and strategies from relevant recovery plans, conservation advice and management plans

Name	Recovery Plan/Conservation Advice/Management Plan	Threats identified as relevant to the activity	Addressed (where relevant)
Migratory Terrestrial / Wetland Species			
Shorebirds (including common sandpiper, Oriental plover and grey plover) Seabirds (including Osprey)	National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (Department of the Environment and Energy [DoEE], 2020) Wildlife Conservation Plan for Seabirds (DAWE, 2020)	Light pollution	**Section 7.6.3**
		Habitat loss and modification	**Section 7.6.1, 7.6.2,** and **7.7.2**

6 Impact and risk Assessment

This CEMP has employed a systematic impact and risk assessment process for the environmental management of the DPD Project construction activities. The impact and risk assessment process has been developed in line with Santos' Environmental Impact Identification (ENVID) process and is consistent with the requirements of the NT EPA Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015).

6.1 Conceptual Site Model

A conceptual site model, as required by the NT EPA, is a written or illustrated representation of the nature, fate and transport of discharges, wastes or contaminants that allows assessment of potential and/or actual exposure of the environment to contaminants (NT EPA, 2015). The conceptual site model for this CEMP is embedded within the risk assessment detailed in **Table 6-7**.

6.2 Impact and risk assessment methods

The CEMP environmental impact and risk assessment was performed consistent with the Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02) and identification of management actions was consistent with Santos' Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02). An environmental aspect, for the purpose of this environmental management plan, is defined as characteristics of the construction activities that could potentially affect the environment.

6.2.1 Identification of environmental hazard

Environmental hazards for this CEMP were identified using Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021), DPD Project Basis of Approval (BAS-210 0005; Santos, 2022c) and discussion by the DPD Project team and environmental specialists. Key DPD Project construction activities and associated hazards and results from key technical studies were presented during ENVID workshops to inform the impact and risk assessment process.

6.2.2 Standard controls

The standard controls identified in **Table 6-7** were drawn from:

+ Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021)
+ Santos' environmental plans and procedures for similar activities
+ Regulator approved management plans developed by other proponents.

Additional controls were provided by ENVID workshop attendees based on their relevant experience.

6.2.3 Impact and risk assessment

All hazards identified were assigned a consequence level following the six levels and criteria outlined in Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02). More detailed criteria were developed to assist in addressing NT EPA Key Environmental Factors. These are the NT EPA consequence descriptors shown in **Table 6-1**.

The consequence is defined as the resulting impact from an event occurring. The consequence level for this assessment was based on the credible worst-case scenario and assumed no management actions were in place. Categories of environmental consequence and detailed definitions of each severity level are outlined in **Table 6-2**

The likelihood can be described as the probability that that the described consequence will occur. When determining the likelihood of consequences, proposed prevention and mitigation controls identified to mitigate potential impacts were considered. A detailed description of likelihood levels is outlined in **Table 6-3**

The consequence and likelihood levels are not presented in this CEMP but are contained in the ENVID documentation. **Section 6.3** and **Table 6-7** outline the residual consequences and likelihoods which is the outcome after standard and additional (as low as reasonably practicable; ALARP) management actions are applied.

A likelihood level was only assigned to unplanned events as per the Santos Risk Matrix Procedures (SMS-LRG-OS01-TP02), shown in **Table 6-4**. The consequence and likelihood for each impact was then assessed to determine the residual risk that remained after proposed standard controls were considered.

Table 6-1: NT EPA consequence descriptor

Consequence Level		I	II	III	IV	V	VI
Acceptability		Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Consequence Level Description		**Negligible** No impact of negligible impact	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors Localised effect	**Moderate** Significant impact to local population industry or ecosystem factors	**Major** Major long-term effect on local population industry or ecosystem factors	**Severe** Complete loss of local population industry or ecosystem factors AND/OR extensive regional impacts with slow recovery	**Critical** Irreversible impacts to regional population industry or ecosystem factors
Environmental Receptors	**Marine Ecosystems** Fauna, habitat, conservation significant areas and ecological function, processes and integrity	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of habitat critical / disruption to the breeding cycle/ vales of a protected area. No introduction of disease and no reduction in habitat area/function.	Detectable but insignificant decrease in local population size and threat to local population viability. Insignificant disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area. Detectable but insignificant loss of area/function of habitat with rapid recovery within 2 years.	Moderate. Significant decrease in local population size but no threat to overall population viability. Significant behavioural disruption or disruption to the breeding cycle of local population / Significant reduction in area of occupancy of species / loss of habitat critical to survival of a species. Modify, destroy, remove or decrease availability of quality habitat to the extent that a long-term decline in local population or function of habitat is likely with recovery over medium term (2-10 years) Introduction of disease likely to cause significant population decline	Long term decrease in local population size and threat to local population viability. Major disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area Fragmentation of existing population / Loss or change of habitat to the extent that a long-term decline in local population and function of habitat is likely with slow recovery over decades Introduction of disease likely to cause long term population decline	Complete loss of local population, habitat critical to survival of local population or protected area/conservation significant area Widespread (regional) decline in population size or habitat critical to regional population Extensive destruction of local habitat with no recovery or long term (decades) or widespread loss of area or function of primary producers on a regional scale	Complete loss of regional population Complete loss of habitat critical to survival of regional population
	Marine Environmental Quality Water quality, sediment quality, ecosystem health and parameters that support fishing, aquaculture, recreation, aesthetics and cultural/spiritual values	Negligible. No or negligible reduction in physical environment nor decrease in ecosystem function/health. No or negligible loss of value to socio-economic activities	Detectable but localised, short term and insignificant impact to physical environment or ecosystem function/health or value to socio-economic activities. Rapid recovery evident within ~ 2 years.	Significant wide-scale medium term impact to physical environment, decrease in ecosystem function/health or value to socio-economic activities. Recovery over medium term (2-10 years).	Wide-scale, long term impact to physical environment, long term decrease in ecosystem function/health or value to socio-economic activities. Slow recovery over decades.	Extensive impact to/destruction of physical environment with no recovery or shutdown of socio-economic activities Long term (decades) and widespread loss of ecosystem function/health on a regional scale that damages value to socio-economic activities.	Complete destruction of regional physical environment / habitat with no recovery Complete loss of area or function of primary producers on a regional scale

Consequence Level		I	II	III	IV	V	VI
	Coastal Processes Geophysical processes, primary productivity/ nutrient cycling, conservation significant areas/coastal landforms and cultural, aesthetic or recreation values	Short term changes to local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale	Detectable but insignificant loss or change to local geophysical/hydrological processes, area or function of primary producers/nutrient cycling or conservation significant areas with rapid recovery within 2 years.	Moderate. Significant modification, destruction, removal or change of local geophysical/hydrological processes, wide-scale loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with recovery over medium term (2-10 years).	Long term loss or change of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with slow recovery over decades	Extensive destruction of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with no recovery or long term (decades)	Complete loss or change of geophysical/hydrological processes. Complete loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale.
	Community and Economy Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping	No or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry. Significant medium-term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry. Permanent loss of key natural features or populations supporting the local industry.	Permanent shutdown of local or regional industry Permanent loss of key natural features or populations supporting the local or regional industry
	Culture and heritage Includes: Indigenous heritage and maritime heritage (i.e. shipwrecks)	No or negligible impact on the area's cultural or heritage values. No or negligible alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Detectable but insignificant impact on one or more of the area's cultural or heritage values. Detectable but insignificant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Significant impact on one or more of the area's cultural or heritage values. Significant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Major long-term effect on one or more of the area's cultural or heritage values. Major alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Complete loss of one or more of the area's cultural or heritage values.	Permanent loss of one or more of the area's cultural or heritage values with no recovery.
	Terrestrial Impacts Includes terrestrial fauna and flora	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of habitat critical / disruption to the breeding cycle/ vales of a protected area. No introduction of disease and no reduction in physical environment/ habitat area/function.	Detectable but insignificant decrease in local population size and threat to local population viability. Insignificant disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area. Detectable but insignificant loss of area/function of physical environment/ habitat with rapid recovery within 2 years.	Significant decrease in local population size but no threat to overall population viability. Significant behavioural disruption or disruption to the breeding cycle of local population / Significant reduction in area of occupancy of species / loss of habitat critical to survival of a species. Modify, destroy, remove or decrease availability of local physical environment/ habitat to the extent that a long-term decline in local population or function of habitat is likely with recovery over medium term (2-10 years) Introduction of disease likely to cause significant population decline	Long term decrease in local population size and threat to local population viability. Major disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area Fragmentation of existing population / Large scale loss or change of physical environment/ habitat to the extent that a long-term decline in local population and function of habitat is likely with slow recovery over decades Introduction of disease likely to cause long term population decline	Complete loss of local population, habitat critical to survival of local population or protected area/conservation significant area Widespread (regional) decline in population size or habitat critical to regional population Extensive destruction of local physical environment/ habitat with no recovery or long term (decades) or widespread loss of area or function of primary producers on a regional scale	Complete loss of regional population, complete loss of habitat critical to survival of regional population Complete destruction of regional physical environment / habitat with no recovery. Complete loss of area or function of primary producers on a regional scale.

Table 6-2: Environmental consequence level descriptions

Consequence Level	Consequence Level Description
I	**Negligible** – No impact or negligible impact
II	**Minor** – Detectable but insignificant change to local population, industry or ecosystem factors
III	**Moderate** – Significant impact to local population, industry or ecosystem factors
IV	**Major** – Major long-term effect on local population, industry or ecosystem factors
V	**Severe** – Complete loss of local population, industry or ecosystem factors AND/OR extensive regional impacts with slow recovery
VI	**Critical** – Irreversible impact to regional population, industry or ecosystem factors

Table 6-3: Likelihood descriptions

No.	Matrix	Description
F	Almost Certain	Occurs in almost all circumstances OR could occur within days to weeks
E	Likely	Occurs in most circumstances OR could occur within weeks to months
D	Occasional	Has occurred before in Santos OR could occur within months to years
C	Possible	Has occurred before in the industry OR could occur within the next few years
B	Unlikely	Has occurred elsewhere OR could occur within decades
A	Remote	Requires exceptional circumstances and is unlikely even in the long term

Table 6-4: Risk assessment matrix

		Consequence					
		I	II	II	IV	V	VI
Likelihood	F	Low	Medium	High	Very High	Very High	Very High
	E	Low	Medium	High	High	Very High	Very High
	D	Low	Low	Medium	High	High	Very High
	C	Very Low	Low	Low	Medium	High	Very High
	B	Very Low	Very Low	Low	Low	Medium	High
	A	Very Low	Very Low	Very Low	Low	Medium	Medium

6.3 Residual consequences and risks

6.3.1 Planned events

The residual consequence levels from the planned events following implementation of standard and additional (as low as reasonably practicable; ALARP) management actions (detailed in **Section 7**) are summarised in **Table 6-5**. Given the likelihood of a planned event occurring is 100% (in other words, it will occur), the risk ranking is not assessed. A comprehensive impact assessment for each of the planned events, and subsequent management actions proposed by Santos to reduce the risk and impacts to ALARP and/or acceptable levels are detailed in the following subsections. Within the ENVID developed by Santos some environmental aspects had multiple residual consequence ratings since multiple environmental factors were assessed against, in these cases the residual consequence of greatest severity was chosen.

Additional management actions have been adopted from the NT EPA referral's environmental management and mitigation measures (BAA-201 0003; Santos, 2021) and the DLNG OEMP (ConocoPhillips, 2018). The NT EPA referral's management actions were included to ensure this CEMP was consistent with the actions identified in the DPD Project NT EPA referral, and the DLNG OEMP's management actions were included to ensure that management of onshore works will be compliant with the DLNG Facility's operational environmental requirements.

Table 6-5: Summary of the residual consequence levels associated with planned events

CEMP Section	Event	Residual consequence
7.6.1	Ground disturbance and clearing – physical presence	II – Minor
7.6.2	Ground disturbance and clearing – acid sulfate soils	I – Negligible
7.6.3	Light emissions	II – Minor
7.6.4	Noise emissions	II – Minor
7.6.5	Atmospheric emissions	I – Negligible

6.3.2 Unplanned events

The residual risk levels from unplanned events following implementation of standard and additional (as low as reasonably practicable; ALARP) management actions (detailed in **Section 7**) are summarised in **Table 6-6**. Comprehensive risk assessment for each of the unplanned events, and subsequent management actions proposed to reduce the risk to ALARP and acceptable levels are detailed in the following subsections. Within the ENVID some unplanned events had multiple residual risk ratings since multiple environmental factors were assessed against, in these cases the residual risk of greater severity was chosen for this summary.

Subsequent to the completion of ENVID workshops, an additional environmental risk associated with the activity was identified; specifically the risk of a fire on site spreading to surrounding bushland.

Table 6-6: Summary of the residual risk levels associated with unplanned events

CEMP Section	Unplanned event	Residual risk level
7.7.1	Interaction with terrestrial fauna	Very low
7.7.2	Introduction or spread of invasive species (plants, insects and fauna)	Low
7.7.3	Release of non-hazardous and hazardous materials	Very low
7.7.4	Spread of fire to surrounding bushland	Low

6.4 Impact/risk assessment summary

The outcomes of the impact/risk assessment are presented in **Table 6-7**, and includes reference to the relevant management strategy within this CEMP used to manage individual environmental aspects.

Table 6-7: Summary of onshore construction impact and risk assessment outcomes

Aspect	Activity	Description of hazard	Spatial scale	Temporal scale	Potential impacts/risks	Sensitive receptors	Residual consequence (planned event) /risk level (unplanned event)	Management strategy
Planned events								
Ground disturbance and clearing – physical presence	Onshore construction including: + temporary storage of fill to be stockpiled in the disturbance footprint for use as backfill + disposal of excess filltrenching done by DLNG from nominal shorepull termination point (2 m above HAT) to the upstream weld of the beach valve	Clearing of regrown native grasses and weeds in a previously disturbed area will be required prior to excavating a trench for onshore pipeline section. Excavated soil will be temporarily stockpiled within the onshore Project Area to be used as fill or disposed of if in excess. The Barossa team will prepare the DPD site pad (**Figure 2-3**), including vegetation clearing, which overlaps part of the onshore pipeline alignment. As such, the DLNG team will only be required to partially clear the onshore pipeline alignment.	Localised within the onshore Project Area.	Temporary duration when the section of trench will be open. The trench will be backfilled at the conclusion of pre-commissioning works. The clearing of any vegetation currently present onsite will be permanent.	Excavating the trench may result in: + minimal clearing of the ground/vegetation + digging soil and placing it adjacent for later re-use + bringing in of geotextile and hardstand + additional fill of specific parameters to be brought to site if engineered backfill required. This may require disposal of excess 'original' soil – may need to be tested/treated prior to disposal + potential risk from erosion + spread of weeds Site clearing may impact terrestrial fauna and may require some ground clearing. If heavy rainfall is received, water may need to be pumped from the trench to adjacent land area. If stormwater runoff enters Darwin Harbour, coastal water quality may be impacted. Onshore construction activities have the potential to generate dust in the immediate and surrounding areas.	+ **Terrestrial impacts** (sediment quality, vegetation and terrestrial fauna) + **Marine environmental** quality (coastal water quality) + Marine ecosystem (marine fauna)	**II – Minor**	**Section 7.6.1**
Acid Sulfate Soils disturbance	Onshore construction including trench / excavation	The alignment of the onshore pipeline has been previously disturbed to install the Bayu-Undan to Darwin pipeline, however trenching works for the DPD pipeline may disturb natural ASS or PASS materials. This presents a risk of oxidation of ASS and subsequent mobilisation of heavy metals and acidification products. If encountered, the ASS or PASS materials will be stored on	The location of ASS or PASS materials potentially disturbed would be localised to the onshore Project Area. Any subsequent mobilisation of heavy metals and acidification products may extend outside the onshore Project Area and into the coastal waters of Darwin Harbour.	Temporary duration when trenching occurs.	Excavating the trench may disturb acid sulfate soils. This presents a risk of oxidation of acid sulfate soils and subsequent mobilization of heavy metals and acidification products. ASS disturbance may potentially impact ground water, surface water and fauna that come into contact with acidification products.	**Terrestrial impacts** (terrestrial fauna, groundwater and surface water quality).	I – Negligible	**Section 7.6.2**

Aspect	Activity	Description of hazard	Spatial scale	Temporal scale	Potential impacts/risks	Sensitive receptors	Residual consequence (planned event) /risk level (unplanned event)	Management strategy
		limestone pads within the onshore Project Area and treated with lime prior to reuse or disposal to landfill. Dewatering is dependent on the groundwater levels at the time of excavation. While it is considered unlikely that dewatering be required dewatering measures that may be implemented are outlined in the ASSDMP						
Light emissions	Onshore construction including operation of onshore plant and equipment e.g. trenching, pipelay and backfill	Potential impacts from light emissions may occur in the onshore Project Area from: + Lighting of the work areas + Lighting on the required onshore equipment and machinery Lighting will typically consist of bright white (in other words, metal halide, halogen, fluorescent) lights. It is expected that majority of activities will be undertaken during daylight hours, for safety and logistical reasons (BAA-201 0003; Santos, 2021).	Localised: Limited light 'spill' or 'glow' on land and surface waters surrounding the onshore location. The night environment is already compromised by artificial light sources from the DLNG Facility. Potential impacts from lighting used during construction (if required) will be minor in this context.	Lighting for night works will be ongoing for the duration of the activity (if required).	Change in fauna behaviour due to light emissions.	**Terrestrial impacts** (terrestrial fauna)	II – Minor	**Section 7.6.3**
Noise emissions	Onshore construction including operation of onshore plant and equipment	Onshore sources of noise emissions will be generated by the operation of required equipment and machinery (i.e., during excavation of trench). The greatest noise emissions will be from air compressors used during dewatering and pre-commissioning works. These noise emissions could change terrestrial fauna behaviour (avoidance / attraction / disruption of normal behaviour).	Noise levels are not expected to impact on the community and economy receptors due to its being localised to the DLNG facility in an industrial setting.	Noise is ongoing for the duration of the activity.	Change in fauna behaviour due to noise emissions including avoidance / attraction / disruption of normal behaviour.	**Terrestrial impacts** (terrestrial fauna)	II – Minor	**Section 7.6.4**
Atmospheric emissions	Atmospheric emissions from onshore combustion engines	Potential impacts from atmospheric emissions may occur in the onshore Project Area from the following source:	Broad: The quantities of gaseous emissions are relatively small however wind will disperse carbon	Temporary and intermittent for the duration of the duration of the onshore construction and pre-commissioning activity.	Atmospheric emissions from combustion engines can result in deterioration of local air quality. Atmospheric emissions can cause an	+ Terrestrial impacts + Air quality / Atmospheric	I – Negligible	**Section 7.6.5**

Aspect	Activity	Description of hazard	Spatial scale	Temporal scale	Potential impacts/risks	Sensitive receptors	Residual consequence (planned event) /risk level (unplanned event)	Management strategy
		+ Operation of generators, and mobile and fixed equipment and vehicles	dioxide evenly throughout the atmosphere		incremental increase in global GHG concentrations. The onshore site is an industrial site (DLNG Plant) and removed from residential/commercial areas. Given the nature and scale of gas export pipeline installation activities (low frequency and relatively short duration), the risk is considered to have a negligible impact.	emissions (local air quality)		
Unplanned events								
Interaction with terrestrial fauna	Onshore construction e.g.trenching, backfilling, excavation, trucking movements, and transportation to/from site	There will be an increased presence of personnel and machinery and vehicle movements in the onshore Project Area during the construction and pre-commissioning works. In addition, the onshore pipeline's trench will remain open for several months until its pre-commissioning works are completed. Increased traffic may result in changes to fauna behaviour or interaction with terrestrial fauna, including potential strike or collision, potentially resulting in severe injury or mortality. The open onshore pipeline trench could potentially result in severe injury or mortality from fauna entrapment.	Localised within the onshore Project Area.	Temporary and intermittent interaction with terrestrial fauna.	Behavioural impacts, injury or death to terrestrial fauna.	**Terrestrial impacts** (terrestrial mammals, reptiles, and birds)	Very low	**Section 7.7.1**
Introduction and spread of invasive species (plants, insects and fauna)	Onshore construction e.g. excavators, trucks and transportation to/from site.	The introduction or spread of invasive plant species or weeds may occur due to vegetation clearing, improper stockpiling of cleared vegetation containing weeds, machinery and vehicle movements, and importing rock and fill from offsite locations. Wind-borne incursions of weeds may also occur, as weeds are present within the DLNG Plant	Localised to the onshore Project Area, and its surrounding local environment	Temporary to long-term (if invasive species and pests become established above current levels)	Potential establishment of an invasive species because of the activity requires that invasive species to: + Be present on a vector + Be released from the vector + Establish in the receiving environment. Potential spread of an invasive species observed around the DLNG	**Terrestrial impacts** (terrestrial flora and fauna)	Low	**Section 7.7.2**

Aspect	Activity	Description of hazard	Spatial scale	Temporal scale	Potential impacts/risks	Sensitive receptors	Residual consequence (planned event) /risk level (unplanned event)	Management strategy
		and the broader surrounds (BAA-201 0003; Santos, 2021). The introduction or spread of invasive insects and fauna (e.g., ants, cane toads) may occur due to machinery and vehicle movements, and attraction to construction or pre-commissioning activities.			Plant because of the activity may also occur. Invasive species could displace and outcompete local species.			
Release of non-hazardous and hazardous materials	+ Onshore construction e.g., excavators, trucks and transportation to/from site. + Storage of hazardous and non-hazardous liquids + Storage of waste	Minor hydrocarbon and chemical spills to land may occur during the storage, handling and transfer of fuel and chemicals during construction and pre-commissioning works. Uncontained waste dispersed into surrounding marine and terrestrial setting.	Localised: Volumes are likely to be minor and be restricted to within the onshore Project Area.	Temporary duration for the activity.	Contamination of soils, surface water or groundwater	+ **Marine environmental** quality (coastal water quality) + Marine ecosystem (marine fauna) + **Terrestrial impacts** (physical environment, terrestrial flora and fauna)	Very low	**Section 7.7.3**
Spread of fire to surrounding bushland	Onshore construction e.g. excavators, trucks and transportation to/from site.	The onshore works have the potential to increase the risk of starting a bushfire, as there will be additional fuel and ignition sources located onsite. A bushfire would lead to destruction of surrounding terrestrial ecosystems and associated terrestrial vegetation and fauna. Bushfires can occur in most vegetated areas with an ignition source, suitable climatic conditions, and sufficient fuel.	Localised to Wickham Point	Temporary duration for the activity	Fire damage to a potentially large area of terrestrial ecosystems and associated terrestrial fauna and vegetation (ConocoPhillips, 2018).	+ Terrestrial impacts + Air quality	Low	**Section 7.7.4**

6.5 Assessment of potential for cumulative impacts

The following section provides a summary of potential cumulative impacts associated with the onshore DPD Project construction activities. Further detail is provided within the DPD Project Supplementary Environmental Report (SER) (BAS-210 0020).

6.5.1 Cumulative assessment methodology

The SER (BAS-210 0020) provides a whole of project assessment of cumulative impacts to three key NT EPA environmental factors: Marine Environmental Quality, Marine Ecosystems and Atmospheric Processes, and three other NT EPA environmental factors: Coastal Processes, Community and Economy and Culture and Heritage (NT EPA, 2022).

Identified projects and activities with the potential for cumulative impacts with the DPD Project are discussed in further detail within Section 12.4 of the SER (BAS-210 0020). Two of the NT EPA environmental factors were considered sensitive for cumulative impacts under the scope of this CEMP and are discussed in **Sections 6.5.2 and 6.5.3**.

6.5.2 Cumulative impacts to atmospheric processes

This Project construction activities will generate atmospheric emissions which will contribute to the overall concentration of GHG in the Earth's atmosphere. Emissions resulting from construction activities (i.e. use of combustion engines) will occur on a short-term basis. The DPD project is included in Santos' Climate transition action plan and will adhere to the Santos GHG management plan and energy management program.

6.5.3 Cumulative impacts to community and economy

Direct impacts to social, recreational and ecological values from activities detailed within this CEMP are not predicted to be significant and will be localised to an existing disturbance area (DLNG facility) where public access is restricted, therefore direct cumulative impacts to these values are not predicted.

7 Environmental management strategies

This section outlines the environmental management strategies (EMSs) that will be implemented for management of areas and activities associated with the DPD Project construction works, therefore minimising and/or mitigating impacts and risks to the environment.

The EMSs to be implemented as part of this CEMP comprise of the following:

+ Planned impact management strategies (**Section 7.6**)
+ Unplanned risks management strategies (**Section 7.7**).

These EMS outline the commitments and objectives that are relevant and state specific measurable targets to achieve proposed objectives. Performance indicators and monitoring activities are used to quantify success in meeting requirements and identify the need for corrective actions. This ensures the continuous improvement of the effectiveness of the DPD Project's EMS. The EMS define the reporting requirements, terms and responsibilities.

All EMS are structured to align with the template presented in **Table 7-1**.

Table 7-1: Environmental management strategies template

Item	Content
Environmental Performance Objectives (EPO)	Environmental management goal(s) tailored to each aspect per NT EPA requirements.
Target	Aspect specific measurable performance necessary to successfully achieve objective. Part 1 of NT EPA required performance criteria.
Performance Indicator	Quantitative or qualitative measures representing the performance related to Target(s). Part 2 of NT EPA required performance criteria.
Management actions	Tasks to be undertaken to meet objective/s.

7.1 NT EPA hierarchy

In the development of the EMS outlined within this CEMP Santos applied the Environmental Decision-Making Hierarchy outlined within the EP Act. This hierarchy being:

+ To ensure that actions are designed to avoid adverse impacts on the environment
+ To identify management options to mitigate adverse impacts on the environment to the greatest extent practicable
+ And if appropriate, provide for environmental offsets in accordance with the EP Act for residual adverse impacts on the environment that cannot be avoided or mitigated[1].

[1] No offsets were deemed appropriate for this project.

7.2 Environmental performance objectives

To ensure environmental risks and impacts will be of an acceptable level, environmental performance objectives (EPOs) have been defined and are listed in following sections for planned and unplanned events. The EPOs were developed based on each environmental aspect and associated impact/risk.

7.3 Performance criteria

To assess whether EPOs are being achieved it is important to define specific performance criteria, which will take the form of targets and performance indicators. Detailed specific measurable targets must be defined and then met to achieve overarching EPOs. Performance indicators are the factor that is measured to assess whether the performance targets have been achieved.

7.4 Management actions

To mitigate impacts of the DPD Project construction activities and to achieve EPOs and performance criteria, management actions will be defined and implemented. This will include standard, additional (ALARP) and adaptive management actions that will be implemented if triggered.

7.5 Adaptive management mechanism

The consequences of all planned events impacts were assessed as minor to negligible and the level of unplanned events risks were assessed as low to very low. A monitoring and adaptive management mechanism will be applied to the following event to ensure EPOs are met:

+ Acid sulfate soils: It is understood that the soil across the onshore zone (within the onshore Project Area) is likely to be non-ASS material. The ASSDMP (BAS-210 0049) provides operating strategies for earthworks and contingency dewatering in the onshore zone, which includes adaptive management measures in the event of encountering PASS or ASS material.

Adaptive management can also be triggered through Santos' incident response and assurance processes, with corrective actions and management adapted as required to address any incidents and non-conformances identified.

7.6 Planned events impact management strategies

Santos' environmental impact assessment identified six impacts arising from planned events to be undertaken in the onshore Project Area. Management strategies have been adopted in this CEMP based on the ENVID outcomes and additional review (refer to **Section 6**).

7.6.1 Ground disturbance and clearing – physical presence

7.6.1.1 Environmental performance objectives, performance criteria and management actions

The EPOs and performance criteria for ground disturbance and clearing – physical presence are described in **Table 7-2**.

Table 7-2: Ground disturbance and clearing – physical presence EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid impacts to native vegetation and fauna from ground disturbance and clearing	Planned ground disturbance is limited to within previously cleared areas	Recorded areas disturbed via excavation logs
	Zero incidents of disturbance to vegetation outside previously cleared areas	Number of recorded incidents of damage to environment outside of previously cleared areas
	Zero incidents of injury to terrestrial native fauna as a result of the DPD construction activities	Number of recorded incidents relating to terrestrial fauna injury or mortality as a result of ground disturbance.

This EPO aligns with the following NT EPA Factor objectives (NT EPA, 2022):

+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
+ Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.
+ Marine environmental quality (coastal water quality)
+ Marine ecosystem (marine fauna)

The management actions considered for this planned event are shown in **Table 7-3**. EPS and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-3: Management actions for ground disturbance and clearing – physical presence during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Avoidance	
DPD-DLNG-MA01	Restrict disturbance to within the onshore Project Area and existing DLNG site area
DPD-DLNG-MA02	Establish appropriate access restrictions to the onshore Project Area
Mitigation	
DPD-DLNG-MA03	Pump water through a silt separator when dewatering in the excavated trench in sections where the trench does not naturally drain to harbour
DPD-DLNG-MA04	Geotextiles will be installed under primary construction area (i.e. site pad)
DPD-DLNG-MA05	Trench inspections to be performed daily to check for trapped wildlife
DPD-DLNG-MA06	Insert caps on ends of pipe if the pipe is to be unattended for periods >12 hours; to prevent fauna ingress.
DPD-DLNG-MA07	Ensure any native vertebrates injured by DPD construction activities are referred to an appropriate wildlife carer group or veterinarian
DPD-DLNG-MA08	Return onshore site to natural grade to match existing topography following completion of the activity
DPD-DLNG-MA09	Maintain batters or install fauna ladders on trench entry and exit to allow fauna to exit the trench
Additional (ALARP) management actions	
Avoidance	
DPD-DLNG-MA10	Limit vehicles to access roads, prepared site pad or defined boundaries within the onshore Project Area/DLNG disturbance envelope
Mitigation	

MA Reference	Management Action
DPD-DLNG-MA11	Use water truck for dust suppression
DPD-DLNG-MA12	Establish and implement vehicle speed controls

7.6.1.2 Demonstration of ALARP and residual impact

Construction works for the activities in this CEMP will be confined to the Project Area and previously disturbed areas within the DLNG site area. Given the type of construction occurring there were no credible alternatives to reduce ground disturbance identified in the ENVID workshops. Table 7.3 details the management actions to reduce impact to onshore sediment quality, water quality, air quality, and terrestrial fauna.

Inclusion of additional fauna impact mitigations means that there will be regular inspections of trenches and preventative measures in place to prevent fauna ingress into the pipeline. Trench batter design will provide a gradient that prevents entrapment and injury, allowing fauna to move freely, with trench ends left open to assist with fauna egress.

Given the temporary and localised nature of the impacts and the existing disturbance at the site, the management actions in place are appropriate for the nature and scale of this activity. Any known impacts and potential risks have been reduced to ALARP and the impact level is considered Minor and acceptable.

7.6.2 Ground disturbance and clearing – acid sulfate soils

7.6.2.1 Environmental performance objectives, criteria and management actions

The EPO and performance criteria for ground disturbance and clearing – acid sulfate soils are described in **Table 7-4** .

Table 7-4: Ground disturbance and clearing – acid sulfate soils EPO and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Prevent project attributable mobilisation of heavy metals and acidification products to the surrounding environment	No incidents of project attributable mobilisation of heavy metals and acidification products to the surrounding environment	Records of ASS presence in sediment/soil via excavation logs/ daily observations/ photographs Incident investigation records

These EPOs align with the following NT EPA Factor objectives (NT EPA, 2022):

+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
+ Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-5**. Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-5: Management actions for ground disturbance and clearing – Acid Sulfate Soils during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Mitigation	
DPD-DLNG-MA13	Implement ASS and groundwater management and monitoring requirements within the ASSDMP (BAS-210 0049) if ASS or groundwater is encountered during onshore construction activities. The ASSDMP includes requirements for: + ASS stockpiling, laboratory testing and treatment + Groundwater laboratory testing and treatment + Maintenance of testing and inspection records + Contingency dewatering
Additional (ALARP) management actions	
Mitigation	
DPD-DLNG-MA14	Treat ASS material such that no acidic soil or runoff can be released to the environment before it can be used as backfill within the Project Area

7.6.2.2 Demonstration of ALARP and residual impact

During the construction of the Bayu-Undan to Darwin GEP natural material within the onshore Project Area was replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m below ground level. Hence it is considered that material at the site is likely to be non-ASS.

None-the-less, should ASS material be encountered during earthworks within the onshore Project Area, it will be managed in line with the ASSDMP (BAS 210 0049). Any suspected ASS will be removed from the onshore zone's excavation area and stockpiled separately from non-ASS materials on a bunded limestone pad ahead of confirmatory testing.

Terrestrial fauna and vegetation may interact with stockpiled soils, however given that these will be managed within short temporal scales in accordance with the ASSDMP, there no significant impact is expected.

Following implementation of standard and additional (ALARP) management actions, including the implementation of the ASSDMP (BAS-210 0049), the assessed residual consequence for this impact is negligible and cannot be reduced further. It is considered therefore that the impact of the activities conducted is ALARP and is considered acceptable.

7.6.3 Light emissions

7.6.3.1 Environmental performance objectives, criteria and management actions

The EPOs and performance criteria for light emissions are described in **Table 7-5** .

Table 7-6: Light emissions EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No harm to native fauna from project lighting	No reports of injury or mortality to native fauna from light generated during DPD construction activities	Reports of sighting of live, injured, or dead terrestrial fauna
	Limit light to that required for safe work environment	Records of light inspections

This EPO aligns with the following NT EPA Factor objectives (NT EPA, 2022):

- Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
- Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-7**. Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-7: Management actions for light emissions during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Mitigation	
DPD-DLNG-MA15	Lights to be orientated directly over the area of work and overspill reduced where practicable by using screens or hoods on lights
DPD-DLNG-MA16	Light audit undertaken within 14 days of commencing construction activities
Additional (ALARP) management actions	
N/A	
Additional (ALARP) management actions not adopted	
1	Marine fauna observers specifically looking out for turtle hatchlings entrapped within light spill with adaptive management measures should a significant number be spotted. Reason for rejection: + The onshore construction area is not near turtle nesting beaches.
2	Construction activities limited to non-nesting timeframes Reason for rejection: + Cost disproportionate to benefit given proximity to important nesting beaches and existing lighting from DLNG facility

7.6.3.2 Demonstration of ALARP and residual impact

Artificial lighting will be required to maintain safe working conditions if night works are undertaken. The onshore Project Area is directly adjacent to the operational DLNG Facility, any artificial lights required for night works are unlikely to have a noticeable effect on the existing night environment, which is already influenced by lighting at the DLNG Facility. No threatened or migratory species are expected to be impacted by the minor and temporary increase in light emissions. Further, the use of artificial lighting, will be oriented away from adjacent vegetation/marine environment and at an intensity to allow work to proceed safely.

The potential consequences of the anthropogenic light in the onshore Project Area are expected to be restricted to short-term behavioural impacts on individual fauna that may be present in the onshore Project Area during the activity. Terrestrial fauna may be disturbed or attracted by artificial light, which may increase their risk of predation or interaction with machinery or vehicles. The short duration of the activity is unlikely to lead to any significant impacts to local populations.

The assessed residual consequence for this impact is minor, following implementation of standard management actions. Therefore, due to management actions in place, the terrestrial impacts from artificial lighting are ALARP and considered environmentally acceptable.

7.6.4 Noise emissions

7.6.4.1 Environmental performance objectives, criteria and management actions

The EPO and performance criteria for noise emissions are described in **Table 7-8**.

Table 7-8: Noise emissions EPO and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Limit harm to native fauna from noise emissions from onshore construction	Full compliance with preventative maintenance procedures for power generating equipment and compressors, including industry standard noise reduction equipment.	Recorded incidents of non-compliance

This EPO aligns with the following NT EPA Factor objectives (NT EPA, 2022):

+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
+ Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-9**. Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

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Table 7-9: Management actions for noise emissions during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Mitigation	
DPD-DLNG-MA17	Preventative maintenance of equipment and machinery
Additional (ALARP) management actions	
N/A	
Additional (ALARP) management actions not adopted	
1	Avoid night works. Reason for rejection: + This would have schedule implications which would extend duration of works thereby extending the period in which the impact is realised. Additionally the cost of implementing far exceeds the benefit gained. ALARP justification will be reviewed if safety risks are unacceptable for certain night activities.

7.6.4.2 Demonstration of ALARP and residual impact

Equipment and machinery used onshore are considered essential to undertaking the installation and pre-commissioning works for the onshore pipeline and noise emissions are an unavoidable consequence of construction activities. Given the routine maintenance of the equipment and machinery by suitably qualified personnel, and adherence to industry standards, all practicable management measures are considered to have been implemented.

Noise emitted by the equipment and machinery during onshore construction and pre-commissioning works may affect fauna behaviour. Avoidance behaviour is likely to be localised to the onshore Project Area and temporary. Considering the location within the existing DLNG Facility disturbance envelope and the surrounding industrial land uses of Darwin Harbour local impacts to fauna may result in detectable but insignificant impacts to in local population size and local population viability.

The residual consequence of noise emissions on receptors is assessed as minor, following the implementation of standard management actions, and will not have a significant impact. The impact of noise emissions to the receiving environment are therefore ALARP and considered acceptable.

7.6.5 Atmospheric emissions

7.6.5.1 Environmental performance objectives, criteria and management actions

The EPO and performance criteria for atmospheric emissions are described in **Table 7-10**.

Table 7-10: Atmospheric emissions EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise atmospheric emissions generated during DPD construction activities.	Full compliance with preventative maintenance procedures for power generating equipment.	Recorded incidents of non-compliances

This EPO aligns with the following NT EPA Factor objectives (NT EPA, 2022):

+ Air quality – Protect air quality and minimise emissions and their impact so that environmental values are maintained.
+ Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-11**. Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-11: Management actions for atmospheric emissions during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Mitigation	
DPD-DLNG-MA17	Preventative maintenance of equipment and machinery
Monitoring	
DPD-DLNG-MA18	Monitor and report fuel consumption
Additional (ALARP) management actions	
Monitoring	
DPD-DLNG-MA19	The Barossa project is included in Santos' Climate transition action plan and will adhere to the Santos GHG management plan and energy management program

7.6.5.2 Demonstration of ALARP and residual impact

Power generation through combustion of fossil fuels is essential to undertaking the onshore construction and pre-commissioning works, either by power generation or by operating equipment and vehicles. There are no practicable alternatives to the use of equipment, vehicles and mobile plant powered by combustion engines for the activity. Given the routine maintenance of these systems by suitably qualified personnel, all practicable management measures are considered to have been implemented.

Records of fuel consumption during the onshore works will be maintained to identify the quantity of GHG emissions that were generated from fuel combustion. This information would inform annual reporting under the *National Greenhouse and Energy Reporting Act 2007*.

The location of the activity is within an industrial site that is removed from residential areas. Given the nature and scale of the activity (low number of equipment and short duration), the residual consequence on air quality and sensitive receptors is expected to be negligible, following the implementation of standard management actions and impacts from emissions that are generated by the activity are considered environmentally acceptable.

7.7 Unplanned events risk management strategies

Santos' environmental risk assessment identified four potential sources of environmental risk associated with the activity. Management strategies have been adopted in this CEMP based on the ENVID outcomes (refer to **Section 6**).

7.7.1 Interaction with terrestrial fauna

7.7.1.1 Environmental performance objectives, criteria and management actions

The EPO and performance criteria are described in **Table 7-12**.

Table 7-12: Interaction with terrestrial fauna EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No harm to native terrestrial fauna from ground disturbance and clearing	Ground disturbance limited to within previously cleared areas	Recorded areas disturbed via excavation logs
	Zero injury to terrestrial native fauna as a result of the DPD construction activities	Recorded number of incidents relating to terrestrial fauna injury or mortality.

This EPO aligns with the following NT EPA Factor objectives (NT EPA, 2022):

+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
+ Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-13**. Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-13: Management actions for interaction with terrestrial fauna during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Avoidance	
DPD-DLNG-MA10	Limit vehicles to access roads, prepared site pad or defined boundaries within the onshore Project Area/DLNG disturbance envelope
Mitigation	
DPD-DLNG-MA07	Ensure any native vertebrates injured by DPD construction activities are referred to an appropriate wildlife carer group or veterinarian
DPD-DLNG-MA12	Establish and implement vehicle speed controls
DPD-DLNG-MA20	Maintain the onshore Project Area as a cleared site during construction activities
Additional (ALARP) management actions	
N/A	

7.7.1.2 Demonstration of ALARP and residual risk

There are no alternative options to using vehicles and machinery to undertake the activity. Any impact caused by the physical presence of vehicles and machinery is likely to be localised and temporary, with terrestrial species expected to resume normal behaviours in the surrounding environment once construction activities are completed.

In the event that vehicles or machinery come in close proximity to terrestrial fauna, management actions will be implemented to reduce the likelihood of a terrestrial fauna collision to ALARP. This includes limiting the vehicle speed, restricting vehicles to designated access roads, informing personnel of risks to environment and maintaining a cleared onshore Project Area. Should fauna become harmed during the activity, they will be appropriately rehabilitated and relocated as required.

The inherent likelihood of encountering fauna in the onshore Project Area is limited by the short duration of the activity, lack of suitable habitat within the onshore Project Area, the fact that the onshore Project Area is highly disturbed and the expected behaviour of individuals to move away from vehicle and machinery noises. With the controls adopted, the assessed residual risk for this impact is very low and considered to be reduced to ALARP and is therefore acceptable.

7.7.2 Introduction and spread of invasive species

7.7.2.1 Environmental performance objectives, criteria and management actions

The EPOs and performance criteria for the introduction and spread of invasive species are described in **Table 7-14**.

Table 7-14: Introduction and spread of invasive species EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	**Performance Indicator/s**
No introduction and spread of invasive species	Zero incidents of increase in abundance or distribution of invasive species from DPD project onshore construction activities.	Records of incidents relating to the introduction of invasive species attributed to the construction works
	Ground disturbance limited to within previously cleared areas	Records of areas disturbed via excavation logs

This EPO aligns with the following NT EPA Factor objectives (NT EPA, 2022):

- Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
- Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-15**. Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-15: Management actions for introduction and spread of invasive species during onshore DPD construction activities

MA Reference	Management Action
Standard management actions	
Avoidance	
DPD-DLNG-MA02	Establish appropriate access restrictions to the onshore Project Area
DPD-DLNG-MA10	Limit vehicles to access roads, prepared site pad or defined boundaries within the onshore Project Area/DLNG disturbance envelope
Mitigation	
DPD-DLNG-MA21	Comply with DLNG inspection requirements for new vehicles, plant, and equipment to site
DPD-DLNG-MA22	All equipment and material imported from overseas will be inspected by the Australia Quarantine and Inspection Service (AQIS)
DPD-DLNG-MA23	Provide and routinely collect onsite covered putrescible waste bins

7.7.2.2 Demonstration of ALARP and residual risk

Importation of equipment and material, and vehicle movement, is required for the activity. Management for invasive species for this activity will comply with the *Weeds Management Act 2001* (NT) and the requirements of the DLNG Facility. The risk of bringing invasive species into the onshore Project Area will be minimised by the inspection requirements of DLNG and AQIS, while the spread of invasive species will be minimised by restricting access to the onshore Project Area and access roads.

Vehicles for construction will not transit to or from the worksite each day. In most cases, they will enter the site, then remain onsite until no longer required, reducing the risks of contamination. Given the existing presence of invasive species and ongoing weed management by the DLNG Facility, with the controls adopted, the residual risk of the introduction or spread of invasive species is assessed as ALARP.

The pathways for introducing and spreading invasive species and the existing presence of invasive flora and fauna species within the DLNG Facility and its surrounds are well known. Following the implementation of management actions, the residual risk of introduction and spread of invasive species is low and therefore considered acceptable.

7.7.3 Release of non-hazardous and hazardous materials

7.7.3.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to the release of non-hazardous and hazardous materials, including performance criteria, are described in **Table 7-16.**

Table 7-16: Release of non-hazardous and hazardous materials EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No significant environmental impact resulting from release of non-hazardous and hazardous materials associated with the DPD construction activities	Zero incidents of release of hazardous materials to the terrestrial or marine environment during DPD construction activities	

These EPOs align with the following NT EPA Factor objectives (NT EPA, 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.
+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
+ Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-17.** Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-17: Management actions for release of non-hazardous and hazardous material

MA reference	Management actions
Standard management actions	
Mitigation	
DPD-DLNG-MA24	Waste Management Plan in place which includes standards for bin types, lids and covers, waste segregation and bin storage
DPD-DLNG-MA25	HSE inductions – cover requirements for waste management, e.g. label and cover waste skips and bins
DPD-DLNG-MA26	No Perfluorinated Chemicals (PFAS)/ Perfluorooctane sulfonate (PFOS) will be used in firefighting foam
DPD-DLNG-MA27	Inspection and maintenance of all equipment using chemicals
DPD-DLNG-MA28	Implement approved chemical selection procedure
DPD-DLNG-MA29	Implement Santos' approved procedures for handling of treated seawater
DPD-DLNG-MA30	Comply with Australian Standards for storage and secondary containment of hazardous chemicals
DPD-DLNG-MA31	Maintain spill response equipment and procedures
DPD-DLNG-MA32	Implement and comply with the existing DLNG Emergency Response Plan (DLNG/HSE/ER/002), including in the event of a storm.
Additional (ALARP) management actions	
N/A	

7.7.3.2 Demonstration of ALARP and Residual risk

The storage and use of hydrocarbons and chemicals is required to undertake the activity. As such their removal from the activity is not practicable.

The identified management actions implemented include chemical selection process, treated seawater handling procedure and spill clean-up equipment and procedures to reduce the impact in a spill event. Management actions relating to waste management are incorporated within the Santos waste management plan and preventative measures are also documented in the DLNG Emergency Response Plan to prevent impact during a cyclone event.

Containment of small spills with secondary containment and spill response equipment will prevent spills spreading into the terrestrial and marine environment. The maintenance of bunding and spill response equipment provides assurance that these are available to contain spills in the event of a small leak. Hazardous liquids will be managed in accordance with relevant legislation and industry standards and Santos' procedures.

The management actions proposed are in line with applicable actions described in relevant recovery plans and conservation advice to reduce the risk of habitat degradation and deteriorating water quality (for example, from pollution) to a level considered to be ALARP by Santos. The assessed residual risk for this impact is low. It is therefore considered that the impact of the activities is acceptable.

7.7.4 Spread of fire to surrounding bushland

7.7.4.1 Environmental performance objectives, criteria and management actions

The EPO and performance criteria for the spread of fire to surrounding bushland are described in **Table 7-18**.

Table 7-18: Spread of fire to surrounding bushland EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No bushfires caused by onshore construction activities	Zero incidents of bushfires resulting from the DPD Project onshore construction activities	Number of recorded incidents

This EPO aligns with the following NT EPA Factor objectives (NT EPA 2022):

+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained. Terrestrial ecosystems – Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this planned event are shown in **Table 7-19** . Environmental Performance Standards and measurement criteria for these management actions will be developed in consultation with the DLNG team and construction contractors, for inclusion in this CEMP prior to the commencement of DPD Project construction activities.

Table 7-19: Management actions for spread of fire to surrounding bushland

MA Reference	Management Action
Standard management actions	
Mitigation	
DPD-DLNG-MA30	Comply with Australian Standards for storage and secondary containment of hazardous chemicals
DPD-DLNG-MA32	Implement and comply with the existing DLNG Emergency Response Plan (DLNG/HSE/ER/002), including in the event of a storm.
DPD-DLNG-MA33	Implement and comply with the existing DLNG Work Permit Procedure (SMS-OS-OS02-PD03) and associated manuals. This includes the requirement to have firefighting equipment close by whilst undertaking hot work activities.

7.7.4.2 Demonstration of ALARP and residual risk

The use of machinery and undertaking hot works (i.e. welding)' and storage and use of potential fuel sources, such as hydrocarbons and chemicals, are required to undertake the activity. As such their removal from the activity is not viable.

The DLNG HSE site induction, which contractors present onsite will be required to complete, will provide information on the facility safety protocols, muster and evacuation processes and emergency response arrangements (ConocoPhillips, 2017). The DLNG Facility has several existing and substantive controls in place to protect the facility, which include:

+ maintaining fire breaks on the property boundary
+ managing weeds as required to reduce the fuel load risk (ConocoPhillips, 2018).
+ Protocols for storage of hydrocarbons and chemicals
+ Permitting required for hotwork activities

Following the implementation of the standard management actions, the residual risk for this impact is assessed as Low and cannot be reduced further. It is considered therefore considered that the impact of the activities is reduced to ALARP and is acceptable.

7.8 Summary of management actions

Appendix 2 contains a summary of all management actions within this CEMP.

8 Implementation Strategy

This section presents the processes and procedures that will be implemented to ensure the environmental requirements within this CEMP will be met, including:

- Specific systems, practices and procedures that ensure both environmental impacts and risks are reduced to ALARP and Environmental Performance Objectives (EPOs), Performance Criteria and Performance Standards of this CEMP are being met;
- A clear chain of command, outlining roles and responsibilities of personnel involved in the implementation, management and review of this CEMP;
- Measures to ensure that employees and/or contractors working in relation to this activity are aware of their responsibilities regarding the environment and have the appropriate skill and training;
- Auditing, review and revision processes;
- Incident recording and reporting in line with Santos and regulatory requirements;
- Maintenance of quantitative records of discharges and emissions; and
- Details of emergency response and oil spill arrangements.

This implementation strategy is consistent with the Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

Stakeholder engagement is assessed separately for the requirements of the activity. Ongoing stakeholder management strategies are discussed in **Section 9**.

While the scope of work covered by this CEMP is located primarily outside the battery limits of the DLNG facility, some activities, including access to the onshore construction site, will occur within the DLNG perimeter and the construction activity will be in close proximity to the DLNG facility perimeter. Therefore, additional DLNG HSE requirements (e.g. permit to work requirements) will apply in some situations.

Environmental requirements for the DLNG facility, including an implementation strategy, are outlined within the DLNG Operations Environmental Management Plan (DLNG/HSE/PLN/001).

8.1 Leadership, accountability and responsibility

To enable the DPD Project to succeed in meeting environmental objectives as outlined within this CEMP, the following measures apply:

- Appropriately skilled and qualified DPD Project team is established with HSE accountabilities, responsibilities, and resources clearly defined;
- Setting of EPOs and Performance Criteria (incl. Targets and Performance Indicators) and establishment of the practices and tools used to measure performance and drive continual improvement (**Section 7**); and
- Implementing HSE Leadership Teams with key contractors to discuss HSE performance and improvement

The Barossa Project Director is responsible for delivery of the Barossa Development, including the DPD Project, and has responsibilities for:

- Accountability for project HSE performance

+ Demonstrating strong and visible HSE leadership
+ Endorsing HSE performance indicators and targets
+ Communicating HSE performance and events to the Chief Operating Officer, Upstream Oil & Gas and Group Executive Committee.
+ Providing HSE resources.
+ Engaging with senior regulatory managers.

The Barossa Project Director is supported by the Barossa Project Management Team. The effective implementation of this CEMP requires collaboration and cooperation among Santos Barossa Team personnel and contractors. The accountabilities of key Santos and contractor personnel in relation to the implementation, management and review of the CEMP is outlined in **Table 8-1**. Santos' OPEP will outline the roles and responsibilities in an emergency.

Roles and responsibilities at the DLNG facility, relevant to environmental management, are outlined within the DLNG Operations Environmental Management Plan (DLNG/HSE/PLN/001).

Table 8-1: Chain of command and key roles and responsibilities

Title (role)	Environmental responsibilities
Office-based personnel	
Santos Darwin Life Extension (DLE) Manager	+ Confirm that the campaign is undertaken in accordance with this CEMP. + Provide sufficient resources to implement the management controls in this CEMP. + Confirm Contractor personnel attend an environmental induction (**Section 8.2.1**) upon commencing work on the campaign. + Action the management controls, as detailed in the EPSs in this CEMP (**Section 7)** as required, prior to the commencement of the activity. + Confirm the Contractor meets the requirements of the Santos management system and relevant standards/procedures.
Santos Barossa HSE Manager	+ Provide assurance that adequate resources are provided to support all environmental activities associated with this CEMP. + Develop a program to implement and monitor CEMP commitments. + Liaise with NT EPA, DITT, DCCEEW and other regulators. + Ensure incident notification process is in place and investigations completed to identify root causes. + Review and submit environmental performance reports and external environmental incident notification reports.

Title (role)	Environmental responsibilities
DLE Pipeline Onshore Scope Lead	+ Confirm the campaign is undertaken in accordance with this CEMP. + Communicate any changes to the activity that may affect the risk and impacts assessment, EPOs, EPSs and MAs detailed in this CEMP to the Santos HSE team. + Coordinate resources required to enable the commitments in this CEMP to be maintained. + Confirm the reporting of environmental incidents meets both external and Santos' incident reporting requirements. + Liaise with Santos Environmental Advisor on environmental incidents and what constitutes a reportable incident. + Track and close out of any corrective actions raised from environmental audits as required by this CEMP.
Santos Barossa Crisis and Emergency Management Specialist	+ Develop Santos Crisis Management and Emergency Response Plans and procedures. + Ensure emergency response drills are undertaken as per Santos Crisis Management and Emergency Response plans and procedures.
Santos Emergency Response Coordinator	+ Undertake Santos Incident Management Team (IMT) drills and exercises in accordance with the Crisis and Incident Management Exercise Schedule. + Undertake assurance activities on oil spill response arrangements + Review Santos Emergency Response Plans and procedures.
Santos Barossa Environmental Advisor/s	+ Develop onshore environmental approval documents, including DPD Project EMPs, for submission and acceptance by DITT. + Provide environmental inductions to contractor personnel. + Ensure environmental inspections and audits are undertaken against EMP commitments as per the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635). + Review and approve chemical products + Prepare environmental performance reports. + Advise on environmental incident reporting requirements, including what constitutes a reportable incident
Santos Barossa External Relations Advisor	+ Prepare and implement the relevant and interested persons consultation program for the DPD activity. + Manage and report on any relevant and interested persons consultation received in relation to the activity. + Undertake ongoing engagement with relevant and interested persons, for the duration of the activity, as required.

Title (role)	Environmental responsibilities
Contractor Project Manager	+ Undertake the onshore construction activity in accordance with this CEMP. + Provide the resources required to enable the commitments in this CEMP to be maintained. + Ensure that all Contractor site personnel attend HSE inductions, as required, and that attendance records are saved. + Ensure incidents are reported and investigated, as required.
Site based personnel	
Santos Senior Client Site Representative	+ Confirm contractors undertake the activity in a manner consistent with the EPOs and environmental management procedures detailed in this CEMP. + Confirm the management measures detailed in this CEMP are implemented. + Communicate any changes to the activity to the Santos Environmental Advisor. + Confirm all chemical components and other fluids that may be used on site are approved for use. + Advise the Santos DLE Onshore Pipeline Scope Lead of any changes in activities that may lead to nonconformance with the EPOs in this CEMP. + Report environmental incidents to Santos DLE Onshore Pipeline Scope Lead.
Construction Superintendent (Contractor Personnel)	+ Responsible for ensuring that pipeline construction activities are performed in accordance with this CEMP.
Onsite HSE Advisors (Santos and/or Contractor)	+ Support the Santos Senior Client Site Representative to ensure that the controls detailed in this CEMP relevant to onshore activities are implemented and assist in collection and recording of evidence of implementation (other controls are implemented and evidence collected onshore). + Support the Santos Senior Client Site Representative to ensure environmental incidents or breaches of objectives and/ or standards outlined in this CEMP, are reported, and corrective actions for incidents and breaches are developed, tracked and closed out in a timely manner. + Ensure periodic environmental inspections/reviews are completed and corrective actions from inspections are developed, tracked and closed out in a timely manner. + Review Contractors procedures, input into Toolbox talks and JSAs. + Provide day to day environmental support for activities in consultation with the Santos Environmental Advisor.

Title (role)	Environmental responsibilities
All Project personnel	+ Act in an environmentally responsible manner. + Undertake work in accordance with accepted HSE systems and procedures. + Comply with this CEMP and all regulatory requirements as applicable to assigned role. + Report any unsafe conditions, near misses or environmental incidents immediately to supervisors. + Attend environmental inductions and HSE meetings, and complete training as required. + Report wildlife sightings as applicable in accordance with Project requirements

8.2 Workforce training and competency

This section describes the mechanisms that will be in place, so all Project personnel (including employee and contractor roles) are aware of his or her responsibilities in relation to the CEMP and has appropriate training and competencies.

8.2.1 Inductions

Santos and its contractors will develop a mandatory project induction, which will detail CEMP requirements. Project induction attendance will be logged and held with the Project Administration Assistant. Santos personnel will be required to complete required contractor site and facility inductions, including DLNG facility inductions, including permitting requirements, as applicable for working in and around the DLNG facility.

All Project site roles will complete an induction that will include a component addressing their CEMP responsibilities. Induction attendance records for all personnel will be maintained. Inductions will include information about:

+ Environment, Health and Safety Policy
+ Regulatory regime
+ Operating environment
+ Activities with highest risk
+ CEMP EPOs, Performance Indicators and management commitments (e.g. **Section 7**)
+ Incident reporting and notifications
+ Regulatory compliance reporting
+ Process for assessing changes to CEMP activities
+ Oil pollution emergency response.

8.2.2 Training and competency

The implementation of training requirements will ensure project personnel have the skills, knowledge and competencies to conduct work in a safe manner without harm to their health or the environment.

All members of the workforce will complete relevant training and/or hold relevant qualifications and certificates for their roles.

Santos and its contractors are individually responsible for ensuring that their personnel are qualified and trained. The systems, procedures and responsible persons will vary and will be managed using online databases, staff on-boarding process and training departments, etc.

Personnel qualification and training records will be sampled before and/or during an activity. Such checks may be performed during the procurement process, inductions, crew change, and operational inspections and audits.

8.2.3 Workforce involvement and communication

Daily operational meetings will be held at which HSE will be a standing agenda item. It is a requirement that supervisors attend daily operational meetings and that all personnel attend daily toolbox or pre-shift meetings. Toolbox or pre-shift meetings will be held to plan jobs and discuss work tasks, including HSE risks and their controls.

HSE performance will be monitored and reported during the activity, and performance metrics (including environmental performance indicators and the number of environmental incidents) will be regularly communicated to the workforce. Findings, learnings and corrective actions identified from assurance activities and incident investigations will be communicated to project personnel to drive continuous improvement (e.g. through HSE Alerts, pre-shift / toolbox meetings).

8.3 Audits and inspections

Environmental Audits and Inspections undertaken to provide assurance of requirements within this CEMP are being met may include:

+ Routine environmental inspections (during Project execution)
+ Contractor Environmental Audits
+ Regulator Inspections and Audits (as required by Regulator)

For this CEMP the environmental audit and inspection processes are described in the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635).

An Environmental Assurance Activities Schedule (EAS) will be developed and maintained by the Barossa HSE Team which will align with the Barossa Project Integrated Audit Schedule. The EAS will provide an overview and schedule of assurance (verification) activities required to meet compliance for each activity (e.g., inspections, audits, assessments, and reviews). Additionally, it will allow Santos and the Barossa HSE Team to plan and resource appropriately to ensure all environmental assurance requirements can be met.

Audit criteria, as included within a terms of reference (ToR), will typically include a selection of management actions and environmental performance standards and outcomes; however, may also include parts of the activity description, stakeholder consultation and implementation strategies.

Audit findings may include opportunities for improvement and non-conformances (requirements not met). Audit non-conformances are managed as described in **Section 8.5**

8.4 Environmental Incident Reporting

8.4.1 Internal incident reporting

All personnel will be informed through inductions and daily operational meetings of their duty to report HSE incidents and hazards. Reported HSE incidents and hazards will be shared during daily operational meetings and will be documented in the incident management systems as appropriate. HSE incidents will be investigated and reported in accordance with the Santos Incident Reporting and Investigation Procedure (SMS-HSS-OS07-PD01) and contractor procedures.

The incident reporting requirements will be provided to all crew on-board the facilities and support vessels with special attention to the reporting time frames to provide for accurate and timely reporting.

8.4.2 External incident reporting

Certain incidents will require notification to external Regulatory authorities under NT and Commonwealth legislation. This includes requirements below; additional requirements may apply as conditions of approval of the DPD Project.

8.4.2.1 Reportable Incident – Waste Management and Pollution Control Act 1998 (NT)

As per Part 3 Section 14 of the Waste Management and Pollution Control Act 1998 (WMCA Act 1998), incidents causing, or that may threaten to cause, pollution resulting in material environmental harm or serious environmental harm, will be reported to the NT EPA as soon as practicable after (and in any case within 24 hours after) first becoming aware of the incident. An incident includes "*an accident, emergency or malfunction and a deliberate action, whether or not that action was taken by the person conducting the activity in the course of which the incident occurred*".

A notification to the NT EPA of an incident as per Part 3 Section 14 of the WMCA Act 1998 will specify:

+ the incident causing or threatening to cause pollution;
+ the place where the incident occurred;
+ the date and time of the incident;
+ how the pollution has occurred, is occurring or may occur;
+ the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
+ the identity of the person notifying.

8.4.2.2 Wildlife incident reporting

Any incident resulting in a significant impact to a species listed as threatened or migratory under the *Environmental Protection and Biodiversity Protection Act 1999* (EPBC Act 1999) is to be reported to DCCEEW as soon as practicable (and in any case within 24 hours) of becoming aware of the event occurring.

The report will contain:

+ time, location and description of the incident
+ a summary of the response being undertaken
+ details of the relevant contact person.

8.5 Corrective actions

Corrective actions identified from environmental assurance activities and incident investigations will be derived in collaboration with contractors. For this CEMP, corrective actions and contingency processes are described as per the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635) and Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

CEMP non-conformances will be addressed and resolved by a systematic corrective action process as outlined in Santos' Management System. Santos' incident and action tracking management system (HSE Toolbox) will be used to track corrective actions in the following instances:

+ Where there has been or potentially been a reportable incident
+ Where there has been a non-compliance in accordance with a statutory plan
+ Where any corrective action requires notification to an external regulatory or statutory body
+ Where there are corrective actions from formal audits (Contractor Pre-Start Audit, external regulator audit etc.).

Once entered, corrective actions, time frames and responsible persons (including action owners and event validators) will be assigned. Corrective action 'close out' will be monitored using a management escalation process.

Environmental corrective actions identified through compliance assurance activities are to be promptly managed to ensure timeframes for external reporting are met and that decision making is made visible.

8.6 Continuous improvement

For this CEMP, continuous improvement will be driven by the list below and may result in a review of the CEMP.

+ Improvements identified from the review of business-level HSE key performance indicators
+ Actions arising from Santos and departmental HSE improvement plans
+ Corrective actions and feedback from HSE audits and inspections, incident investigations and after-action reviews
+ Opportunities for improvement and changes identified during pre-activity reviews and MoC documents
+ Actions taken to address concerns and issues raised during the ongoing stakeholder management process (**Section 9**).

Identified continuous improvement opportunities will be assessed in accordance with the MoC process (**Section 8.9.2**) to ensure any potential changes to this CEMP are managed in a controlled manner.

8.7 Emergency preparedness and response

Emergency preparedness and response arrangements, applicable to activities covered by this CEMP, including for spill response, will be included in Santos and Contractor procedures.

Emergency response arrangements as outlined within the DLNG facility Emergency Response Plan (DLNG/HSE/ER/002) may apply for some incidents.

8.7.1 Contractor Emergency Plans

DPD Project contractors are responsible for having comprehensive Emergency Response Plans (ERP) that address emergency response actions associated with all credible incidents for the activity. These will describe the interface arrangements between Contractor and Santos Incident Management structures and cover all aspects of emergency response including technical, logistical and medical support.

Contractor ERPs will outline roles and responsibilities of contractor personnel for emergency events. The ERP is accepted by Santos and reviewed on an annual basis by the contractor or if a significant change has occurred to the incident management or emergency response arrangements.

Scenario-based drills are performed to test the emergency response arrangements and updates are made to improve the ERPs, if required.

8.7.2 Santos Incident Management and Oil Spill Response Arrangements

Santos maintains Incident and Crisis Management Teams (IMT and CMT) and support arrangements to respond to all-hazard incidents, including oil spill incidents, at its sites and for activities under its control or influence, including activities covered under this CEMP. Santos' crisis and incident management arrangement are outlined within the Crisis, Incident Management & Emergency Response Procedure (SMS-HSS-OS05-PD01). IMT and CMT training and exercise requirements, including OPEP exercises, are included within an annual training and exercise plan and schedule.

8.8 Reporting and notifications

Environmental reporting for the DPD Project construction activities will include reports between Subcontractors and Contractors, Contractors and Santos, and Santos and Stakeholders, including Regulatory authorities. Reports will be delivered within agreed upon timeframes. outlines an initial assessment of reporting requirements relevant to this CEMP.

External reporting requirements may be dictated by approval conditions associated with the DPD Project and finalisation of this CEMP will include all relevant external regulatory reporting requirements.

A detailed schedule of reporting requirements and submission dates for the DPD Project will be developed as per the Barossa Project Environmental Compliance Plan (BAA-200 0635).

Table 8-2: **Summary of key environmental reporting requirements.**

Report/ Notification	Responsibility	Content	Frequency	Recipient
Pre-start				
Pre-start contractor audit	Santos DLNG/Barossa Team	Confirmation of compliance with CEMP commitments relating to operational procedures and processes that Santos require to be in place prior to the commencement of the activity.	Prior to commencement of the activity	Santos
Pre-start notifications	Santos Barossa Team / Contractors	Details on DPD Project commencement to meet requirements of stakeholders (including Regulatory authorities)	Prior to commencement of the activity	Various stakeholders
Execution and completion				
Regular Stakeholder updates	Santos Barossa Team	Regular updates on DPD Project during planning and execution as per Stakeholder Management Plan (refer Section 9)	Throughout planning and execution	Various stakeholders
Contractor environmental execution audit	Santos Barossa Team	Confirmation of compliance with CEMP commitments relevant to execution of the activity.	Prior to completion of the activity	Santos
Daily Reports	Contractor Site Superintendent	Update on day's activities, including any identified non-conformance against this CEMP, and any issues that may need addressing.	Daily	Santos
Environmental Reports/Checklists	Contractor Site Superintendent	Compliance against key regulatory and contractual commitments (including CEMP commitments). Reporting of fuel usage, discharges and emissions etc.	Monthly at minimum	Santos

Report/ Notification	Responsibility	Content	Frequency	Recipient
HSE Meetings Records	Contractor and Santos Barossa Team	Monthly, dedicated HSE meetings are held with the onshore and Perth-based management (including contractor management) and advisors to address targeted health, safety and environment incidents and initiatives. Minutes of these meetings are produced and distributed as appropriate.	Monthly	Santos
Completion notifications	Santos Barossa Team / Contractors	Details on DPD Project completion to meet requirements of stakeholders (including Regulatory authorities)	Following completion of the activity	Various stakeholders
Acid Sulfate Soils Monitoring, Inspection and Testing Records (as required)	Santos Contractor and ASS Monitoring Contractor	Records of ASS monitoring, inspection and testing (if applicable) as per requirements of the DPD Project Acid Sulfate Soils and Dewatering Management Plan (BAS-210 0049)	Dependent upon detection of ASS	Santos DEPWS DITT NT EPA
Environmental Performance/ Compliance Assurance Report	Santos Barossa Team	Provides a summary of compliance performance, including the environmental performance objectives, standards and measurement criteria within this CEMP and any other conditions of approval on the DPD Project.	At completion of the activity and not less than annually	DITT NTEPA (DEPWS) DCCEEW (if required)
Incident reporting				

Report/ Notification	Responsibility	Content	Frequency	Recipient
Incident Report – Internal	Contractor and Santos Barossa Team	Provides framework for Internal notification of incidents including spills. The first report contains tools for assessing the severity of the incident and escalating as per the incident notification procedure. Incident reporting will also be undertaken through Santos' online EHS Toolbox system.	Incident specific	Santos
Incident Report – Reportable Environmental Incident (WMPC Act 1998)	Santos Barossa Team	Reporting of Reportable Incidents as per Part 3 of the Waste Management and Pollution Control Act 1998 (WMPC Act 1998) (Refer **Section 8.4.2.1**)	Incident specific	NT EPA
Incident Report – Wildlife Incidents	Santos Barossa Team	Reporting of incidents involving EPBC Act species (Refer **Section 8.4.2.2**)	Incident specific	DCCEW DEPWS

8.9 Document management

This CEMP will be revised based on conditions of environmental approvals and/or licences and submitted to the appropriate regulator, for review and approval as required, prior to DPD Project implementation (i.e. commencement of construction activities).

8.9.1 Information management and document control

This CEMP, as well as any approved management of change (MoC) documents, are controlled documents and current versions will be available on Santos' document control system and made available to Project contractors.

8.9.2 Management of change

Following regulatory review and approval of this CEMP any changes to Project activities as described in this document, which have the potential to materially increase environmental impacts and risks, will be evaluated and controlled following the impact and risk assessment process followed in **Section 6**. The documentation and approval of management of change (MoC) assessments will follow the process outlined within the Santos Management of Change Procedure (SMS-LRG-OS01-PD04). MoC records will be retained and details of MoCs outlined within Regulatory compliance/performance reports.

If there is a change in the petroleum instrument holder, or operator for the activity, a revision of the CEMP will be submitted to DITT as soon as practicable after the change.

8.9.3 Reviews

This CEMP addresses a temporary construction activity. The CEMP will be reviewed annually, or as required in response to regulatory requirements and any changes to impacts, risks or management actions raised in Santos' assurance processes, incident response, stakeholder engagement or contractor engagement. These changes will be evaluated through the MoC process, and significant updates required to be communicated to regulators will be submitted to DITT.

9 Stakeholder Consultation

The stakeholder engagement approach used for the Project is in accordance with Santos's corporate approach to stakeholder engagement and industry leading standards and practice. The approach recognises and is aligned with the NT EPA's Guidance for Proponents – Stakeholder Engagement (NT EPA 2021a), the NT EPA's guidance for Preparing a Supplementary Environmental Report (NT EPA 2021b) and the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement (IAP2 2015).

Due to the iterative nature of the stakeholder process all relevant details have been contained in one document, the SER (BAS-210 0020), to contain updates to one location. The SER provides an outline of the objectives, process and key stakeholders consulted for the DPD Project. Additionally, the Stakeholder Engagement Plan (SEP) is attached to the SER. It details all consultation undertaken to date and information on future engagement activities.

In preparing the SER, and project management plans, Santos has considered and assessed each submission individually, and taken into consideration the issues raised when engaging with stakeholders to assess potential impacts and proposed management measures.

The SER provides a summary of the issues raised relevant to the Project and Santos' assessment and response to these issues. A full register, with all submissions and responses, is provided as an attachment to the SER.

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Appendix 1 Santos Environment, Health and Safety Policies

Environment, Health & Safety

Santos

Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Jodie Hatherly, General Counsel and VP Legal, Risk and Governance		
Approved by:	The Board	Version:	3

20 August 2019 Page 1 of 1

Appendix 2 Summary of management actions and associated performance criteria for the proposed activity

MA reference	Management Actions
DPD-DLNG-MA01	Restrict disturbance to within the onshore Project Area and existing DLNG site area
DPD-DLNG-MA02	Establish appropriate access restrictions to the onshore Project Area
DPD-DLNG-MA03	Pump water through a silt separator when dewatering in the excavated trench in sections where the trench does not naturally drain to sea
DPD-DLNG-MA04	Geotextiles will be installed under primary construction area (i.e. site pad)
DPD-DLNG-MA05	Trench inspections to be performed daily to check for trapped wildlife
DPD-DLNG-MA06	Insert caps on ends of pipe if the pipe is to be unattended for periods >12 hours; to prevent fauna ingress.
DPD-DLNG-MA07	Ensure any native vertebrates injured by DPD construction activities are referred to an appropriate wildlife carer group or veterinarian
DPD-DLNG-MA08	Return onshore site to natural grade to match existing topography following completion of the activity
DPD-DLNG-MA09	Maintain batters or install fauna ladders on trench entry and exit to allow fauna to exit the trench
DPD-DLNG-MA10	Limit vehicles to access roads, prepared site pad or defined boundaries within the onshore Project Area/DLNG disturbance envelope
DPD-DLNG-MA11	Use water truck for dust suppression
DPD-DLNG-MA12	Establish and implement vehicle speed controls

MA reference	Management Actions
DPD-DLNG-MA13	Implement ASS and groundwater management and monitoring requirements within the ASSDMP (BAS-210 0049) if ASS or groundwater is encountered during onshore construction activities. The ASSDMP includes requirements for: + ASS stockpiling, laboratory testing and treatment + Groundwater laboratory testing and treatment + Maintenance of testing and inspection records
DPD-DLNG-MA14	Treat ASS material such that no acid can be released to the environment before it can be used as backfill within the Project Area
DPD-DLNG-MA15	Lights to be orientated directly over the area of work and overspill reduced where practicable by using screens or hoods on lights
DPD-DLNG-MA16	Light audit undertaken within 14 days of commencing construction activities
DPD-DLNG-MA17	Preventative maintenance of equipment and machinery
DPD-DLNG-MA18	Monitor and report fuel consumption
DPD-DLNG-MA19	The Barossa project is included in Santos' Climate transition action plan and will adhere to the Santos GHG management plan and energy management program
DPD-DLNG-MA20	Maintain the onshore Project Area as a cleared site during construction activities
DPD-DLNG-MA21	Comply with DLNG inspection requirements for new vehicles, plant, and equipment to site
DPD-DLNG-MA22	All equipment and material imported from overseas will be inspected by the Australia Quarantine and Inspection Service (AQIS)
DPD-DLNG-MA23	Provide and routinely collect onsite covered putrescible waste bins
DPD-DLNG-MA24	Waste Management Plan in place which includes standards for bin types, lids and covers, waste segregation and bin storage
DPD-DLNG-MA25	HSE inductions – cover requirements for waste management, e.g. label and cover waste skips and bins
DPD-DLNG-MA26	No Perfluorinated Chemicals (PFAS)/ Perfluorooctane sulfonate (PFOS) will be used in firefighting foam
DPD-DLNG-MA27	Inspection and maintenance of all equipment using chemicals
DPD-DLNG-MA28	Implement approved chemical selection procedure

MA reference	Management Actions
DPD-DLNG-MA29	Implement Santos' approved procedures for handling of treated seawater
DPD-DLNG-MA30	Comply with Australian Standards for storage and secondary containment of hazardous chemicals
DPD-DLNG-MA31	Maintain spill response equipment and procedures
DPD-DLNG-MA32	Implement and comply with the existing DLNG Emergency Response Plan (DLNG/HSE/ER/002), including in the event of a storm.
DPD-DLNG-MA33	Implement and comply with the existing DLNG Work Permit Procedure (SMS-OS-OS02-PD03) and associated manuals. This includes the requirement to have firefighting equipment close by whilst undertaking these activities.

Santos

Appendix 12: Acid Sulfate Soil and Dewatering Management Plan

Santos

Darwin Pipeline Duplication (DPD) Project - Acid Sulfate Soil and Dewatering Management Plan

PROJECT / FACILITY	Barossa DPD Project
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	**Owner**	**Reviewer/s** Managerial / Technical / Site	**Approver**
	Project Environmental Lead	Project HSE Manager	Project Director
E			

Santos

Rev	Rev Date	Author / Editor	Amendment
A	15/07/2022	RPS	Issued for Santos review
B	05/09/2022	RPS	Issued for Santos review
C	16/12/2022	RPS	Issued for Santos review
D	09/03/2023	RPS	Issued for Santos review
E	26/04/2023	RPS	Issued for NT EPA review

Contents

Abbreviations and acronyms		**5**
1	**Executive Summary**	**6**
1.1	Background	6
1.2	Proposed works	6
1.3	Objectives	7
1.4	Soil findings	7
1.5	Management measures	7
2	**Introduction**	**9**
2.1	Acid sulfate soils – definition	9
2.2	Dewatering – regulatory context	14
2.3	Project background	14
2.4	Site background	15
3	**Site description**	**19**
3.1	Site details	19
3.2	Site setting	19
4	**Proposed earthworks and dewatering program**	**22**
4.1	Earthworks program	22
4.2	Proposed ground disturbance	22
4.3	Proposed dewatering	23
5	**Soils**	**24**
5.1	Previous investigations	24
5.2	Dames & Moore Pty Ltd, July 1997	24
5.3	URS Australia Pty Ltd, 19 July 2002	24
5.4	URS Australia Pty Ltd, 6 April 2004	26
5.5	ConocoPhillips, 21 April 2004	26
5.6	Summary	27
6	**Groundwater**	**28**
7	**Groundwater modelling**	**29**
7.1	Empirical approach	29
7.2	Dewatering scenario	30
7.3	Results	30
7.4	Limitations of empirical method	30

8	**Assessment of potential environmental impacts**	**32**
9	**Earthworks operating strategy**	**35**
9.1	Overview	35
9.2	ASS management measures	35
10	**ASS environmental reporting**	**37**
10.1	ASS closure report	37
10.2	Unexpected ASS	37
11	**References**	**38**
Appendix A:	**Identification and management of unexpected ASS – onshore zone**	**40**
Appendix B:	**Dewatering operating strategy**	**46**

Figures

Figure 2-1: DPD Project Area 10
Figure 2-2: DPD shore crossing and onshore Project Area 11
Figure 2-3: Site layout 12
Figure 2-4: Historical investigation locations 13
Figure 2-5: Conceptual model of management plan geographical scopes 15
Figure 2-6: Aerial image of the site and surrounds – June 2004 (Image source: Google Earth, accessed: 19/08/22) 16
Figure B-1: Typical treatment system configuration for dewatering discharge 47
Figure B-2: Aerial image of the DLNG Facility groundwater monitoring well network (Image source: CDM Smith, 2021) 50

Tables

Table 2-1: Trench zone locations 16
Table 2-2: Report format 19
Table 3-1: Site details summary 21
Table 4-1: Summary of proposed earthworks at the site 24
Table 8-1: Potential Environmental Impacts 35
Table 9-1: Summary of ASSDMP performance indicators – intertidal zone 38
Table A-1: Monitoring Roles and Responsibilities 43
Table A-2: Indicative maximum periods for medium-term stockpiling 45
Table A-3: Validation sampling numbers 46
Table A-4: Summary of ASSDMP Performance Indicators – Unexpected ASS 47
Table B-1: Dewatering treatment method and materials 49
Table B-2: Dewatering strategy operating guidance 50

Table B-3: Monitoring Roles and Responsibilities 51
Table B-4: Dewatering Effluent Monitoring Program and Responsibilities 53
Table B-5: Groundwater Monitoring Program and Responsibilities 54
Table B-6: Dewatering effluent quality 56

Appendices

Appendix A: Identification and management of unexpected ASS – onshore zone
Appendix B: Dewatering operating strategy

Abbreviations and acronyms

Abbreviation/acronym	Definition
~	approximately
%	per cent
%S	percentage sulfur
AASS	actual acid sulfate soils
AHD	Australian Height Datum
ANC	acid neutralising capacity
ASS	acid sulfate soils
ASSDMP	Acid Sulfate Soils and Dewatering Management Plan
bgl	below ground level
$CaCO_3$	calcium carbonate
CRS	chromium reducible sulfur
EC	electrical conductivity
ENV	effective neutralising value
HAT	highest astronomical tide
km	kilometres
LAT	lowest astronomical tide
m	metres
m^3	cubic metres
mm	millimetres
NT EPA	Northern Territory Environmental Protection Agency
PASS	Potential Acid Sulfate Soils
pH_F	field pH
pH_{FOX}	field peroxide pH
pH_{KCl}	potassium chloride pH
Pty Ltd	Proprietary Limited
RPS	RPS Australia West Pty Ltd
Scr	chromium reducible sulfur
S_{POS}	peroxide oxidisable sulfur
TPA	titratable peroxide acidity
TTA	total titratable acidity

1 Executive Summary

1.1 Background

This acid sulfate soils (ASS) and dewatering management plan (ASSDMP) has been prepared for the intertidal / onshore earthworks to be undertaken as part of the Darwin Pipeline Duplication Project ('the DPD Project').

This ASSDMP applies to the proposed earthworks associated with the construction of the pipeline shore crossing, adjacent to the existing Darwin liquefied natural gas ('DLNG') Facility at Wickham Point Road, Wickham, Northern Territory 0822 ('the site') (**Figure 2-1**). The shore crossing earthworks comprises an approximately 533 m linear trench extending from the lowest astronomical tide (LAT) mark to the upstream weld of the proposed beach valve tie-in point at the existing DLNG Facility.

The proposed pipeline shore crossing for the DPD Project is adjacent to the existing Bayu-Undan to Darwin pipeline and within the same disturbance corridor. As part of the construction of the Bayu-Undan Pipeline, natural material was removed and replaced by site-won, non-ASS, fill material across the length of the on-shore pipeline crossing.

Based on this information, this ASSDMP has been prepared on the assumption that material across the proposed development extent at the site is likely to be non-ASS material except within the intertidal zone, where ASS (as lateritic clay) may be present.

1.2 Proposed works

The construction of a duplicated pipeline shore crossing will comprise the excavation of an approximately 533 m long trench, extending inshore from the LAT to a proposed beach valve connection point. The trench is anticipated to be up to 5.0 m deep and 4.0 m wide (at its base).

The site is broadly split into two sections:

+ An 'intertidal' zone, extending from the LAT mark to the shore pull onshore termination point.
+ An 'onshore' zone, extending approximately 206 m from the shore pull onshore termination point to the upstream weld of the proposed beach valve tie-in point.

At the time of writing, the proposed earthworks methodology and schedule for the intertidal and onshore zones was still to be finalised, however the anticipated earthworks plan is as follows:

+ Intertidal zone – where the tide allows (i.e., during periods of high tide), the trench will be excavated via a vessel-based backhoe dredge (BHD) assisted by split hopper barges (SHB). During periods of low tide, the trench will be excavated via conventional land-based methods (tracked excavator)
+ Onshore zone – the trench will be excavated using a land-based backhoe excavator.

The trench will be excavated in a staged approach and will be undertaken from the shore site using an excavator from temporary causeways (up to approximately 200m long and 25 m wide either side of the pipeline).

Based upon information presented within the DPD Project's onshore Delivery Management Plan (Downer, 2022), earthworks at the site are anticipated to commence during the following timeframes:

+ Intertidal zone – between Q1 2024 and Q2 2024.

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- Onshore zone – between Q2 2024 and Q4 2024.

These timeframes are indicative only and may be revised.

1.3 Objectives

The principal objectives for the ASSDMP are as follows:

1. Present relevant historical ASS investigation data and management measures
2. Detail the proposed soil management programs to be adopted during the site earthworks to mitigate or control potential impacts relating to the disturbance of ASS associated with construction earthworks (i.e., open trench excavations).
3. Detail the proposed dewatering management programs (if required) to be adopted during the excavation and dewatering of soils associated with construction earthworks (i.e., open trench excavations).

1.4 Soil findings

Historical investigation data indicated that prior to the development of the DLNG Facility, ASS material at the site could be found up to 2.5 m below ground level (bgl), underlain by siltstone bedrock.

Based upon a review of historical earthworks undertaken at the site as part of the development of the DLNG Facility, the site has had its natural material removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m bgl.

Based on this, ASS associated with the naturally occurring soil material is no longer expected to be present within the onshore zone, however the presence of ASS cannot be completely discounted and may require management.

Based upon data provided within the historical investigations undertaken at the site and surrounds, ASS material previously present at the site was characterised as 'Lateritic clays with various amounts of sand, silt and quartz gravel' (estuarine mud) and is present from natural surface level in the intertidal zone.

1.5 Management measures

For the purposes of managing ASS, the following management measures will be implemented:

1.5.1 Intertidal zone

- ASS material, as estuarine mud, is anticipated from surface level.

Management during high-tide periods:

- Excavation via Marine BHD assisted by SHB.
- Disposal of excavated material will be at an offshore spoil disposal ground.

Management during low-tide periods (where dredging vessel draught permits):

- Conventional earthworks plant, namely: backhoe or tracked excavator
- All encountered material (including ASS) will be stockpiled at a predetermined location situated below mean sea level and as close to the LAT mark as possible, resulting in the material being exposed during low tides

- The tidal action would gradually remove the stockpiled material and disperse it to the marine environment
- The excavated material would be removed directly from the trench excavation to the stockpile location and remain saturated at all times due to periodic tidal inundation: thereby limiting the likelihood of drying out and acidification
- This management measure is for material located within the intertidal zone, extending from LAT inshore.

1.5.2 Onshore zone

ASS material, as estuarine mud, is not anticipated in this section of the site.

Should this material be encountered during earthworks for trenching and site preparation works, suspected unexpected ASS material is to be removed from the excavation and stockpiled separately from non-ASS materials on a limestone pad ahead of confirmatory testing. Due to the timing of excavation and construction of the anchor pit (which is to occur during site preparation works), specific management procedures for the anchor pit excavation are detailed below.

The requirements for management of this material are detailed in **Appendix A**.

1.5.2.1 Anchor pit excavation

As excavation and construction of the anchor pit will occur during the site preparation works, should ASS be encountered, such material will be placed as close to the LAT mark as possible (per the intertidal zone management measures above), whilst the causeway in the intertidal zone is available. Once the causeway is unavailable, encountered ASS material, must be treated on a limestone pad as per the onshore zone management above.

Should ASS material be encountered, during the excavation, and present at the base of the anchor pit, as a contingency measure, a thin layer (10 – 20 mm) of limestone should be placed at the base of excavation and on the batters, where ASS is present.

2 Introduction

This acid sulfate soils (ASS) and dewatering management plan (ASSDMP) has been prepared for the intertidal / onshore earthworks to be undertaken as part of the Santos Darwin Pipeline Duplication Project ('the DPD Project').

This ASSDMP applies to the proposed earthworks associated with the construction of the pipeline shore crossing, adjacent to the existing Darwin LNG ('DLNG') Facility at Wickham Point Road, Wickham, Northern Territory 0822 ('the site') (**Figure 2-1**).

The shore crossing earthworks comprises an approximately 533 m linear trench extending from the Lowest Astronomical Tide mark (LAT) to the upstream weld of the proposed beach valve tie-in point at the existing DLNG Facility.

The location and layout of the site is presented in **Figure 2-1** to **Figure 2-3** (overleaf).

2.1 Acid sulfate soils – definition

ASS are naturally occurring soils, sediments and peats that contain iron sulfides, predominantly in the form of pyrite materials. These soils are commonly found in estuarine and river settings and low-lying land bordering the coast.

ASS materials are benign when in a waterlogged state. However, when these soils or sediments are drained or excavated, oxygen from the atmosphere reacts with the iron sulfides in the soil, resulting in the production of sulfuric acid. This acidity releases elements such as metals and nutrients from the soil profile which can then be mobilised/transported to waterways, wetlands and groundwater systems, often with damaging environmental and economic impacts (DER, 2015a).

The oxidation of metal sulfides is a natural weathering process that generally occurs slowly and does not pose an environmental concern. However, excavation and drainage can exponentially increase the rate of acid generation. Additionally, water draining from oxidised ASS can be strongly acidic, which acts upon soils and sediment to produce high solution concentrations of toxic metals, especially aluminium and iron. These high concentrations of metals may have a deleterious effect on human health, the environment and potentially damage infrastructure. Potential Acid Sulfate Soils (PASS) are soils containing iron sulfides or sulfidic materials in an anaerobic environment and therefore have not been exposed to air and oxidised. However, if disturbed and exposed to air and oxidised, PASS become Actual Acid Sulfate Soils (AASS).

For the purpose of this management plan, the term ASS also includes PASS.

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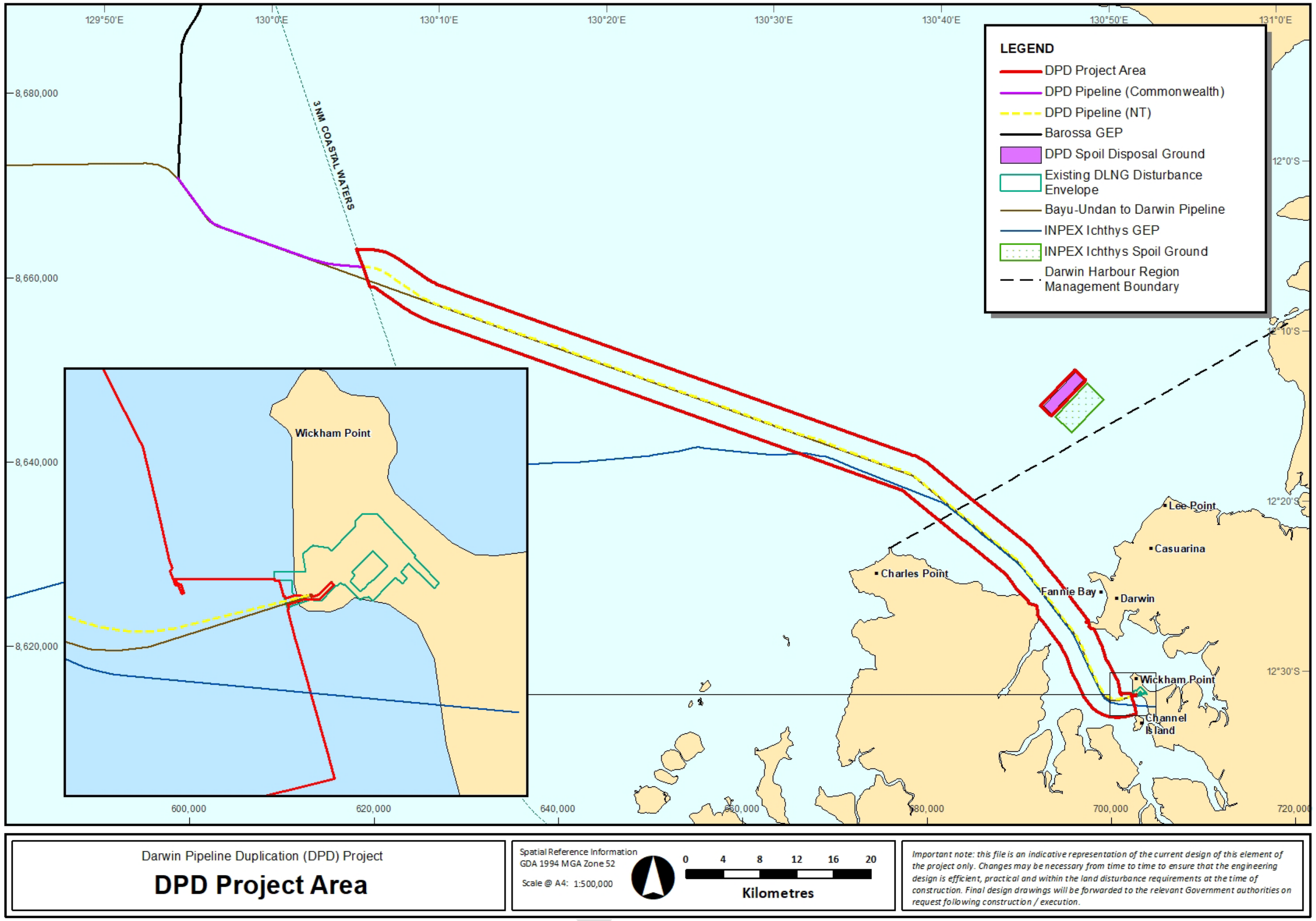

Figure 2-1: DPD Project Area

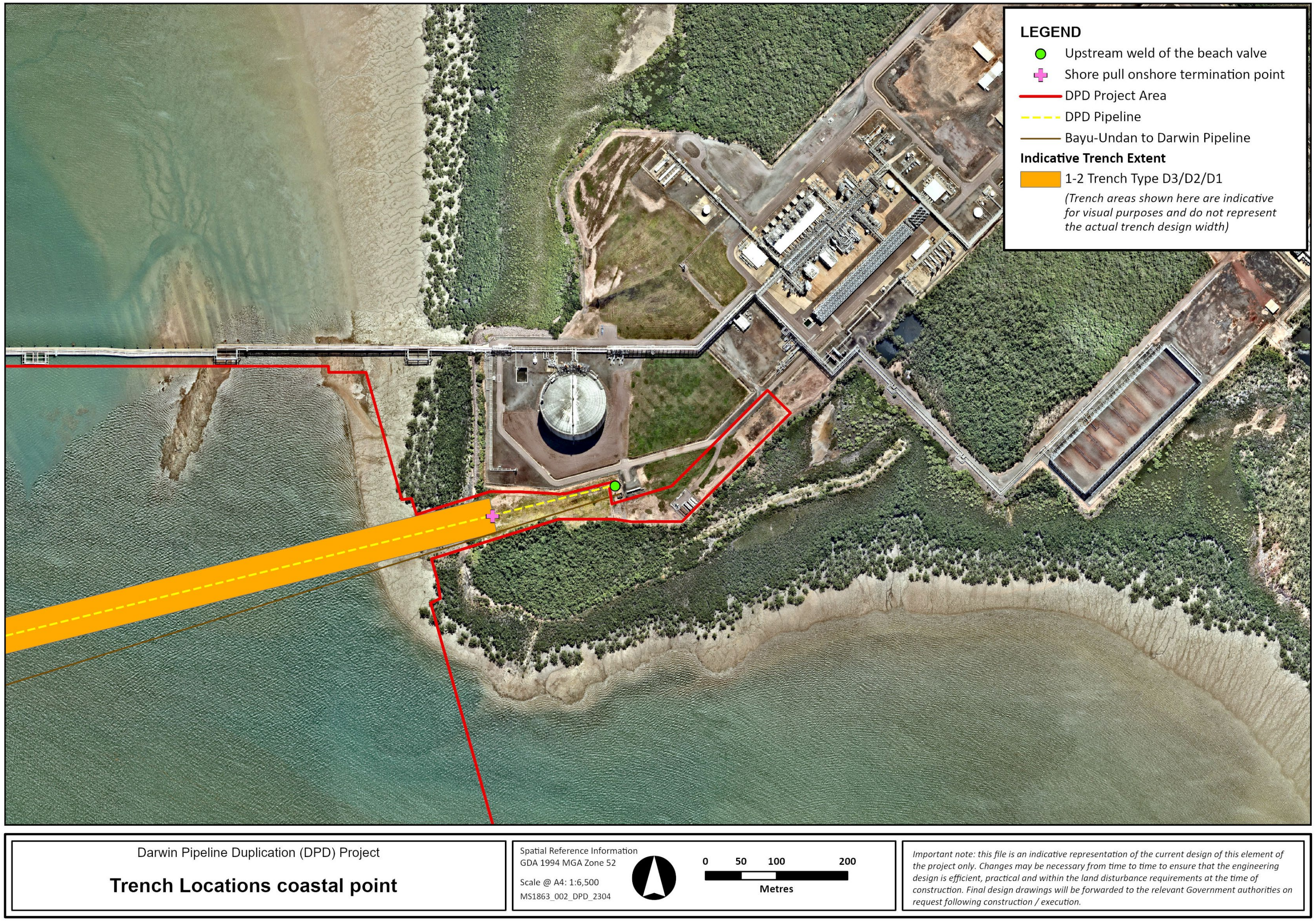

Figure 2-2: DPD shore crossing and onshore Project Area

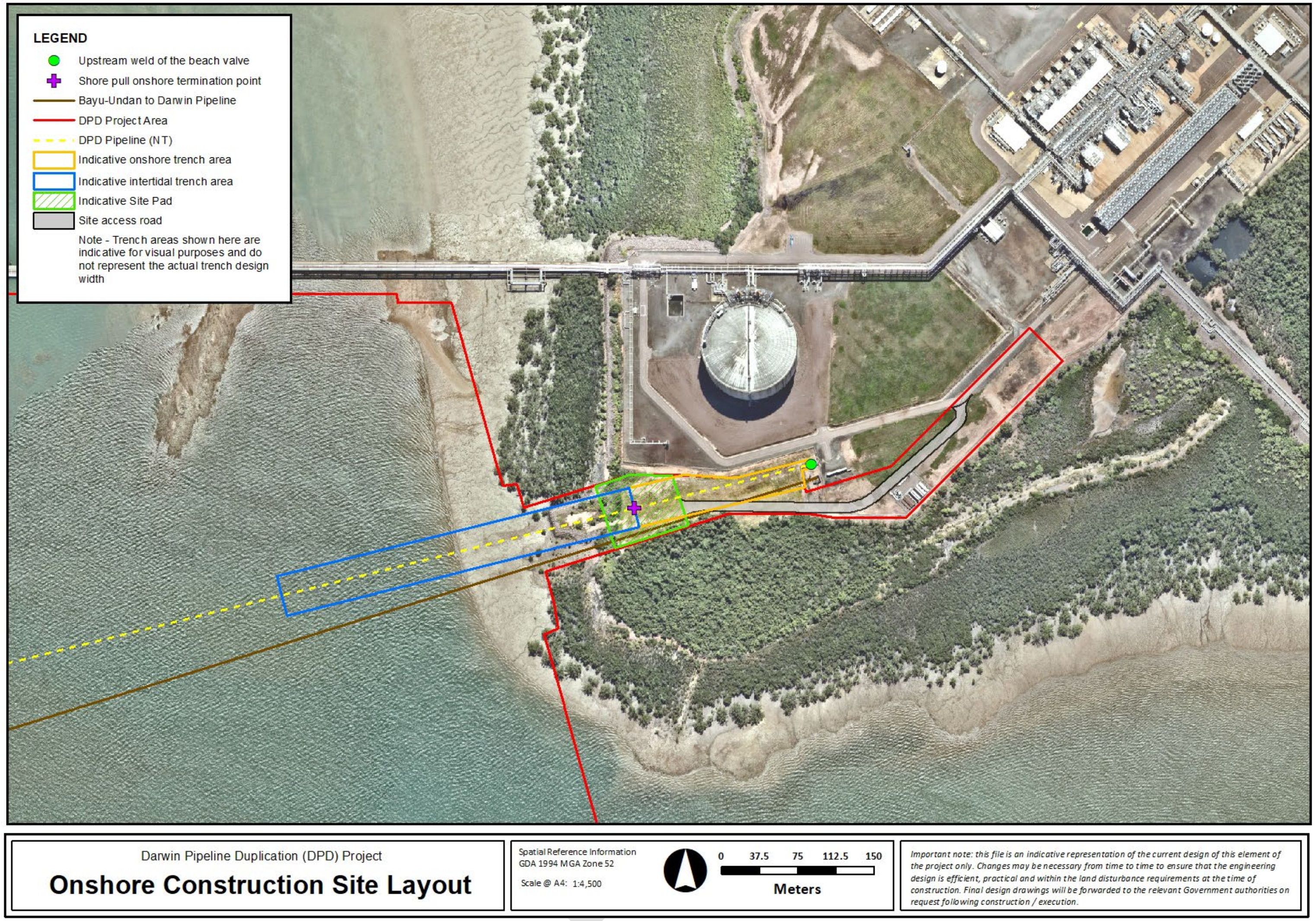

Figure 2-3: Site layout

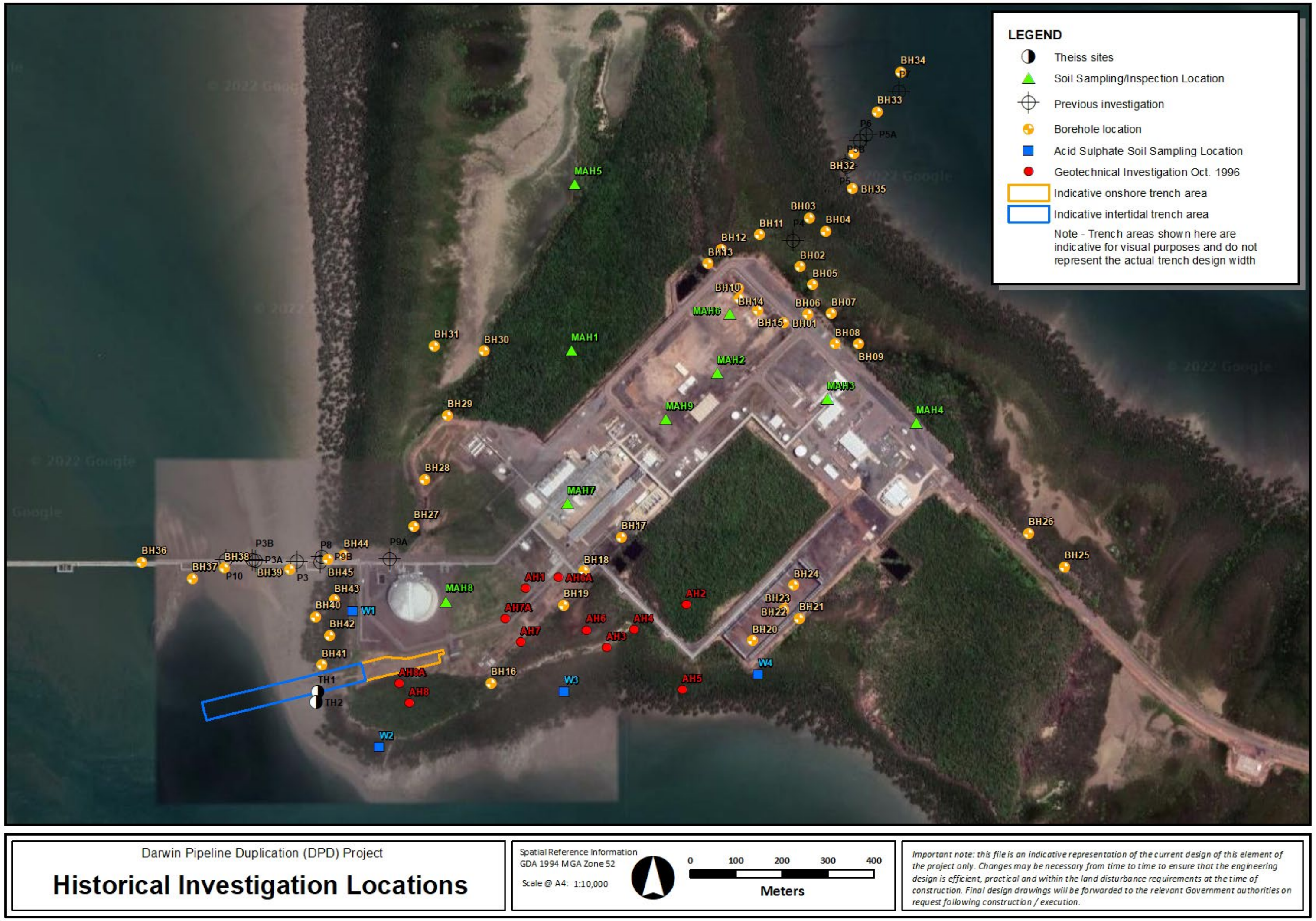

Figure 2-4: Historical investigation locations

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2.2 Dewatering – regulatory context

Guidance for the approach to dewatering in shallow groundwater environments is presented in the National Acid Sulfate Soils Guidance document '*Guidance for the dewatering of acid sulfate soils in shallow groundwater environments*' (Water Quality Australia, June 2018d).

The guidance presents management principles to dewatering which '*should be applied across Australia*'. One of the principles is as follows:

'Receiving marine, estuarine, brackish, or fresh waters are not to be used as a primary means of diluting and/or neutralising ASS or associated contaminated waters.'

Given the setting of the site in close proximity to the marine environment, this report presents the dewatering approach that will ensure this guiding principle is adhered to, and that appropriate treatment and management practices for dewatering effluent are followed.

2.3 Project background

The DPD Project involves the construction of a pipeline to connect the existing Barossa Gas Export Pipeline (GEP) to the DLNG. The pipeline will run from where the Barossa GEP approaches the existing Bayu-Undan pipeline to the existing DLNG facility in Darwin Harbour. The DPD Project pipeline includes a ~23 km segment in Commonwealth waters (DPD Pipeline (Commonwealth)) and ~100 km segment in NT waters and lands (DPD Pipeline (NT)).

2.3.1 Report context

This ASSDMP applies to the proposed earthworks associated with the intertidal and onshore project area of the pipeline, covering an area from the LAT mark, to an onshore beach valve tie-in point.

This ASSDMP forms part of a suite of environmental management plans under overarching Construction Environmental Management Plans (CEMPs) for onshore and offshore construction which cover all activities from the 3 nautical mile (NM) Commonwealth/NT waters boundary to the beach valve receipt point:

+ The DPD Project Offshore Pipeline CEMP (BAS-210 0024) addresses all construction activities to be completed from the 3 NM Commonwealth/NT waters boundary to the upstream weld of the proposed beach valve receipt point (Santos, 2022c)
+ The DPD Project Onshore Pipeline CEMP (BAS-210 0025) addresses all onshore construction activities to be completed from the upstream weld of the proposed beach valve to the pipeline shore pull onshore termination point.

The work under the Offshore and Onshore CEMPs will be undertaken by different contractors. Under the offshore CEMP, there are two additional management plans that address specific activities during construction (**Figure 2-5**). These are the:

+ Trenching and Spoil Disposal Monitoring and Management Plan (TSDMMP) (BAS-210 0023) that addresses all trenching and spoil disposal activities from the 3 NM Commonwealth/NT waters boundary to the shore pull onshore termination point
+ Marine Megafauna Noise Management Plan (MMNMP) (BAS-210 0022) that addresses all activities associated with noise impacts to marine megafauna from the 3 NM Commonwealth/NT waters boundary to the shore pull onshore termination point.

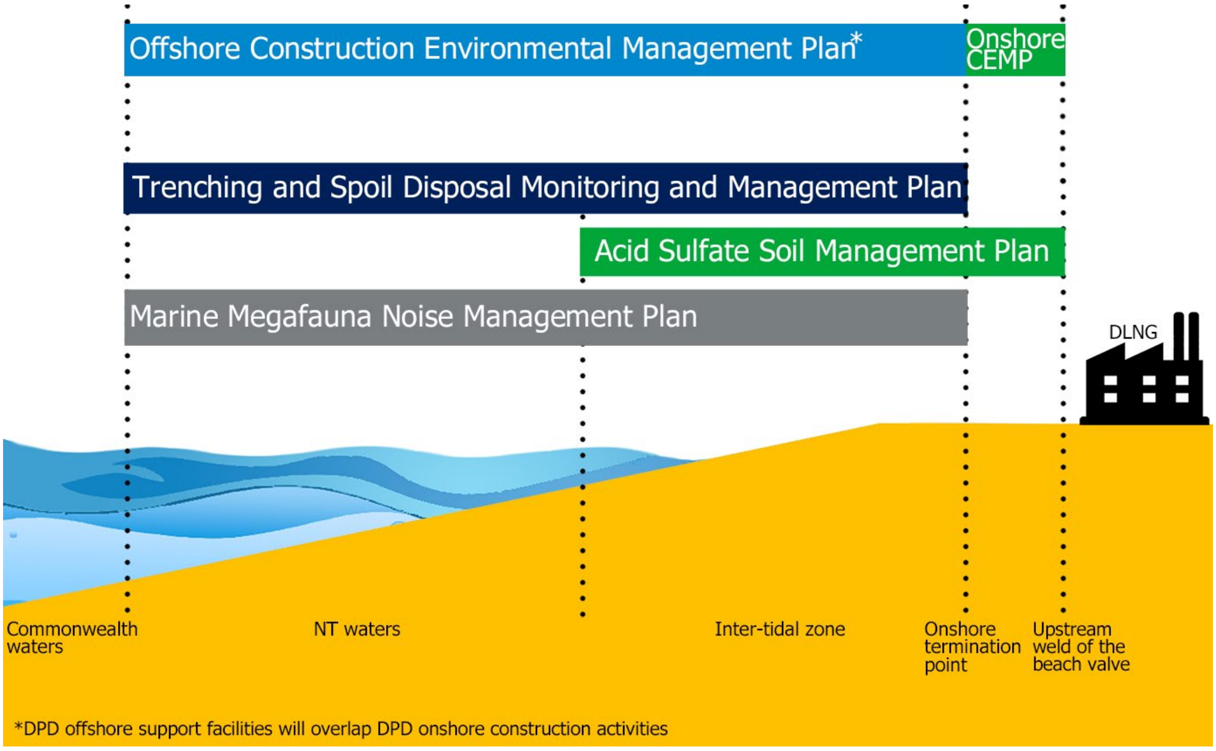

Figure 2-5: Conceptual model of management plan geographical scopes

2.3.2 Site works

The site is broadly split into two sections:

+ An 'intertidal' zone, extending from the LAT mark, to the shore pull onshore termination point.
+ An 'onshore' zone, extending 206 m from the shore pull onshore termination point to the upstream weld of the proposed beach valve tie-in point.

The location of these sections is presented in **Figure 2-2** and **Table 2-1**.

Table 2-1: Trench zone locations

Location	Kilometre point	Coordinates1	
		Easting	Northing
Upstream weld of the beach valve	KP122.690	702,472.29	8,614,655.73
Shore pull onshore termination point	KP122.484	702,272.73	8,614,606.40
LAT mark	KP122.157	701,954.81	8,614,527.82

Note:

1. Coordinates are displayed in Geocentric Datum of Australia (1994) (GDA94 MGA Zone 52).

2.4 Site background

The site is located within the DLNG Facility approved disturbance footprint. Santos is the registered owner and operator of the DLNG Facility.

This DLNG Facility and Bayu-Undan to Darwin GEP has been operating since 2006. The shore crossing route for the Bayu-Undan to Darwin GEP is situated to the south-western corner of the DLNG Facility (in the same development footprint as the site).

Several phases of desktop-based and intrusive investigations were undertaken in the vicinity of the site and across the wider area to support the development of the DLNG Facility, including work to assess and manage ASS risks across the development area.

A historical investigation undertaken by URS in 2002 (URS, 2002b) previously identified the presence of ASS across the DLNG Facility development area adjacent to the site. A subsequent ASSDMP (URS, 2004) was prepared for the development of the DLNG Facility and focussed on the presence of ASS across the wider development area.

A review of the 'Darwin 10 MTPA LNG Facility Public Environmental Report' prepared for the development of the DLNG Facility (URS, 2002a) identified the proposed earthworks strategy for the DLNG Facility development included retaining mangrove mud identified to underlie its development footprint.

As part of the construction of the initial Bayu-Undan to Darwin GEP crossing, natural material was removed and replaced by site-won, non-ASS, fill material across the length of the on-shore pipeline crossing.

The extent of historical ground disturbance associated with the development of this pipeline crossing is indicated in aerial imagery from June 2004, presented in **Figure 2-6**: . The image indicates the Bayu-Undan sea-to-shore pipeline crossing site has been subject to extensive ground disturbance, with extensive excavations present.

Based on this information, this ASSDMP has been prepared on the assumption that material across the proposed development extent at the site is likely to be non-ASS material except in the intertidal zone.

Figure 2-6: Aerial image of the site and surrounds – June 2004 (Image source: Google Earth, accessed: 19/08/22)

2.4.1 Scope and objectives

The principal objectives for the ASSDMP are as follows:

+ Present relevant historical ASS investigation data and management measures.
+ Detail the proposed soil management measures to be adopted during the site earthworks to mitigate or control potential impacts relating to the disturbance of ASS associated with construction earthworks (i.e., open trench excavations).
+ Detail the proposed dewatering management programs (if required) to be adopted during the excavation and dewatering of soils associated with construction earthworks (i.e., open trench excavations).

To meet the objectives of this ASSDMP, the following scope of work was undertaken:

+ A desktop review of publicly available information and pertinent historical reports for the site, including summarising the findings of the historical investigations
+ Assessment of ASS risk at the site, based on historical data, including the assessment of potential environmental impacts associated with the proposed earthworks
+ Assessment and presentation of ASS management measures based on historical data
+ Development of management measures, which detail the following:
  – Soil removal, handling and stockpiling operations, including the neutralisation of acidity associated with ASS (if required)
  – Treated soil validation testing programs (if required)

– Contingency measures and appropriate responses that may be implemented to rectify any breaches of the nominated triggers and management measures
– Contingency dewatering strategy.

The control measures presented herein are based on the review of historical reports only.

2.4.2 Assumptions

This management measures presented within this ASSDMP are based on the following assumptions:

+ The site has undergone extensive historical earthworks, and ground disturbance activities associated with the DPD Project will be limited to disturbance of historically imported non-ASS material except within the intertidal zone.
+ The management measures are based on a desktop review of historical information for the site and wider area.
+ The site extends to the upstream weld of the proposed beach valve tie-in point, approximately 205 m inshore of the shore pull onshore termination point. Further onshore works, between the upstream weld of the beach valve and the DLNG Facility process tie-in point are outside the scope of this ASSDMP

2.4.3 ASSDMP format

The remainder of this ASSDMP comprises the following sections:

Table 2-2: Report format

Section	Title	Description
3	Site description	Details the relevant environmental characteristics of the site with respect to ASS management.
4	Proposed earthworks and dewatering program	Outlines the overall earthworks and dewatering operations for the site.
5	Soil results	Assesses the presence and distribution of ASS within the soil at the site.
6	Groundwater quality	Provides a baseline assessment of groundwater prior to construction
7	Groundwater modelling	Details the findings of empirical groundwater modelling undertaken in support of the proposed dewatering program.
8	Assessment of potential environmental impacts	Details the potential environmental impacts from the DPD Project that might result due to disturbance of ASS through the earthworks program.
9	Proposed earthworks operating strategy	Outlines the proposed earthworks associated with the DPD Project.
10	ASS environmental reporting	Presents the environmental reporting requirements associated with the management of ASS at the site.
11	References	Lists the guidance and literature references referred to within this report.

Section	Title	Description
Appendix A	Identification and management of unexpected ASS – onshore zone	Presents procedures for the on-site identification and management of unexpected ASS material in the onshore zone.
Appendix B	Dewatering operating strategy	Presents the proposed options in managing dewatering effluent and containing relevant monitoring requirements for dewatering effluent and groundwater.

2.4.4 Guidance literature

Preparation of this ASSDMP report was undertaken with reference to the following key guidance documents on ASS and water quality:

+ Acid Sulfate Soils Laboratory Methods Guidelines (McElnea, A.E. and Ahern, C.R. 2004)
+ Australian/New Zealand Standard 5667.1:1998, Water quality – Sampling. Part 1: Guidance on the design of sampling program, sampling techniques and the preservation and handling of sampling (Standards Australia, 1998a)
+ Australian/New Zealand Standard 5667.4:1998. Water Quality – Sampling. Part 4: Guidance on sampling from lakes, natural and man-made (Standards Australia, 1998b)
+ Australian/New Zealand Standard 5667.12:1998, Water Quality — Sampling. Part 12: Guidance on Sampling of Bottom Sediments (Standards Australia, 1998c)
+ National Acid Sulfate Soils Guidance. National acid sulfate soils identification and laboratory methods manual. (Water Quality Australia, June 2018a).
+ National Acid Sulfate Soils Guidance. Guidance for the dewatering of acid sulfate soils in shallow groundwater environments. (Water Quality Australia, June 2018d).

3 Site description

3.1 Site details

A detailed site summary is provided in **Table 3-1**, below, with the site locality presented in **Figure 2-1**.

Table 3-1: Site details summary

Reference name	Darwin Pipeline Duplication (DPD) Project	
Address	Darwin LNG Facility, Wickham Point Road, Wickham, NT 0822	
Designated plant and pipeline operator	Santos	
Local government authority	Litchfield Municipality	
Current zoning	Industrial	
Area and elevation	**Area**	**Elevation**
	0.40 ha	DLNG: 12 – 15 m LAT
Site location and layout	**Figure 2-1** **Figure 2-2** **Figure 2-3**	
Coordinates – LAT (GDA 94, Zone 52)	**Easting**	**Northing**
	701,954.81	8,614,527.82
Coordinates – Shore pull onshore termination point (GDA 94, Zone 52)	**Easting**	**Northing**
	702,272.73	8,614,606.40
Coordinates – Upstream weld of the beach valve tie-in (GDA 94, Zone 52)	**Easting**	**Northing**
	702,472.29	8,614,655.73

3.2 Site setting

3.2.1 Climate

Relevant information pertaining to the site's wider setting is presented within the DPD Project's Northern Territory Environmental Protection Authority (NT EPA) referral document (Santos, 2021).

The site's climatic setting can be summarised as follows:

+ The climate is characterised by a tropical monsoonal climate with a distinct dry season (May to September) and wet season (October to March), separately by a relatively short transition period.
+ The average annual rainfall for Darwin is 1,720 millimetres (mm), with the wettest months being January to March.

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- Rainfall is higher than evaporation from December to March and lower from April to November. The mean maximum temperature range is from 30.6°C (July) to 33.3°C (October and November).

3.2.2 Geology

The site's regional geological setting (based on Dames & Moore, 1997) is described as:

- Quaternary Deposits (Q)
  - Qcl – Sand, silt, clay: colluvial sediments deposited by unconcentrated surface runoff
  - Qca – Mud, clay, silt: intertidal marine alluvium
- Early Proterozoic Deposits – Finniss River Group – Burrell Creek Formation (Pf)
  - Pfb – shale, siltstone, and phyllite in places, colour banded fine to very coarse sandstone (quartz, arentite, sublitharenite, arkose), quartzite, quartz pebble conglomerate, minor graphitic phyllite, quartz-mica schist and gneiss.

The site's local geological setting (URS, 2002), prior to construction of the DLNG Facility is summarised as follows:

- Characterised by a strongly foliated and metamorphosed sequence of steeply dipping interbedded sandstone and siltstone
- Thick lateritic ironstone soil has developed on hinterland areas, whereas marine and mangrove mud characterises the seaward margin
- The marine and mangrove mud comprises predominantly silty sediments with varying amounts of sand, clay, and lateritic gravel
- Based on the understanding of the previous earthworks at the site, it is understood the site's geological setting has been highly modified, and the presence of the natural geology at the site is not anticipated.

3.2.3 Intertidal setting

The site is situated in a low-lying intertidal area of the Middle Arm Peninsula, within the wider Darwin Harbour area (**Figure 2-1**).

The clayey nature of the underlying soils and the surrounding area results in localised pooling of rainfall and limited/low infiltration rates. The site is largely cleared of large vegetation due to historical earthworks associated with the installation of the Bayu-Undan pipeline.

The coastline of the site is fringed by mangroves and clayey tidal flats to the north and south of the site.

3.2.4 Topography

The site's topographic profile is largely flat across the onshore half of the proposed pipeline extent, at approximately 12 m LAT, with a maximum height of approximately 15 m LAT. The topography of the site slopes gradually towards the coast extending towards its western extent, to a height of 0 m LAT on its western boundary.

3.2.5 Acid sulfate soil risk

The Australian Soil Information System (ASRIS) is an online data resource provided by the Federal Government's Department of Agriculture, Fisheries, and Forestry, in conjunction with the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

A review of the ASRIS database (accessed: 25/05/2022), based upon an undisturbed site, indicates the site has a 'high probability' of ASS being present, albeit with 'low confidence'.

3.2.6 Groundwater and surface water

Groundwater and surface water information presented within the DPD Project's NT EPA Referral (BAA-201 0003; Santos, 2021) is summarised as follows:

+ There are no permanent freshwater habitats at the shore crossing or the adjacent mainland peninsula. However, there are several small creek lines that flow from upland areas to the harbour during the wet season.
+ Periodic monitoring of groundwater has been undertaken at the DLNG Facility and wider area since 2015. During periodic monitoring, encountered depths to groundwater at monitoring locations closest to the Site (BH05 and BH07) ranged between 1.34 m below top of casing (btoc) (approximately 0.80 m bgl) at BH05 in April 2021; and 3.14m btoc (approximately 2.60 m bgl) at BH07 in April 2021.
+ Periodic groundwater monitoring at the location closest to the site (BH7) has indicated that groundwater levels monitored in 2021 (the latest available annual reporting timeframe) range between approximately 2.4 m AHD (5.4 m LAT) and 4.7 m AHD (7.7 m LAT), dependent upon seasonal rainfall cycles. A higher groundwater level has been noted during the wet season compared to the dry season. This data is based on an historical monitoring location situated to the north of the site, and so groundwater levels at the site may vary.
+ During historical monitoring, the ambient groundwater pH typically varied between 3.9 to 6.7 pH units, whilst the recorded conductivity range varied between 109 to 82,000 micro-Siemens per centimetre (µS/cm). This variation was attributed to the climatic seasonality of the area. Increased rainfall of the wet season presents a freshwater input into the groundwater regime.
+ The Darwin Harbour surface water body is located across the intertidal zone, extending from 0 m LAT to 8.2 m above LAT during periods of high tide.

4 Proposed earthworks and dewatering program

The timing and extent of ground disturbance and dewatering associated with the development of the site can play a large role in the extent of management measures required for the site.

The proposed earthworks and dewatering programs are summarised in the following sections.

4.1 Earthworks program

The following presents a general summary of the anticipated earthworks at the site:

Table 4-1: Summary of proposed earthworks at the site

Earthworks zone	Zone definition	Proposed earthworks
Intertidal zone	Extending from 0 m LAT to the shore pull onshore termination point, over a distance of approximately 327 m (see **Figure 2-2**).	High-tide periods: + Vessel-based backhoe dredge (BHD) assisted by split hopper barges (SHB) + Disposal of excavated material will be at an offshore spoil disposal ground Low-tide periods: + Conventional earthworks plant, namely: land-based backhoe or tracked excavator + Disposal of excavated material will be through stockpiling as close to the LAT mark as possible, as per the procedures presented below.
Onshore zone	Extending from the shore pull onshore termination point to approximately the upstream weld of the beach valve tie-in point over a distance of approximately 206 m (see **Figure 2-2**).	+ The trench, including the anchor pit, will be excavated via conventional earthworks plant, namely: backhoe or tracked excavator + Management of excavated material will be as per the stockpiling and treatment procedures presented in **Appendix A**.

4.2 Proposed ground disturbance

The following presents a general summary of the anticipated ground disturbance extents:

4.2.1 Intertidal zone:

+ Trenching across this part of the site is anticipated to be approximately 327 m long, up to 5.0 m deep, and up to 4.0 m wide at the base.
+ Trenching will be undertaken by means of a combination between excavator and BHD. The exact location where vessel-based excavation and land-based excavation are separated will be determined during the course of the work.

+ This trenching may require the construction of temporary causeways (up to approximately 131.9 m long and 21.75 m wide either side of the pipeline) to enable trenching via conventional earthmoving equipment (excavator and dump trucks).
+ Given the location of this section of trenching, the excavation is anticipated to be periodically inundated by the tide.

4.2.2 Onshore zone:

+ A backhoe excavator will be used for land-based excavation. The excavations will create a trench, approximately 210 m in length, in a staged approach.
+ Based on the anticipated duration of earthworks, the trench may remain open for up to four months.
+ The trench is anticipated to be up to 5.0 m deep, and 4.0 m wide at its base.
+ Excavation pit for the hold back anchor (anchor pit), it is anticipated that the pit will be 25 m x 30 m, with battered sides, and 5 m deep (maximum depth of 8.5 m LAT).

4.3 Proposed dewatering

The use of the term 'dewatering' refers to the removal/pumping of groundwater.

The removal and/or pumping of rainwater from excavations is considered not to be required during construction and as such is not considered within this management plan. As a contingency however, a dewatering management plan has been included (Appendix B) should it be required.

4.3.1 Intertidal zone

Given the intertidal setting of this extent of the trench, no dewatering is proposed for earthworks in this section of the site as it will be subject to periodic tidal inundation.

4.3.2 Onshore zone

The requirement for dewatering is in part dependent on the groundwater levels at the time of excavation, hence varies seasonally with rainfall. Based on the current understanding of the earthworks and associated timeframes, dewatering is considered not to be required across the onshore zone.

Should however groundwater be encountered during the onshore earthworks, dewatering measures should be implemented.

The dewatering measures (if required) are presented within **Appendix B**.

5 Soils

5.1 Previous investigations

The identification and assessment of ASS for the site is based on the following historical reports:

+ D&M, 1997. 'Darwin LNG Plant – Draft Environmental Impact Statement: Appendix G – Wickham Point and Middle Arm Peninsula Terrain Analysis', Dames & Moore Pty Ltd. Ref.: 0053-164-073. July 1997
+ URS, 2002. 'Acid Sulfate Soil Investigation – Wickham Point, Northern Territory', URS Australia Pty Ltd. Ref.: 00533-244-562 R001. 19 July 2002
+ URS, 2004. 'Bayu-Darwin Pipeline Project – Acid Sulfate Soil Management Plan', URS Australia Pty Ltd. Ref.: 561-F6359.1. 6 April 2004
+ BHBJV, 2004. 'ConocoPhillips Bayu-Darwin Pipeline Project: Shore Approach, Dredging & Rock Dumping Subcontract No. BDPP-S-CO-002: Manufacturing Procedure Specification Dry Excavation', Ballast Ham / Boskalis Joint Venture, Ref.: BD-O-PR-1824, 21 April 2004.

5.2 Dames & Moore Pty Ltd, July 1997

Dames & Moore Pty Ltd (D&M) completed a historical investigation of ASS as part of a terrain analysis across the wider Wickham Point area in October 1996 on behalf of Phillips Petroleum as part of the development of the new DLNG facility.

5.2.1 Scope

The investigation comprised the following:

+ Review of desktop data for the area
+ Collection of six soil samples from near-shore locations across the wider area
+ Sample locations were accessed by boat and were collected from depths of up to 1.0 m bgl
+ Laboratory analysis on the collected soil samples.

5.2.2 Findings

Two sample locations (WP-W1 and WP-W2) were in the intertidal area in close proximity to the DPD Project site. The soils were identified as estuarine mud (brown/dark grey/green clayey silts/sands/ gravels) and the results of the laboratory analysis are summarised as follows:

+ Sulfate concentrations ranged between 0.21%S (WP-W1 0.0–0.5 m) and 0.34%S (WP–W1 0.1 m).
+ Acid neutralising capacity (ANC) concentrations ranged between 9.91%S (WP-W2 0.0–0.5 m) to 11.9%S (WP–W1 0.1 m).

The report concluded the following:

+ Sulfur concentrations in the samples could give rise to acid generation, however, due to the inherent neutralising capacity of the materials (largely due to the finely disseminated $CaCO_3$ content in the soil most likely generated from shell fragments and/or coral detritus), being an order of magnitude higher than sulfur concentrations "there would not be any nett acid production potential".

5.3 URS Australia Pty Ltd, 19 July 2002

URS completed an historical investigation of ASS across the wider Wickham Point area in 2002 on behalf of Phillips Petroleum as part of the development of the new DLNG facility.

5.3.1 Scope

The investigation comprised the following:

- Review of historical reports for the area
- Advancement of 45 boreholes, distributed across six 'sites', spread across the wider Wickham Point area, and installation of monitoring wells
- Completion of ASS field tests and laboratory analysis (peroxide oxidation combined acidity and sulfur (POCAS) suite analysis and Chromium reducible sulfur (CRS)) on soil samples at 0.5 m depth intervals
- Collection of soil samples at 0.5 m intervals for laboratory analysis
- Boreholes were advanced by hand auger to refusal, or to the 'limit of the hand auger'.

5.3.2 Findings

One of the sites (Site 6) was adjacent to the northern boundary of the DPD Project site, and included ten boreholes, of which six were advanced in onshore locations.

- A review of a geotechnical study (JFA, 2001) for the DLNG Facility, which included Site 6, identified the following:
  - Eight samples were obtained from three boreholes (P8, P9B, and P10) for laboratory (POCAS) analysis, with only Peroxide Oxidisable Sulfur (S_{POS} %S) and Titratable Peroxide Acidity (TPA; %S) reported.
  - S_{POS} concentrations ranged between 0.02 and 0.74%S (in P10_0.55–0.72 m and P9B_0.35–0.50 m respectively).
  - 'Non-detections' of TPA (i.e., 0.01%S) indicate a high acid self-neutralising capacity in all samples tested. This is likely due to the presence of large shell-grit/carbonate content
- The URS, 2002 investigation encountered the following ground conditions at Site 6:
  - Sediments comprised marine silts, sand, and gravel underlying the shoreline mangrove communities.
  - Hand auger refusal occurred on bedrock at depths ranging from 0.1 to 1.0 m bgl.
  - Field testing was undertaken upon four samples with the test results indicating 'zero to very low' likelihood of ASS.
  - Laboratory analysis was undertaken upon two samples from the Site 6 which indicated:
- SCR results ranged between 1.26–1.62%S (from sample depths of 0.2–0.6 m and 0.2–0.4 m bgl, respectively).
- High self-neutralising capacity in the samples, based on the high acidity (pHNaCl – between 8.7 and 8.8), and the concentration of 25–30% fine carbonate/shell content with a particle size of <1mm.

- The laboratory analysis indicated the samples were indicative of PASS.
- The report states that 'no additional lime should be required for neutralisation of acidity if complete oxidation were to occur'.
- These results were broadly consistent across the remaining investigation areas, distributed across Wickham Point.

5.4 URS Australia Pty Ltd, 6 April 2004

URS completed a historical ASSDMP document on behalf of a Multiplex-Saipem Joint Venture. The ASSDMP was prepared to enable the assessment of potential ASS impacts to the Bayu-Darwin Pipeline Project, and to present a contingency plan for unexpected disturbances of ASS.

The context for the document, as presented within the ASSDMP itself, was as follows:

- Although not expected to be present or be of major significance on this site, a detailed ASSDMP has been prepared prior to the proposed pipeline excavation works within estuarine sediments (mudflats). ASS have been identified in areas in close proximity to the proposed mudflat excavation site and on site but based on available site information these sulfidic soils are believed to have the capacity to self-neutralise.

The ASSDMP included a summary of historical investigations at the site, including an additional scope of investigation work undertaken by Thiess Pty Ltd (Thiess) in 2003. Theiss advanced boreholes at two locations within the development footprint of the subject site of this ASSDMP (the site).

The findings of the historical investigations were summarised as follows:

- The encountered sediments were generally marine silts and sand layers, extending to depths of up to 1.0 m bgl.
- Two samples taken from the proposed excavation site confirmed the presence of sulfidic material. The self-neutralising capacity of the soil was found to be such that the net acid generating capacity is negative (i.e., the soil has a high buffering capacity).
- Whilst these samples did not extend down the length of the excavation, they are similar in nature to those collected 100–300 m to the north of the proposed excavation site (Site 6, URS 2002).
- At Site 6 an extensive ASS investigation was carried out with all samples also having a negative net acid generating capacity. Similar ground conditions and results are anticipated at the site.
- The site investigations confirmed that the underlying strongly foliated metamorphosed sequence of interbedded sandstone and siltstone (URS, 2002) does not contain sulfidic material and therefore does not have the potential to generate acid when exposed to the atmosphere, thus does not require ASS management.

5.5 ConocoPhillips, 21 April 2004

The ConocoPhillips, 2004 report presents a Manufacturing Procedure Specification for the construction of the DLNG Facility, as part of the 'Bayu-Darwin Pipeline Project'. The document makes reference to the URS ASSDMP (URS, 2004) as the main reference document for the management of ASS.

The report presents a summary of a Thiess risk assessment undertaken for the interception of ASS material during earthworks. The scope of work undertaken by Thiess included:

- A review of historical ASS investigation data and conclusions
- Additional ASS sampling undertaken in January 2004, comprising:
  - Obtaining one soil sample from 'centreline' of the proposed onshore pipeline easement
  - Obtaining one soil sample from 'south of the centreline' of the proposed onshore pipeline easement
  - Laboratory analysis for SPOCAS analysis on both samples, which indicated that whilst sulfur concentrations were above management criteria, the soils were identified as self-neutralising.

5.6 Summary

Based upon a review of historical earthworks undertaken at the site as part of the development of the DLNG Facility, the site has had its natural material removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand).

Based on this, it is understood that ASS associated with the naturally occurring soil material is no longer present within the onshore zone, however its presence in the Onshore and Intertidal Zones cannot be discounted and may require management.

Based upon data provided within the historical investigations undertaken at the site and surrounds, ASS material previously present at the site was characterised as follows:

- 'Lateritic clays with various amounts of sand, silt and quartz gravel.' (URS, 2002).
- Generally self-neutralising due to its inherent high buffering capacity, generally associated with its high fine carbonate/shell content.

Historical investigation data indicated that prior to the development of the DLNG Facility, ASS material at the site could be found up to 2.5 m bgl, underlain by siltstone bedrock.

For management purposes, all material at the site should be considered non-ASS unless it matched the visual ASS descriptions, presented within this ASSDMP.

Whilst the majority of material onshore is considered to not require management, vigilance will be maintained during on-site works to identify natural in-situ material PASS (lateritic clays) which may have not been removed during the DLNG Facility construction.

6 Groundwater

This ASSDMP provides a discussion of the site's baseline groundwater conditions recognising the interrelationship between PASS and groundwater quality (e.g., existing ASS impacts), and the potential significance of dewatering management in maintaining shallow groundwater quality in the short and longer terms, i.e., both during and after construction.

Historical groundwater monitoring data undertaken as part of the DLNG Facility's operational license requirements (CDM Smith, 2021) identified the following groundwater quality information for the local area adjacent to the onshore zone:

+ Localised recharge of the groundwater table occurs via infiltration of rainfall through alluvial sediments.
+ Groundwater, if discharging at the coastlines, may be mixing with marine water where it is saline and seeping to near-surface environments where it is fresh.
+ Groundwater monitoring undertaken as part of the July 2021 report identified the following:
  - Groundwater across the monitoring network was identified to be acidic, with the field pH of groundwater in the local area ranging from 4.53 to 6.35 pH units.
  - Field pH values for groundwater across the monitoring well network exceeded the applied Darwin Harbour Water Quality Objectives for the site.
  - Dissolved aluminium concentrations in groundwater ranged from 0.005 mg/L to 0.852 mg/L.

Based upon a review of historical groundwater information, groundwater at the site is anticipated to be acidic and will require treatment, prior to infiltration, should dewatering of groundwater across the onshore zone be necessary.

7 Groundwater modelling

Dewatering may be required as part of the earthworks in the onshore zone.

Should groundwater be encountered during earthworks, dewatering must be implemented in accordance with the measures presented in **Appendix B**.

To inform the proposed dewatering requirements for the onshore zone, an overall approach to dewatering based on the historical groundwater information for the area is presented below.

7.1 Empirical approach

Based on the information for the DPD Project, no defined timeline or anticipated duration is available for dewatering at the site during the construction and installation of the pipeline.

Groundwater drawdown estimates were conducted utilising the empirical method as outlined in National Acid Sulfate Soils Guidance '*Guidance for the dewatering of acid sulfate soils in shallow groundwater environments*' (Water Quality Australia, June 2018d).

The radius of the cone of depression of the water table was estimated using Sichardt's equation:

$$R_o = 3000 * \mathrm{s} * \sqrt{k}$$

Where:

R_o = radius of influence of an equivalent pumping bore (m)

s = maximum drawdown of ground water (m)

k = hydraulic conductivity of aquifer matrix (units of m/s)

In the absence of site-specific hydraulic data, a K value of 3.5 x 10^{-4} m/s has been assumed (Water Quality Australia, June 2018d).

Changes in the water table elevation resulting from dewatering activities correlate with the pumping rate, the hydraulic conductivity of the aquifer matrix and the radius of influence of pumping by the following equation:

$$H^2 - h^2 = \frac{nq}{\pi k}(\ln R_o - \ln r_e)$$

Where:

H = saturated thickness of the aquifer undisturbed by pumping (m)

h = saturated thickness of the aquifer at maximum drawdown (m)

re = effective radius of an equivalent pumping bore (m)

q = pumping rate of individual dewatering well points (m^3/s)

n = number of well points used to dewater the excavation

Other parameters have been previously defined

The pumping time required for the cone of depression of the water table to extent out to the radius of influence (Ro) is given by the Cooper-Jacob empirical relationship.

$$R_o = \left(\frac{2.25 * k * h * t}{S}\right)^{\frac{1}{2}}$$

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Where:

t = pumping time (s)

h = specific yield of aquifer sediments

Other parameters have been previously defined

Groundwater dewatering calculations were undertaken to assess potential environmental impacts resulting from the dewatering. The calculations provide guidance and estimations for:

+ The extent and magnitude of on- and off-site drawdown arising from dewatering operations and its potential environmental impacts on surrounding areas
+ An estimate of the volume of water that will be abstracted to achieve the required on-site drawdown.

7.2 Dewatering scenario

The following scenario for dewatering at the site was based upon the proposed earthworks. The dewatering scenario is based upon the trench having a width of five metres, being conducted in 50 m lengths. A maximum drawdown of 6 m was anticipated.

The calculation adopted the following assumptions, which were biased to being conservative in the estimation of aquifer properties (i.e., tending to over-predict dewatering required):

+ The saturated thickness of the aquifer undisturbed by pumping (H): 10.0 m
+ The saturated thickness of the aquifer at maximum drawdown (h): 4.0 m
+ A well point (n) per 2 metres of length: 10
+ The hydraulic conductivity of the aquifer matrix (k) is 1.16×10^{-5} m/s as described in the National Guidance (Water Quality Australia, June 2018a) for clayey sands
+ Groundwater is required to be drawdown by 6 m
+ The specific yield (S) is 0.1 in the absence of site-specific hydraulic information.

7.3 Results

The following results were obtained based on the assumptions presented above. The results related to each 50 m length of pipeline:

+ The radius of influence was 61 m.
+ The pumping rate was calculated at 1.6 L/s (per well) taking approximately 16 hours to achieve the drawdown for a 50 m section of the trench.
+ A calculated total of 6,327 kL of dewater was estimated to be abstracted requiring disposal to achieve drawdown per 50 m section of the excavation, i.e., cone of depression.

Based on the above, an average pumping rate of ~1.6 L/s per 50 m linear excavation extent was adopted for the site, which equates to an extracted volume of water of 6,327 m^3 over a 16-hour period per day.

7.4 Limitations of empirical method

The empirical method for estimating dewatering volumes is provided in the National Guidance (Water Quality Australia, June 2018d), however it is simplistic and does not take potential hydrogeological complexities into account. This empirical method provides estimated flows from groundwater based upon simplistic geological conditions, default hydraulic conductivity estimates and theoretical calculations.

Similarly, the method does not include the influence of rainfall recharge which can affect groundwater inflow and dewatering rates. For these reasons, the results provided are broad estimates only and may require some adjustment on-site.

8 Assessment of potential environmental impacts

The identified potential environmental impacts associated with earth working and dewatering of ASS for the various proposed construction activities are detailed in **Table 8-1**.

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Table 8-1: Potential Environmental Impacts

Potential impact	Description	Predictions	Management measure
Oxidation of PASS			
Soils/sediments (excavated)	+ Generation of ASS through the inappropriate handling, treatment or disposal of excavated soils.	+ PASS in the intertidal zone is anticipated to have suitable self-neutralising capacity to avoid potential ecological damage. + PASS in the onshore zone is not anticipated to be encountered however, if encountered, will require management. + The receiving environment (the surface water) for the disposal of encountered ASS will have a high buffering capacity: minimising potential impacts from ASS disposal.	+ As per the Earthwork Operating Strategy (**Section 9**)
Soils/sediments (*in-situ*)	+ ASS oxidation effects caused through exposure of the soils to air via open excavation.	+ Drawdown of groundwater is not anticipated to impact ASS within the extent of proposed excavations. + Excavated material from the intertidal zone will remain saturated at all times prior to placement at disposal location. + Excavated material from the onshore zone is anticipated to be non-ASS (as historically imported fill). ASS oxidation and impacts associated with this zone are not anticipated.	+ As per the Earthwork Operating Strategy **(Section 9)**
Groundwater	+ Potential for acid and metal leaching through groundwater from oxidised ASS.	+ Drawdown of groundwater, if required, will be managed via the dewatering operating strategy. + Excavated material from the onshore zone is anticipated to be non-ASS (as historically imported fill). ASS oxidation and impacts associated with this zone are not anticipated.	+ As per Dewatering Operating Strategy (**Appendix B**).

Potential impact	Description	Predictions	Management measure
Surface water	+ Potential for acid and metal mobilisation into adjacent surface water (inter-tidal area of Darwin Harbour) from oxidised ASS.	+ Drawdown of groundwater, if required, will be managed via the dewatering operating strategy. + Excavated material from the intertidal zone will remain saturated at all times prior to placement at disposal location.	+ As per Dewatering Operating Strategy (**Appendix B**) and the Earthwork Operating Strategy (**Section 9**).
Sediment plume			
Poor surface water quality	+ Sediment plumes generated in Darwin Harbour during the excavation and placement of sediments/soils from the intertidal zone.	+ Given the low anticipated sediment generation volumes associated with the excavation and dispersals of emplaced PASS material at the site, the risk of adverse impacts on surface water quality is low.	+ None required.
Dewater Discharge			
Impacts to the adjacent surface water body	+ Discharge of acidic groundwater sourced from dewatering of the excavated trench in the Onshore Zone could impact the adjacent surface water body (Darwin Harbour) if not treated appropriately.	+ Should dewatering be undertaken as part of the Onshore Zone earthworks, a dewatering rate of 1.6 L/sec will be required. + This will need to be managed in accordance with the procedures presented in this document in order to avoid impacts to the adjacent surface water body (Darwin Harbour). + Note: discharge of dewatered groundwater from the Onshore Zone directly to Darwin Harbour is not acceptable.	+ As per Dewatering Operating Strategy (**Appendix B**).

9 Earthworks operating strategy

9.1 Overview

For the purposes of managing ASS, the site is spilt into the following zones (as presented in **Figure 2-3**):

+ The 'intertidal' zone, extending from the LAT mark to the shore pull onshore termination point.
+ The 'onshore' zone, extending approximately 206 m from the shore pull onshore termination point to the upstream weld of the proposed beach valve tie-in point.

For the purposes of managing ASS, the following applies:

+ Intertidal zone: ASS management measures will be required for estuarine muds (brown/dark grey/green clayey silts, sand and gravels) material from natural surface level to the top of encountered hard strata.
+ Onshore zone: All material is considered non-ASS and does not require active management. There remains the potential, albeit low, for natural in-situ lateritic (red/brown) clays/silt/sand to be present which will requirement management if encountered.

Further information on the identification of ASS *in-situ* is presented in **Appendix A**.

9.2 ASS management measures

This management measure will comprise similar steps to that presented within the ASSDMP for the DLNG Facility (URS, 2004), and is summarised below.

9.2.1 Intertidal zone

+ ASS material, as estuarine mud, is anticipated from surface level. Management measures are as follows:

High-tide periods:

+ Excavation via vessel-based BHD assisted by SHB
+ Disposal of excavated material will be at the DPD offshore spoil disposal ground (**Figure 2-1**).

Low-tide periods:

+ Conventional earthworks land-based plant, namely: backhoe or tracked excavator
+ All material will be stockpiled at a predetermined location situated as close to the LAT mark as possible, resulting in the material being saturated across most tidal states.
+ All material would be removed directly from the trench excavation to the stockpile location and remain saturated during most tidal states due to periodic tidal inundation: thereby limiting the likelihood of drying out and acidification.
+ The tidal action would gradually remove the stockpiled material and disperse it to the marine environment.

Visual inspections will be undertaken of the immediate marine environment to ensure adequate dispersal of material placed in the intertidal zone. Where residual material (mounding) is identified during the visual inspection, excess will be transferred via SHB to the DPD offshore spoil disposal ground.

Table 9-1 presents a summary of the performance indicators used to assess the effectiveness of the ASS management. The adherence to these performance indicators should be documented throughout the treatment process for inclusion in the final ASS Closure Report.

Table 9-1: Summary of ASSDMP performance indicators – intertidal zone

Item	Performance Indicator
Soil handling	+ All material will be managed as ASS (or suspected ASS) and will be stockpiled accordingly. + Accurate material movement records kept.
Stockpile all suspected ASS as close to the LAT mark as possible and have it transported to the DPD offshore spoil disposal ground or removed by tidal action.	+ All ASS placed in the intertidal zone removed by tidal action within 2.5 days from being excavated. + Where ASS is still present in a stockpile beyond 2.5 days, the remaining material should be moved via vessel-based BHD assisted by SHB and then disposed of at the DPD offshore spoil disposal ground. + All ASS material is kept saturated from excavation to placement as close to the LAT as possible, for removal via tidal action. + Records are kept for the volume of ASS material disposed of in this manner.

9.2.2 Onshore zone

+ ASS material, as estuarine mud, is not anticipated in this section of the site.

Should this material be encountered during earthworks for trenching and site preparation works, suspected unexpected ASS material is to be removed from the excavation and stockpiled separately from non-ASS materials on a limestone pad ahead of confirmatory testing. Due to the timing of excavation and construction of the anchor pit (which is to occur during site preparation works), specific management procedures for the anchor pit excavation are detailed below.

The requirements for management of this material are detailed in **Appendix A**.

9.2.2.1 Anchor pit excavation

As excavation and construction of the anchor pit will occur during the site preparation works, should ASS be encountered, such material will be placed as close to the LAT mark as possible (per the intertidal zone management measures above), whilst the causeway(s) in the intertidal zone is available. Once the causeway(s) is unavailable, encountered ASS material, must be treated on a limestone pad as detailed above (**Section 9.2.2**).

Should ASS material be encountered, during the excavation, and present at the base of the anchor pit, as a contingency measure, a thin layer (10 – 20 mm) of limestone should be placed at the base of excavation and on the batters, where ASS is present.

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10 ASS environmental reporting

10.1 ASS closure report

A closure report will be prepared by an environmental professional and issued to the NT EPA at the completion of earthworks and detail (where required):

+ Management measures undertaken at the site and their effectiveness.
+ Soil validation results, both field and laboratory testing as specified in the ASSDMP (if required; see **Appendix A**).
+ Amount of neutralising agent used during construction (if required; see **Appendix A**).
+ Discussion of potential human health and environmental risk, and any remediation required.
+ Photographic record of the earthworks program.

10.2 Unexpected ASS

Should unexpected ASS be encountered the Contractor's site manager shall be responsible for:

+ Ensuring laboratory analysis is carried out to verify treatment for each identified ASS location at the frequency stipulated in this ASSDMP (see **Table A-2**, **Appendix A**).
+ Applying additional lime/calculating additional liming rates, where soils require further treatment, submitting subsequent verification samples to a laboratory for analysis, and verifying that the results meet the neutralisation criteria.
+ Maintaining a register of testing results and a record of inspections.
+ Compiling a summary report of all test results and inspections at the end each week and submitting to the Santos Project Manager.

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'Guidelines for the Siting, Design, and Management of Solid Waste Disposal site in the Northern Territory', Northern Territory Environmental Protection Authority, January 2013. (NT EPA, 2013) https://ntepa.nt.gov.au/__data/assets/pdf_file/0006/284685/siting_design_landfills.pdf

Appendix A: Identification and management of unexpected ASS – onshore zone

General

The procedures outlined below are provided for the identification and management of unexpected ASS material that may be exposed during onshore ground disturbance activities (open excavations in the onshore zone).

Suspected unexpected ASS material is to be removed from the excavation and stockpiled separately from non-ASS materials on a limestone pad ahead of confirmatory testing as outlined below.

Identification of ASS at the site

Vigilance should be maintained during on-site works to assist with the identification of potential unexpected silt/clay or suspected ASS material encountered at the site during the course of earthworks.

Suspected ASS materials are often fine grained and located near the water table and may exhibit a “rotten egg” odour. Based on the results of previous investigations, material which appears to be clayey should be assumed to ASS.

The following visual indicators can be used to assist with the on-site identification of ASS:

+ Unusually clear or milky green drain water
+ Extensive rust coloured iron stains on any drain surfaces
+ Iron-stained drain water
+ Butter coloured jarosite present in surface spoil
+ Iron oxide mottling.

Other indicators, where none of the above is present, are waterlogged estuarine sands or silty sands having:

+ Mid to dark grey to dark greenish grey in colour; or
+ Soft and buttery clay consistency.

Material that is suspected ASS material and possesses the above traits can be confirmed by suitably qualified personnel or consultant.

If encountered the material should be stockpiled separately and treated in accordance with the management measures presented below.

Training

Equipment operators and supervisors shall be trained in the basic recognition of ASS as part of induction training. It is recommended that an experienced ASS practitioner shall be appointed to conduct site inspections and assist in the identification of ASS on an as required basis.

Auditing

An experienced ASS practitioner shall make weekly site inspections for the first two weeks of the works (dependent upon the proposed earthworks duration). The frequency of inspections required following this initial inspection period would be reviewed based on specific requirements of the ground disturbance works. The frequency may be reduced once a high level of compliance has been demonstrated.

Unexpected ASS management procedure – onshore zone

ASS is not anticipated within the proposed earthworks extent at the onshore zone. Given this, the requirements of this management measure (as an 'unexpected ASS' management procedure) are summarised below with specific procedures for the anchor pit:

Roles and responsibilities

The following responsibilities for the monitoring requirements are outlined below. All formal reporting to the Regulator will be undertaken by a suitably qualified person.

Table A-1: Monitoring Roles and Responsibilities

Monitoring activity	Parameters	Responsibility
Validation of Treated PASS Soils		
Collection of soil samples upon notification from site contractor	+ Laboratory: pHF and pHFOX, and SPOCAS[1]	+ Environmental Consultant
Review of results and notification to site contractor	+ -	+ Environmental Consultant

Note

1. Suspension Peroxide Oxidation and Combined Acidity and Sulfate.

Excavation and stockpiling of unexpected ASS material

+ Suspected ASS should be excavated and kept separate to non-ASS material.
+ The suspected ASS should be transported to a defined, bunded limestone pad for stockpiling.

Details on the construction of the treatment pad are provided below:

+ The limestone pads will be constructed in accordance with National Acid Sulfate Soils Guidance (2018b); i.e., ~300 mm thickness, with 150 mm high perimeter bunds and graded to corner/sump to capture any leachate/runoff from the drying vegetation.
+ A 'suitably qualified person' should undertake confirmatory sampling and assessment of the material to confirm the presence of ASS and required treatment rate.
+ ASS field screening (pH_F and pH_{FOX}) and CRS suite analysis with the inclusion of TPA is to be conducted at a minimum rate of 2 per 250 m^3 of recovered suspected ASS material (as per National Acid Sulfate Soils Guidance. [WQA, June 2018a]).
+ Based on the outcome of this testing, i.e., Net Acidity > 0.03%S, the 'suitably qualified person' will determine the appropriate aglime treatment rate.
+ Where aglime is applied, the 'suitably qualified person' will be notified to allow visual inspection and sampling and analysis (i.e., pH_F and pH_{FOX} per the Validation Sampling requirements).

- Based upon the results of the sampling:
  - If the treated material does not comply with the validation criteria the material should be treated with additional aglime as determined by the 'suitably qualified person'. Should the results indicate partial treatment then the liming rate, based upon SPOCAS analysis results, may be reduced to ensure that material is not over limed.
  - If treated material complies with relevant validation criteria, then no addition treatment will be necessary.
- Treated ASS materials should not be used as backfill within excavations below the groundwater table. Only non-ASS materials shall be used to backfill below the water table.
- Alternatively, ASS material can be removed from the site and disposed of to a suitably licensed waste disposal facility that is licensed to accept untreated ASS, in accordance with the waste classification guidelines (NT EPA, 2013). Sampling and disposal requirements should be confirmed with the chosen waste disposal facility prior to removal off-site.

Anchor Pit

As excavation and construction of the anchor pit will occur during the site preparation works, should suspected ASS be encountered the following is to be implemented depending on whether the intertidal zone causeway(s) is available or not:

- Causeway(s) available:
  - Suspected ASS material will be placed as close to the LAT mark as possible and allowed to disperse with the tide (per the intertidal zone management measures (Section 9.2.1).
- Causeway(s) not available
  - suspected ASS should be transported to a defined, bunded limestone pad for stockpiling or removed from the site and disposed of to a suitably licensed waste disposal facility (as detailed above),

Should ASS material be encountered, during the excavation, and present at the base of the anchor pit, as a contingency measure, a thin layer (10 – 20 mm) of limestone should be placed at the base of excavation and on the batters, where suspected ASS is present.

Stockpile management

Specifications for the preparation of the bunded treatment area and the monitoring of collected runoff are provided below.

It is important to note, as stated in the relevant guidelines (WQA, June 2018b) 'Stockpiling of soils is not to be used as an alternative to soil neutralisation, and all soils that are to be replaced in an excavation should be appropriately treated.'

Table A-2 presents the duration that ASS materials may remain untreated in medium-term stockpiles, i.e., those stored on a limestone pad (WQA, June 2018b). Exceedances of these timescales will result in non-conformances with this ASSDMP. Irrespective of how long material a stockpile, all ASS material must be treated prior to reuse onsite.

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Table A-2: Indicative maximum periods for medium-term stockpiling

Type of material		Duration of stockpiling	
Texture (AS 17626-1993)	**Approx. clay content (%)**	**Days**	**Weeks**
Coarse Texture Sands to loamy sands	<5	14 days	2 weeks
Medium Texture Sandy loams to light clays	5 - 40	21 days	3 weeks
Pyritic Peat	N/A	21 days	3 weeks
Fine Texture Medium to heavy clay with silty clays	≥40	28 days	4 weeks

Preparation of a temporary treatment facility

As part of the on-site treatment of ASS, a bunded treatment area with crushed limestone pad (a dedicated facility for stockpiling and treatment of soils) shall be prepared as follows:

+ An area of at least 2 m width shall be left between the treatment areas and bunds to allow collection of runoff and direction to sumps.
+ The treatment area shall be bunded using compacted low permeability materials. The bund wall shall be of sufficient height to contain and collect runoff from stockpiled materials. the treatment pad should be constructed from crushed limestone (minimum of 300 mm in thickness).
+ Bunds will be constructed to allow collection of run-off directed to sumps (shallow drains may be employed to assist in directing flow to sumps). sumps shall be sized to allow containment of stormwater runoff from treatment areas with due consideration of possible treatment and discharge limitations.
+ The treatment areas shall be divided into a series of identifiable treatment lots. where possible, treatment lots should consist of the same lithological unit to allow for uniform liming rates. each treatment lot shall be large enough to treat up to 250 m^3 of material. stockpile height is not to exceed 2.5 m in height.

Liming rate

Should unexpected ASS be encountered, it is recommended that stockpiled material is sampled to enable the calculation of a suitable liming rate.

The calculation of liming rates is generally based upon a bulk density of 1.6 tonne/m^3, a safety factor of 1.5, and effective neutralising value (ENV) of 50%. The liming rate has been calculated as follows:

$$LR = \%S * \rho_{soil} * CF * SF * (\frac{100}{ENV})$$

Where:

LR = liming rate

S = percentage sulfur

ρ_{soil} = bulk density of soil (tonne/m^3) assumed at 1.6 tonne/m^3

CF = conversion factor (%S to kg pure $CaCO_3$/tonne) = 31.202

SF = safety factor of 1.5 as National Acid Sulfate Soils Guidance (2018a)

ENV = effective neutralising value

Sampling protocol

Samples should be collected for ASS field screening (pH_F and pH_{FOX}) testing on all samples, and the CRS Suite with TPA on all samples to enable Acid Base Accounting and the calculation of a suitable lime treatment rate.

The number of samples required (**Table A-3**) will be in accordance with the sampling densities as specified in National Acid Sulfate Soils Guidance, National acid sulfate soils sampling and identification method manual (Water Quality Australia, June 2018a).

Table A-3: Validation sampling numbers

Volume (m^3)	Number of samples
<250	2
251-500	3
1000	4
>1,000	4 plus 1 per additional 500 m^3

Quality Control and Assurance

A minimum of one field duplicate sample will be collected per 20 primary samples.

Validation criteria

In order to verify the success of the treatment, ASS field screening (pH_F and pH_{FOX}) shall be completed on all samples, and the SPOCAS suite shall be conducted on 25% of the total samples to confirm net acidity by Acid Base Accounting.

As per national acid sulfate soils identification and laboratory methods manual. (Water Quality Australia, June 2018a), the following verification conditions must be achieved to confirm the successful treatment of ASS material:

+ Net Acidity (Potential Acidity + Existing Acidity – Acid Neutralisation Capacity) ≤ 0
+ pH_{KCL} >6.5
+ TPA < laboratory's limit of reporting (LOR).

Additional lime treatment and further verification testing shall be conducted where adequate neutralisation is not initially indicated. Where additional treatment is required, the liming rate would be based on the results of the CRS verification results.

Validation and reuse of treated material

Upon completion of lime treatment, validation samples should be collected to confirm the successful treatment of the stockpiled ASS.

Once successful on-site treatment has been undertaken, the soil may be:

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- Used as backfill in excavated areas of the **onshore zone** of the site (in accordance with specification requirements including but not limited to embedment, compaction, and hygiene), or
- Reused on-site.

The reuse of treated ASS materials on-site must be supported by sampling and laboratory analysis (in accordance with NEPM, 2013) to confirm the material's geochemical suitability for re-use on-site (i.e., to confirm the material is not contaminated).

The reuse of treated ASS materials as backfill must not include the placement of treated ASS beneath the groundwater table; the placement of treated ASS must be at unsaturated depths only.

Treatment of excavation areas – onshore zone

Upon excavation of suspected ASS material, the walls and base of the trench should be evenly covered by a thin layer of aglime at a rate of 2 kg per linear metre.

Photographic evidence of this coverage, along with detailed written records of the amount and location of aglime application, should be kept.

This applies to the onshore zone only.

Treatment performance indicators

Table A-4 presents a summary of the performance indicators used to assess the effectiveness of treatment.

The adherence to these performance indicators should be documented throughout the treatment process for inclusion in the final ASS Closure Report.

Table A-4: Summary of ASSDMP Performance Indicators – Unexpected ASS

Item	Performance Indicator
Identification of ASS Units	+ Inspections conducted by suitably qualified person + Unexpected ASS units are identified correctly + All contractors/contractor personnel responsible for identification of ASS have received appropriate training.
Soil handling	+ ASS (or suspected ASS) has been stockpiled separately from non-ASS material + Accurate material movement records kept
Suitably prepared treatment area	+ Treatment areas to be constructed as per measures presented in this appendix (i.e., treatment pad, bunding, sump, stockpile height) + Guard layer used between pad and stockpile + Treatment areas collecting runoff efficiently with no seepage to surrounding environment (i.e., bunding, drains, sumps)
Liming rates	+ Correct liming rates are applied through mixing of lime into soil.
Lime Addition	+ Lime addition to be undertaken based on the rate to be calculated by the Environmental Consultant.
Treatment verification	+ Verification of treatment on each treated lot + Correct verification laboratory analysis used

Item	Performance Indicator
	+ If verification shows material has a positive net acidity, additional treatment has been employed.
Non-conformance	+ All non-conformances are reported and rectified.

Responsibilities

With regards to the monitoring and reporting of treatment, the Contractor's site manager shall be responsible for:

+ Ensuring the treatment areas are constructed as described above
+ Maintaining records of all materials being disposed of or treated at the site
+ Maintaining a register of the construction details of each treatment area prepared at the site including photographs
+ Ensuring laboratory analysis is carried out to verify treatment at the frequencies presented in **Table A-3**. Where soils require further treatment, the Contractor's Site Manager shall be responsible for calculating additional liming rates, submitting subsequent verification samples to a laboratory for analysis, and verifying that the results meet the neutralisation criteria
+ Maintaining a register of testing results and a record of inspections
+ Compiling a weekly summary report of all test results and inspections for submission to the Santos Project Manager.

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Appendix B: Dewatering operating strategy

The use of the term 'dewatering' refers to the removal/pumping of groundwater.

The removal and/or pumping of rainwater from excavations (where required) is not considered within this management plan.

Given the broadly-acidic state of localised groundwater at the site and the setting of the site with regards to the marine environment, **off-site discharge of acidic groundwater without treatment should not be undertaken.**

Administrative requirements

The Dewatering Operating Strategy presented in the sections below is based on National Guidance (Water Quality Australia, June 2018d) and describes how the groundwater dewatering (where required) will be managed within the site to ensure minimal impact to the environment.

This operating strategy should be reviewed by a groundwater professional upon confirmation of the extent of ground disturbance and dewatering requirements.

The groundwater potentially encountered during the proposed trenching is a superficial aquifer system. Groundwater levels in the superficial aquifer will be monitored and reviewed, during construction, by a groundwater professional.

Dewatering treatment method and materials

Table B-1 presents the dewatering effluent treatment method and neutralising agent should dewatering be required in the onshore zone.

Table B-1: Dewatering treatment method and materials

Dewatering element	Requirement
Dewatering treatment method	Automated Dosing Unit
Neutralising agent	Calcium-based neutralising agent, the use of sodium-based neutralising agents will not be permitted.

Dewatering treatment set-up

Where dewatering is undertaken, the following management procedures will be applied to the management of dewatering effluent:

+ Effluent will be pumped into a passive lime dosing (treatment) unit for the duration of the dewatering and earthworks program, to increase the pH level. Lime dosing will be manually controlled and based upon the results of monitored pH, acidity and alkalinity.
+ Treated dewater effluent discharged from the passive lime treatment unit will be directed to a settlement basin, lined by compacted limestone. Sufficient retention time will be provided to enable the precipitation of trace metals and settlement of solids from the dewatering effluent.
+ The capacity of the passive lime treatment unit and settlement basin will be maintained such that overflow does not occur to surrounding land. A small percentage of water is expected to recharge into the superficial aquifer via the settlement pond, where compacted limestone is used as a liner.

+ Treated effluent will then be directed to a bunded recharge area, constructed into in situ soils, to recharge the treated effluent to the superficial aquifer.

Figure B-1 presents the general configuration and component parts of the typical treatment system. Prior to discharging the water into a settling basin, the dewatering effluent is processed through a passive lime treatment unit. Aeration occurs upon discharge to the settling basin and is then discharged into the recharge trench/basin system.

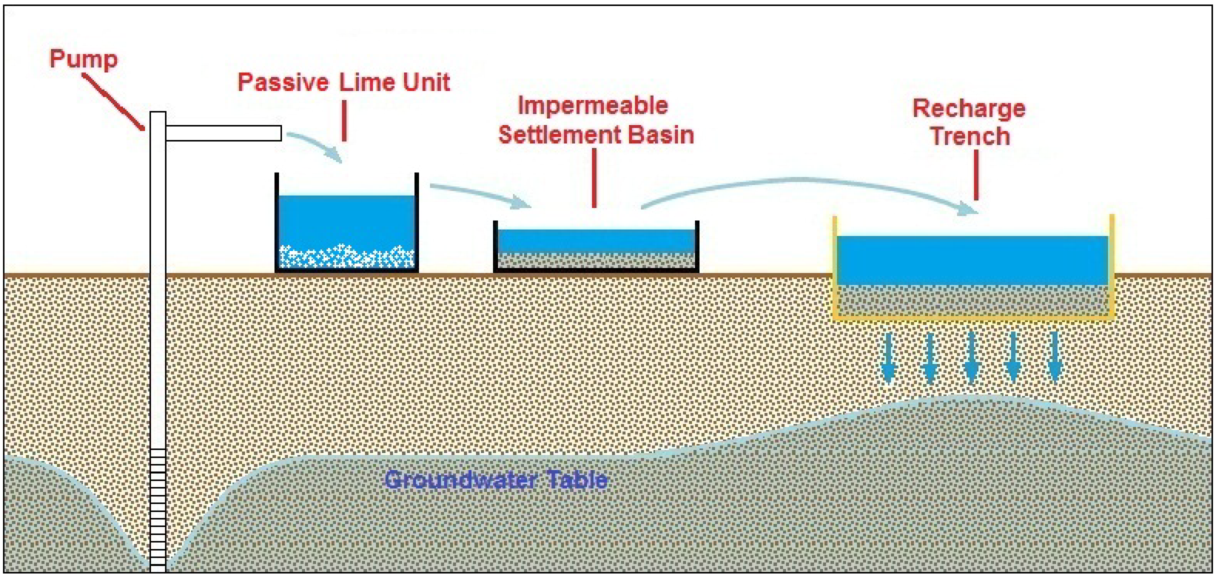

Figure B-1: Typical treatment system configuration for dewatering discharge

Should there be deterioration in the water chemistry observed at the time of construction, i.e., increase acidity and decrease in pH, then an automated lime dosing may be used in replace of the passive lime dosing unit.

Operating guidance

Table B-2: Dewatering strategy operating guidance

Dewatering element	Guidance
Criteria for Source Use	+ Potential short-term dewatering of superficial groundwater to allow the excavation of soil for the installation of the pipeline.
Dewatering Program	+ Dewatering will be limited (where required) and, if required, will be, at relatively low pumping rates, depending on the water level at the time of construction.
Timing of Pumping	+ Pumping if required will occur 24 hours a day when dewatering is required. Pumping may be temporarily suspended if dewatering is not required.
Method of Dewatering	+ The excavations are potentially to be dewatered using either groundwater spears or sump pumps. Dewater will be treated on site before being recharged to the superficial aquifer.
Abstraction Rate	+ The abstraction rate for earth works is predicted to be an average rate of 1.6 L/s, with higher initial rates.

Dewatering element	Guidance
Dewatering Effluent Treatment	+ It is recognised that the quality of abstracted dewater might differ from the monitored shallow baseline groundwater results presented in this ASSDMP. However, using the baseline data available (CDM Smith, 2021), it would appear likely that dewater would have a pH of 5.4–6.3, the total titratable acidity (TTA) will potentially exceed 40 mg/L and the alkalinity potentially be below 40 mg/L. Hence treatment for pH, acidity and alkalinity will potentially be required + Dewater treatment for pH, acidity and alkalinity correction (as necessary) would be in accordance with National Guidance, which specify that dewater having pH <6.0 and/ or TTA >40 mg/L and/or alkalinity <40 mg/L shall be subject to lime neutralisation.
Dewatering Effluent Treatment Material	+ Dewatering effluent is required to be treated with a calcium-based product.
Dewatering Effluent Disposal	+ The primary option for disposing of dewatering effluent is via recharge to the superficial aquifer.

Roles and responsibilities

The following responsibilities for the monitoring requirements, if dewatering occurs, are outlined below. Note: the baseline groundwater monitoring event is required to completed, as a contingency should dewatering occur. All formal reporting to the Regulator will be undertaken by a suitably qualified person.

Table B-3: Monitoring Roles and Responsibilities

Monitoring activity	Parameters	Responsibility
Dewatering monitoring		
Daily	+ Field analysis: pH, electrical conductivity (EC), TTA, and total alkalinity, standing water level	+ Site Contractor
Weekly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Environmental Consultant
Fortnightly	+ Laboratory: Full Dewatering Analytical Suite[1]	
Groundwater Monitoring		
Baseline monitoring event, prior to construction	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Every second day	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Site Contractor
Fortnightly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Immediately After Dewatering		
Post-Construction		
Accumulated Sediments		

Monitoring activity	Parameters	Responsibility
Upon completion of dewatering	+ Heavy metals	+ Environmental Consultant

Note

1. Total and dissolved metals, total acidity, total alkalinity, sulfate, chloride, total suspended solids (TSS), total dissolved solids (TDS), and nutrients. Field parameters including pH, EC, TTA, dissolved oxygen and redox are recorded during sampling.

All formal reporting to the Regulating Body (NT or National) will be undertaken by a suitably qualified environmental consultant.

Dewatering effluent monitoring and groundwater monitoring

Dewatering effluent monitoring:

During and following the completion of dewatering operations, monitoring will be undertaken for dewatering effluent and groundwater with reference to the applicable National Guidance (Water Quality Australia, June 2018d).

In recognition of the groundwater quality at the site, based upon the historical monitoring, the schedule for dewater having total titratable acidity (TTA) between 40–100 mg/L ($CaCO_3$ equivalents) and pH between 4–6 has been adopted and is detailed below (Table B-4). Monitoring will incorporate analysis of dewater samples collected both prior to, and following any treatment process, prior to discharge.

Table B-4: Dewatering Effluent Monitoring Program and Responsibilities

Monitoring activity	Parameters	Responsibility
Daily	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Civil Contractor
Weekly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Environmental Consultant
Fortnightly	+ Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant

Note:

1. Total and dissolved metals, total acidity, total alkalinity, sulfate, chloride, cations, total suspended solids (TSS), total dissolved solids (TDS), and nutrients. Field parameters including pH, EC, TTA, dissolved oxygen and redox are recorded during sampling.

Upon the commencement of works, the quality of the pre-treatment dewatering effluent will be assessed, and the monitoring regime amended, if required, in line with National Guidance (Water Quality Australia, June 2018d).

Groundwater monitoring:

Per National Guidance (Water Quality Australia, June 2018d), a minimum of three groundwater bores will be monitored during the works: this will require wells from the wider DLNG Facility monitoring network to be monitored.

Based upon a review of the existing well monitoring network, the proposed monitoring wells are as follows:

+ BH5
+ BH6
+ BH7.

The location of these wells is presented below.

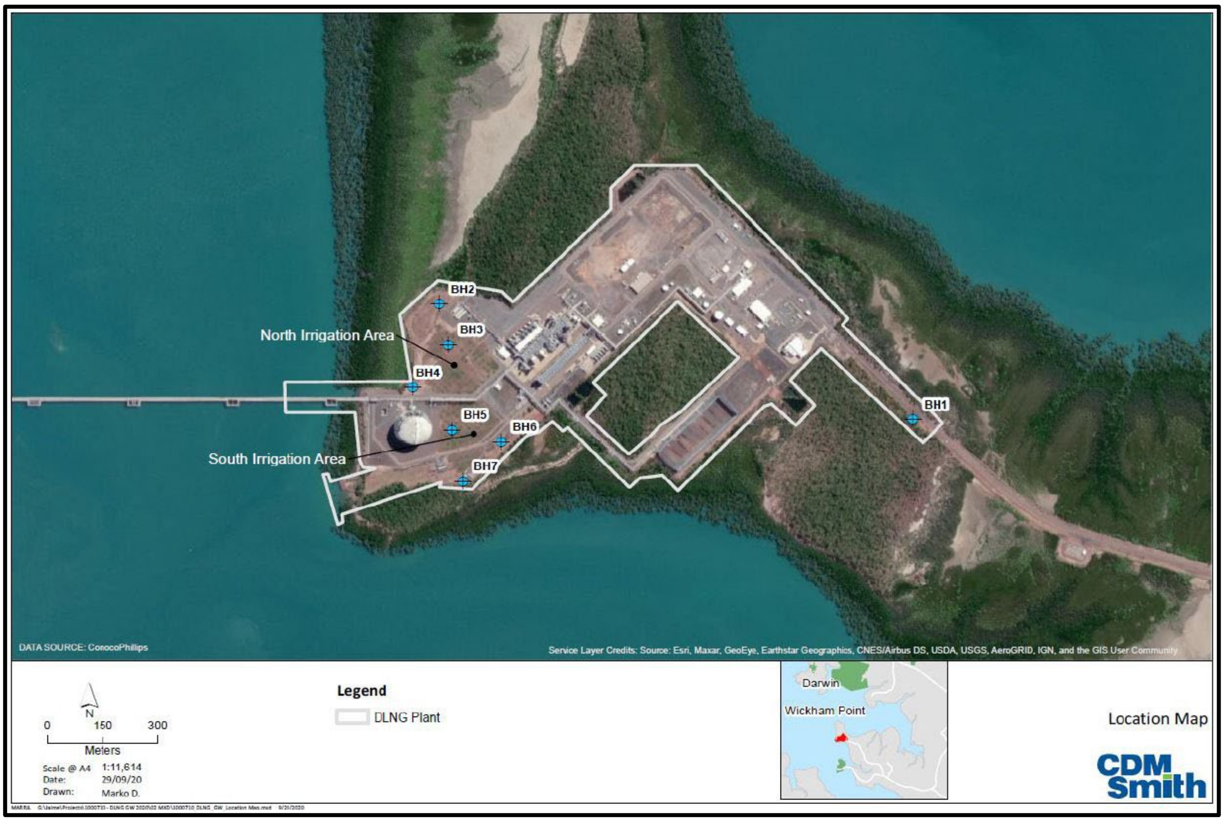

Figure B-2: Aerial image of the DLNG Facility groundwater monitoring well network (Image source: CDM Smith, 2021)

The monitoring schedule will comprise:

Table B-5: Groundwater Monitoring Program and Responsibilities

Monitoring activity	Parameters	Responsibility
Baseline monitoring event	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Every second day	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Civil Contractor
Fortnightly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Immediately after dewatering		
Post-dewatering monitoring		

Note:

1. Total and dissolved metals, total acidity, total alkalinity, sulfate, chloride, cations, total suspended solids (TSS), total dissolved solids (TDS), and nutrients. Field parameters including pH, EC, TTA, dissolved oxygen and redox are recorded during sampling.

Should dewatering be required for greater then four weeks in total, groundwater will be collected every second month for six months (three sampling events) from the groundwater monitoring network for

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the full ASS groundwater laboratory suite. Post-construction monitoring will commence once all dewatering works for the site has been completed.

Methodology:

Where possible for the groundwater monitoring events, groundwater samples submitted for laboratory analysis will be recovered using a low-flow bladder pump in accordance with USEPA (1996) guidance (as referenced by Australian Standard, AS/NZS 5667.11:1998). Low-stress (low-flow) purging and sampling is recommended by VEPA (2000) as samples returned are considered to be most representative of aquifer conditions, as disturbances that affect inorganic and organic contaminants are minimised.

Prior to sampling, groundwater will be purged to stability (reference parameters being pH, EC, DO, redox and temperature), measured using electronic probes. Groundwater samples will then be collected into appropriately preserved laboratory supplied containers (being field filtered for dissolved metals, as applicable). All groundwater samples will be chilled and submitted to the primary NATA accredited laboratory, for analysis within 24 hours of collection.

Quality control:

Quality control samples will be collected during each groundwater monitoring event, including a field duplicate, equipment rinsate and field blank. The full analytical suite will be conducted on the duplicate with the total and dissolved metals only from the aforementioned suite conducted on the rinsate and blank.

Water quality reference and trigger criteria

Groundwater level (drawdown) triggers:

Groundwater level triggers (below) are developed to control the depth of groundwater extraction across the site, and thereby to manage the dewatering of PASS soils.

The basis for setting the trigger levels is defined below:

+ The estimated maximum dewatering drawdown at the bore, in addition to a tolerance of 0.2 m (modelled tolerance).
+ At least three nominated groundwater monitoring wells will be monitored during the installation of the pipeline, with additional bores installed where required by the environmental consultant (e.g. should existing wells be damaged or destroyed or if monitoring indicates additional bores are required). These nominated groundwater wells will include three monitoring wells located near the site as part of the DLNG Facility monitoring network, namely: BH5, BH6, and BH7.
+ The depth to groundwater in the monitor bores and the groundwater level determined prior to the commencement of earthworks, and based upon the estimated maximum dewatering drawdown at the bore, in addition to a tolerance of 0.2 m, the drawdown triggers revised where required.

Dewatering effluent and groundwater quality reference criteria:

The criteria nominated below are consistent with targets established in National Guidance literature and have been standardised across all bores. It is noted that ASS criteria had exceeded the guidelines during the DLNG routine groundwater monitoring. It can therefore be expected that these reference criteria will likely be exceeded during the construction program.

The reference criteria will serve as a value, against which contingency responses would be considered, when taken in the wider context of "monitored data trends" over time, i.e., trends identifying deteriorating conditions.

The bore reference criteria for all bores are as follows:

+ Minimum pH: 6.0 pH units.
+ Maximum total acidity: 40 mg/L ($CaCO_3$ equivalents).
+ Maximum dissolved aluminium: 1 mg/L.

Dewatering effluent discharge reference criteria:

Presented below is a summary of the dewatering discharge criteria for groundwater dewatering effluent, as specified in National Guidance (WQA, 2018d).

Table B-6: Dewatering effluent quality

Analyte	Discharge Reference Criteria
Acidity	<40 mg/L ($CaCO_3$ equivalents)
pH	7.5 to 8.0 pH units
Alkalinity	>30 mg/L ($CaCO_3$ equivalents)

Contingency responses

The contingency responses provided below are examples of operating measures that can and may[1] be applied where water quality/levels in the receiving environment is compromised. The approach to determining a contingency response is based upon identifying, managing and addressing the specific cause of the water quality impact.

Groundwater pH and drawdown:

Where the drawdown triggers or pH refence criteria are exceeded, the following contingency measures may be implemented in consultation with the Regulator:

+ Monitoring frequency increased to daily.
+ The addition of a comprehensive suite of groundwater monitoring at an appropriate frequency may be required where dewater discharge varies significantly from pre-dewatering conditions.
+ Pumping rates may be reduced.
+ The area under abstraction at any one time may be reduced.
+ The groundwater recharge infrastructure may be modified.
+ Where a reduction in pumping rate or area under abstraction does not abate drawdown, pumps shall be suspended to allow groundwater levels to recover above the nominated trigger thresholds, unless otherwise agreed with the Regulator / project engineers.

Dewatering discharge:

[1] The word "may" is used because more than one appropriate response might apply. In any case, where a breach occurs, the incident would be reported to the Regulator and advice given and received regarding the appropriate course of action to take.

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Where the dewatering effluent discharge reference criteria (Table B-6) are exceeded, the following contingency measures may be implemented in consultation with the Regulator:

+ Increased liming of dewater, and or adjustment/enhancement of existing infrastructure.
+ Pumping rates decreased.
+ Reducing the area under abstraction.
+ Modifications to the settlement basin infrastructure to promote improved settling, and precipitation of metals.

Dewatering management:

The dewatering settlement and infiltration infrastructure should be maintained in such a state to ensure the integrity of the ponds, and all dewater is contained within the ponds.

Where the integrity of the ponds is compromised and or effluent is not contained within the ponds, the following measure may be implemented in consultation with the engineers and regulators (if necessary):

+ Reduce pump rates or cease all dewatering.
+ Reduce the area under abstraction.
+ Modifications to the settlement and infiltration pond infrastructure to ensure all dewater is contained in bunded areas. This may include the addition of extra ponds, increasing the area of the bunded infiltration and or utilising storage bladders to allow slower infiltration rates.
+ Pumping of effluent from the settlement pond to the infiltration area. Any pumping should be minimal and pumping occurring the furthest distance from any treatment (i.e., lime dosing) as possible.

Where any breaches occur, the environment/groundwater consultant and engineer are required to be notified immediately and the aforementioned contingency measures implemented under direction from the Regulator.

Appendix 13: Stakeholder Engagement Plan (SEP)

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Darwin Pipeline Duplication (DPD) Project – Stakeholder Engagement Plan

PROJECT / FACILITY	DPD
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	Owner	Reviewer/s Managerial/Technical/Site	Approver	Date
0	Barossa Stakeholder Adviser	Barossa Environmental Approvals Adviser	Barossa HSE Manager	8 December 2021
1	Barossa Stakeholder Adviser	Barossa Environmental Approvals Adviser	Barossa HSE Manager	17 March 2023

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Contents

1	**Introduction**	**3**
1.1	Purpose	3
1.2	Outcomes and Objectives	3
1.3	Regulatory Requirements	4
2	**Engagement Approach**	**5**
2.1	Overview of Approach	5
2.2	Principles for Project Engagement	5
2.3	Engagement Undertaken to Date	6
3	**Stakeholder Analysis**	**7**
3.1	Approach to Analysis	7
3.2	IAP2 Core Values	7
3.3	Stakeholder Groups	7
3.4	Level of Engagement	8
3.5	Identification of Potential Concerns and Opportunities	9
3.6	Level of Engagement and Activities	12
3.7	Monitoring and Evaluation	13
4	**Stakeholder Engagement Program**	**14**
5	**References**	**23**

Tables

Table 3-1:	IAP2 Levels of Engagement	9
Table 3-2 :	Potential concerns and opportunities that may be experienced by stakeholders during the project lifecycle	10
Table 3-3:	Different depths of engagement / communication	12
Table 4-1	Engagement Program	15

Appendices

Appendix 1 Stakeholder List

Appendix 2 Consultation Register

1 Introduction

1.1 Purpose

On 8 December 2021, Santos submitted a referral form and supporting information to the NT EPA for the activities required to construct and operate a 100 km gas export pipeline segment in NT waters and lands (Darwin Pipeline Duplication Project).

The NT EPA published a statutory notice on 18 January 2022 inviting public comment on the submitted referral form and supporting information. The initial version of this Stakeholder Engagement Plan (SEP) was amongst the supporting documentation provided for public comment.

On 7 April 2022 the NT EPA published a Notice of Decision and Statement of Reasons advising that the method of environmental impact assessment for the DPD Project would be via a Supplementary Environmental Report (SER) that responds to submissions received on the referral and provides any additional information required by the NT EPA.

The submitted SER includes a high-level summary of Santos' engagement process (**Section 4**) while Section 5 summarises the key issues raised in submissions by stakeholders and the responses and actions taken by Santos as a result. An updated version of the Stakeholder Engagement Plan (this document) is also provided as Appendix 13.

The Stakeholder Engagement Plan (SEP) has been updated to include information on all consultation that has been undertaken by Santos since submittal of the initial referral and after the public comments were provided to Santos by the NT EPA. It also provides additional information on Santos' ongoing plan to communicate and consult with stakeholders during the remainder of the NT EPA assessment process, including the further public comment period, and during the lead-up to and execution of the proposed activities.

The SEP creates a structured process of engagement to guide Project team members on their engagement and enable Santos to articulate its commitments clearly and transparently to Government, community and other stakeholders.

The SEP enables Santos to build an understanding of stakeholder values and concerns by creating meaningful opportunities for stakeholder participation from the early stages of preparation for the Project environmental referral.

1.2 Outcomes and Objectives

1.2.1 Outcomes

Engagement for the Project is focused on achieving the following outcomes:

+ All identified key stakeholders are appropriately informed of the Project;
+ Stakeholders are provided with meaningful opportunities for consultation on the Project;
+ Traditional Owners are provided opportunities for meaningful engagement and their culture and values respected; and

- The Project specific environmental assessment has been actively informed by the input and feedback received from stakeholders.

1.2.2 Objectives

The SEP aims to achieve outcomes by:

- Creating a structured process focused on:
  - Building trust and mutual understanding between Santos and Project stakeholders
  - Addressing statutory stakeholder consultation requirements
  - Meaningfully engaging with stakeholders, specifically with regards to the environmental assessment and approvals process.
- Providing opportunities for Santos to understand stakeholder values and expectations;
- Embedding the importance of using local contractors and employees as much as possible throughout the Project;
- Ensuring that Traditional Owners and Indigenous groups are engaged in the appropriate manner;
- Securing stakeholder feedback that will be used as input for the environmental assessment process and to inform Santos' longer-term activities and community involvement; and
- Aligning with Santos' Corporate approach to stakeholder engagement.

1.3 Regulatory Requirements

As per the NT EPA environmental impact assessment guidance, proponents are responsible for undertaking stakeholder engagement and consultation from the earliest stage of the environmental impact assessment process and continuing throughout the process.

Santos is required to provide details of any stakeholder engagement and consultation undertaken to meet the requirements of section 43 of the EP Act and outline how this consultation has informed the assessment, including the environmental impact assessment, identification and management of impacts, and selection of offsets. Section 43 of the EP Act provide the general duty of proponents and states the following with regard to stakeholder consultation:

A proponent of an action has the following general duties under an environmental impact assessment process:

a. To provide communities that may be affected by a proposed action with information and opportunities for consultation to assist each community's understanding of the proposed action and its potential impacts and benefits;

b. To consult with affected communities, including Indigenous communities, in a culturally appropriate manner; and

c. To seek and document community knowledge and understanding (including scientific and traditional knowledge and understanding) of the natural and cultural values of areas that may be impacted by the proposed action."

2 Engagement Approach

2.1 Overview of Approach

Santos is committed to undertaking projects in a manner that will both deliver on regulatory requirements and engage and contribute to the communities in which it operates. More broadly, Santos is focused on understanding and integrating those matters that will ensure the long-term outcomes aspired to by relevant stakeholders. The key focus will be on:

+ Governance and systems frameworks to support the business operations and how Santos works with stakeholders;
+ The formation of long-term, meaningful relationships and partnerships with stakeholders;
+ Alignment with relevant Northern Territory standards regarding stakeholder impact assessment, management and social investment; and
+ An active risk management approach and a focus on creating longer term value for the communities where Santos operates.

2.2 Principles for Project Engagement

In developing its approach for project engagement, Santos has referred to industry leading standards and practice including the Northern Territory Stakeholder Engagement and Consultation guidance (NT EPA, 2021a), Northern Territory guidance for preparing an environmental impact statement ((NT EPA, 2021b), the International Association for Public Participation's (IAP2) Quality Assurance Standard For Community and Stakeholder Engagement (IAP2, 2015) and relevant International Finance Corporation guides (IFC, 2007).

The NT EPA guidance related to stakeholder consultation focuses on an ongoing process of stakeholder engagement that involves building relationships, actively sharing information, and bringing stakeholder voices into decisions that may affect or interest them. The Project SEP has been prepared with this outcome as a key focus.

As outlined above, Santos actively builds community investment into its overall business and planning process. Engagement for this Project will be based on the following key principles:

+ Focusing on achieving genuine outcomes for communities;
+ Providing a flexible and proactive approach;
+ Being visible and transparent;
+ Where investment in communities is undertaken, supporting projects that encourage community self-sufficiency and sustainability; and
+ Enhancing social return on investment through strategic reviews of outcomes.

To achieve engagement objectives and outcomes it is important to define and explain the parameters of the Project including decisions that have already been made, decision-making processes and governance structures, statutory obligations and regulatory requirements.

When Santos engages with stakeholders it is important that there is clarity regarding what can and cannot be influenced with regards to the Project. This is particularly important in terms of managing stakeholder expectations. The following points provide a frame of reference for what can and cannot be influenced.

2.3 Engagement Undertaken to Date

Santos has undertaken engagement throughout the Project planning and formal assessment period. Engagement has occurred with key stakeholders, including government agencies, representative industry and community bodies, regular Harbour users and the Port of Darwin where a significant portion of the project activities will be undertaken. A summary of the consultation undertaken by Santos to date is provided in **Appendix 2**.

3 Stakeholder Analysis

3.1 Approach to Analysis

The analysis of stakeholders has been undertaken with a focus on understanding stakeholder values, understanding concerns and opportunities arising from the Project, and understanding potential impacts, risks, and levels of interest and influence. The intent of this initial analysis is to provide Santos with the foundation through which to inform the referral and continue engagement as the Project develops.

3.2 IAP2 Core Values

Stakeholder values are an important frame through which to understand what may be of importance. In accordance with the NT EPA stakeholder engagement and consultation guidelines, consultation will be guided by the principles of engagement, based on stakeholder level of interest and concern as outlined by the. The IAP2 core values for practicing public participation and community engagement are:

1. Public participation is based on the belief that those who are affected by a decision have a right to be involved in the decision-making process;
2. Public participation includes the promise that the public's contribution will influence the decision;
3. Public participation promotes sustainable decisions by recognising and communicating the needs and interests of all participants, including decision makers;
4. Public participation seeks out and facilitates the involvement of those potentially affected by or interested in a decision;
5. Public participation seeks input from participants in designing how they participate;
6. Public participation provides participants with the information they need to participate in a meaningful way; and
7. Public participation communicates to participants how their input affected the decision (IAP2 2014).

The purpose of these core values is to help make better decisions which reflect the interests and concerns of potentially affected people and entities (IAP2 2014).

3.3 Stakeholder Groups

A full list of currently identified stakeholders for the Project is provided in **Appendix 2**.

It is to be acknowledged that this is an initial list and as the SEP is implemented, further categories, stakeholders and more specific stakeholder details will be added.

3.4 Level of Engagement

The Project consultation associated with the referral and subsequent phases of the Project will be in accordance with the IAP2 principles to determine the appropriate levels of engagement (IAP2 2015). As the Project progresses, the level of engagement will be identified and determined on a case-by- case basis and certain stakeholders may be involved and collaborate on aspects of the Project.

Stakeholder engagement is an essential component in the process of assessing the Project’s social, economic and environmental impact.

For the purpose of managing the level of engagement with stakeholder, stakeholders have been grouped as follows:

+ Level 1: Landholders, Indigenous Stakeholders or Traditional Owners, surrounding tenure holders, operating licence holders (e.g. fishing tourism, industry) and Government;
+ Level 2: Key interest groups and local communities;
+ Level 3: General public, community and special interest groups, wider region and Territory - based organisations.
+ Approaches or requirements that must be implemented due to statutory obligations and regulatory requirements.

Table 3-1 provides the IAP2 spectrum’s level of engagement and Santos’ relevant approach at each level. For Level 3 stakeholders the level of participation for this Project is anticipated to be inform and consult, for Level 2 stakeholders inform, consult and involve, and for Level 1 stakeholders, collaboration is anticipated.

The stakeholders’ ability to influence decisions depends on the decision type and what aspects of the Project are negotiable and what aspects are non-negotiable (IAP2 2015). The process is intended to be flexible and open to including relevant stakeholders to the maximum extent possible, while maintaining focus on targeted engagement where it makes sense.

Table 3-1: IAP2 Levels of Engagement

Level of Engagement	Stakeholder Level	Approach to the Community and Stakeholders
Inform	1, 2 and 3	Santos will aim to keep stakeholders informed
Consult	1, 2 and 3	Santos will keep stakeholders informed, listen to and acknowledge concerns and aspirations, and provide feedback on how stakeholder input influenced the decision.
Involve	1 and 2	Santos will work with stakeholders to ensure that their concerns and aspirations are directly reflected in the assessment completed and control measures employed and provide feedback on how stakeholder input influenced decision.
Collaborate	1	Santos will look to stakeholders for advice and innovation in formulating solutions and incorporate their advice and recommendations into the decisions to the maximum extent possible.
Empower	1	Santos will implement relevant stakeholder decisions where appropriate and feasible.

Amended from IAP2 2015

3.5 Identification of Potential Concerns and Opportunities

Potential concerns and opportunities that may be experienced by stakeholders during the lifecycle of the project have been outlined in **Table 3-2** below. The purpose of this identification is to understand stakeholder perspectives on what may be of concern to them regarding the project so that Santos can understand potential impacts to stakeholders and what may trigger potential risks.

Understanding stakeholder concerns and their view regarding potential impacts (both actual and perceived) means that Santos can tailor why and how it engages with stakeholders and control the key messages that are communicated. This is also critical to understanding potential stakeholder risks, which in many cases are driven by perceptions stakeholders have of things that are important to them and may often be emotive and subjective. Often these perceptions may not be 'actual impacts' or supported by technical studies but it is critical to understand these.

Table 3-2 is an initial identification of potential concerns and opportunities and as such must be re- visited once Santos has undertaken more detailed engagement with stakeholders during the life of the Project. It is important that as part of this, environmental concerns and opportunities are identified as these are often key areas of interest for stakeholders.

Although this SEP is focused on the pre-construction lifecycle phase, potential concerns and opportunities have been identified across the project lifecycle as these perceptions and potential impacts will influence how stakeholders need to be engaged from the beginning of the project.

Table 3-2 : Potential concerns and opportunities that may be experienced by stakeholders during the project lifecycle

Project Phase	Potential concerns (perceived or actual)	Potential opportunities (perceived or actual)
Pre-construction (includes approvals)	+ Potential contamination of water or land from access for surveys + Potential introduction of invasive species from access for surveys + Potential direct mortality of fauna from vessel/vehicle access + Potential to disturb unidentified Indigenous and non- Indigenous cultural heritage items through initial surveys and investigations + Potential for minor rubbish from initial investigative surveys and site investigations	+ Surveys build understanding of activities likely to be impacting greater regional environment + Build understanding of the fauna condition and habitat values + Protection of fauna habitat due to any offsetting + Increased training and employment opportunities improving capabilities and skills in local and regional areas + Increase in local and regional socio-economic conditions + Opportunities for local suppliers and contractors + Employment and business opportunities for Indigenous community members
Construction (construction of the Project)	+ Potential water quality impacts, resulting from disturbance, accidental pollutant and contaminant releases + Exposure of soil to erosive factors during earthworks + Potential contamination of water or land through contaminant release (e.g. diesel leakage) + Site clearance and resulting environmental impact + General interference to the activities of other users of the marine environment + Disturbance to habitat connectivity + Excessive noise during construction potentially leading to species fragmentation	+ Data from monitoring health of water resources during construction + Greater understanding of ecological environment due to any ongoing Project investigations + Management and protection of fauna habitat + Increased training and employment opportunities improving capabilities and skills in local and regional areas + Increase in the local and regional socio-economic conditions + Opportunities for local suppliers and contractors + Employment and business opportunities for Indigenous community members

Project Phase	Potential concerns (perceived or actual)	Potential opportunities (perceived or actual)
	+ Artificial light spill on the environment potentially disturbing and altering behaviour of a range of species + Visual amenity impacts + Potential for inappropriate behaviour of contractors and employees + Potential disturbance of unidentified Indigenous and non-Indigenous cultural heritage (despite cultural heritage clearance)	+ Protection of any identified items of cultural heritage significance
Operations (Note: majority of listed concerns relate to the resulting ongoing operation of the DLNG facility)	+ Potential water quality impacts, resulting from watercourse disturbance, accidental pollutant and contaminant releases + Potential contaminant release (e.g. diesel leakage) + Disturbance to habitat connectivity + Potential spread and introduction of weeds during operation + Potential fire leading to destruction of habitat + Site clearance and resulting environmental impact + Potential for inappropriate behaviour of personnel + Potential disturbance of unidentified Indigenous and non-Indigenous cultural heritage (despite cultural heritage clearance) + Potential increase in local waste volumes during operation + Potential water and land contamination	+ Management and protection of remaining flora on site + Greater understanding of ecological environment due to any ongoing Project investigations + Management and protection of fauna habitat remaining on site + Potential to provide visual amenity management measures + Increased training and employment opportunities improving capabilities and skills in local and regional areas + Increase in the local and regional socio-economic conditions + Opportunities for local suppliers and contractors + Employment and business opportunities for Indigenous community members + Protection of any identified items of cultural heritage significance
Decommissioning	+ Loss of jobs and employment (Note: the majority of risks listed above for construction and operations would also apply for decommissioning work)	+ Rehabilitation of the Project site and habitat + Potential re-use of Project components

3.6 Level of Engagement and Activities

Based on the analysis above, the following levels of engagement have been identified for stakeholder groups. These levels are based on the principle that engagement will be tailored by considering levels of stakeholder impact, interest and influence, and risk – with the assumption that the higher the level of impact and risk – the deeper the level of engagement required. This approach needs be flexible based on each specific stakeholder group and potential changes in stakeholder expectations and risk. Description of engagement levels and example activities are provided in **Table 3-3**.

Table 3-3: Different depths of engagement / communication

Level of engagement	Description	Example Activities
General	+ General provision of project information and updates (this includes overview of potential impacts and mitigation / management strategies) + Opportunities to provide feedback through general activities and communication mechanisms (e.g. via website, email, as part of statutory consultation approach) + Audience: all stakeholders have access to information and activities	+ Website + Project information sessions + Media releases + Public consultation process
Targeted	+ Targeted engagement and communications specific to stakeholder group + Targeted engagement and communication activities designed to gain specific feedback + Ongoing opportunities to provide feedback and discuss key project elements (e.g. how potential impacts to a specific value could be managed) + Audience: while information may or not be publicly available activities are targeted towards specific group of stakeholders and are generally not open to 'general public'	+ Targeted group briefings or presentations + Targeted group or individual meetings + Targeted information portal e.g. ICN + Access to all general activities
Individualised	+ Engagement and communications developed for needs and expectations of specific stakeholder + Focus on gaining specific feedback and input from individuals / small group of individuals + Information in the form it was provided only + accessible to specific party with which it was shared e.g. while a Minister may be provided + information about jobs etc. that is available to the public the content of the conversation will be confidential	+ One-on-one meetings focused on specific topic of interest for both parties + Negotiation of formal contract or partnership (e.g. supplier agreement) + Shared value definition workshop / partnership + regarding social investment + Personalised email / phone conversations

Level of engagement	Description	Example Activities
Regulatory	+ Ongoing interaction with the regulator. This will be tailored depending on agency roles + More structured and individualised engagement will occur with lead agency + Ongoing opportunities to provide feedback	+ Structured meetings and communication schedule with lead agency + One-on-one / group meetings as required + Ongoing email and phone communication as required

3.7 Monitoring and Evaluation

Santos will maintain a stakeholder management register to record external stakeholder interactions for the Project (pre-construction, construction, operation). It is important that this register is updated by all team members following engagement activities so these can be monitored and any stakeholder concerns or opportunities followed up. This is particularly important for the approvals process as records of engagement activities need to be summarised and provided as part of approvals documents to demonstrate adequate engagement has been undertaken.

From a risk management perspective, this is also important for Santos as/if issues arise there is a formal record of engagement that has been undertaken, and how these issues have been closed out as appropriate. If Santos undertakes broader sustainability reporting at a corporate level, these types of records can also be drawn on to align with Corporate.

With regards to monitoring the effectiveness of this plan, the implementation will be reviewed quarterly. The plan should be revised, including the stakeholder analysis, prior to the commencement of each Project stage to incorporate lessons learned, stakeholder feedback and evolving issues, opportunities and risks that may have arisen.

Any review should consider the following:

+ Feedback from the regulator, external stakeholders, Santos employees and contractors;
+ Any complaints or findings from audit, review and inspections;
+ The outcomes of any incidents and how they can be managed / mitigated in the future;
+ Changes in Santos organisation structures, roles and responsibilities; and
+ Changes in regulation and guidelines that may impact engagement expectations of the regulator and community.

4 Stakeholder Engagement Program

The following engagement program establishes the activities to be undertaken and key project milestones. All engagement undertaken for the Project to date is summarised in the register located in **Appendix 2**.

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Table 4-1 Engagement Program

Stage	Aims and Activities	Deliverables	Status
Stage 1 – Preparation of Referral prior to submittal to NT EPA October to December 2021	Aims: Advise stakeholders of proposed DPD activities and regulatory assessment process and discuss key issues/concerns to inform preparation of referral Key activities: + Initial engagement with NT regulators (EPA, DEPWS, DIPL, DITT) and key stakeholders representing other users of the marine environment + Notification to all identified stakeholders on submittal of referral and ongoing opportunity to engage with Santos + Initial engagement with Commonwealth Waters regulator (DCCEEW) to discuss EPBC Referral process. + Ongoing engagement with potential suppliers via ICN NT	+ Total of 40 stakeholder meetings held + Email, phone contact + Distribution of fact sheet via email + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statements issued	Complete
Stage 2 – Public Comment Period on Referral and ongoing engagement awaiting NT EPA decision January to March 2022	Aims: To ensure stakeholders are aware of opportunity to comment on referral documentation, respond to requests for further information and continue to gather information on issues/concerns. Key activities: + Engagement with NT EPA (via DEPWS) on referral contents and public comment process + Notification to all identified stakeholders of availability of referral documents for public comment + Engagement with stakeholders (e.g. Paspaley Pearling, AFANT) responding directly to Santos on issues/concerns related to the referral + Continued engagement with NT Government agencies and private organisations on technical issues, secondary project approvals (e.g.	+ Total of 22 stakeholder meetings held + Email, phone + Distribution of project update via email + Publication of Referral documentation on NT EPA website + Notification via email of public comment period + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statements issued	Complete

Stage	Aims and Activities	Deliverables	Status
	planning permits, pipeline licences, waste discharge permits) and collaborative opportunities + Engagement with the Aboriginal Areas Protection Authority (AAPA) on the process for obtaining a Clearance Certificate for the proposed Operational Area, including independent consultation with indigenous Traditional Owners and Representative Bodies + Ongoing engagement with potential suppliers via ICN NT + Continued engagement with Commonwealth Waters regulator (DCCEEW) to discuss EPBC Referral process.		
Stage 3 – Preparation of SER prior to submittal to NT EPA April 2022 to January 2023	Aims: To ensure all issues/concerns raised by stakeholders are addressed in the SER; ensure additional stakeholders identified are provided opportunity to engage with Santos; seek specific information from stakeholders on future communication and consultation activities. Key activities: + Engagement with NT EPA (via DEPWS) on public and government agency submissions, process for preparation of SER and provision of additional information required + Engagement with government and other stakeholders to discuss issues/concerns raised in submissions and inform Santos' responses to be provided in SER + Wider engagement with other stakeholders identified in submissions or during meetings/communications + Project update to all identified stakeholders on regulatory assessment process and progress + Engage with community and indigenous organisations on opportunities to support/collaborate associated directly with project activities (e.g. Larrakia Rangers) or community-based activities	+ Total of 53 stakeholder meetings held + Email, phone + Distribution of project update via email + Publication of public and government submissions on NT EPA website + Referral documentation on NT EPA website + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statement issued	Complete

Stage	Aims and Activities	Deliverables	Status
	+ With Indigenous Groups and Representative bodies, via Santos and AAPA, to gather information and provide forums for further discussions to allow Traditional Owners and Custodian the opportunity to provide input and gain clarification. + Continued engagement with Commonwealth Waters regulator (DCCEEW) to discuss EPBC Referral process + Continued engagement with NT Government agencies and private organisations on technical issues, secondary project approvals and/or collaborative opportunities + Ongoing engagement with potential suppliers to the project via ICN NT		
Stage 4 – Public Comment Period on SER and ongoing engagement awaiting final NT EPA decision Q2/3 2023	Aims: Ensure all issues/concerns raised by stakeholders during the assessment process have been addressed; as many additional stakeholders as possible have been identified; all stakeholders are aware of the final decision and opportunities to further engage with Santos. Key activities: + Engage with DEPWS and stakeholders on additional issues/concerns raised during public comment period. + Continued engagement with NT Government agencies and private organisations on technical issues, secondary project approvals and/or collaborative opportunities. + Notification to all stakeholders re assessment outcome and conditions placed on Project; progress on approved activities and required associated approvals; stakeholder communication and consultation process going forward.	+ Stakeholder meetings + Presentations at stakeholder events (see potential list below) + Email, phone communication + Distribution of project update via email + Publication of SER documentation on NT EPA website + Notification via email of SER public comment period + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statements	Pending

Stage	Aims and Activities	Deliverables	Status
	+ Continued engagement with NT Government agencies and other relevant stakeholders for all secondary project approvals that are required prior to activities commencing + Engage with indigenous organisations on outcomes from AAPA investigation and Clearance Certificate conditions + Continued engagement with community and indigenous organisations on opportunities to support/collaborate associated directly with project activities (e.g. Larrakia Rangers) or community-based activities + Engage with key contractors to be undertaking activities on Santos' behalf and owners of land upon which activities will occur (e.g. Darwin Port, DIPL- East Arm, DLNG, Wickham Point Deed Reference Group, Mount Bundy) + Ongoing engagement with potential suppliers via ICN NT + Ongoing engagement with the following stakeholders on specific issues raised: – Opportunities for collaboration on dredging-related activities – NT DIPL, Inpex, Department of Defence – Pipelay activities within Reef Fish Protection Area – NT DITT – Fisheries, AFANT, NTSC – Indigenous consultation resulting from AAPA Clearance Certification – AAPA, NLC, Wickham Point Deed Reference Group, other identified Larrakia stakeholders – Opportunities for collaboration on environmental studies and modelling – NT DPEWS, Inpex, Darwin Harbour Advisory Group, Larrakia Rangers – Road traffic management – NT DIPL		

Stage	Aims and Activities	Deliverables	Status
	– Darwin Harbour impacts management – NT DIPL, Darwin Port, DHAC, Tourism NT, Top End Tourism, AFANT, NTGFIA		
Stage 5 – Lead-up to execution of activities Q4 2023	Aims: Ensure all identified stakeholders are aware of pending activities, timeframes, how issues/concerns have been mitigated/are being managed, how complaints will be handled and ongoing communications process and contact points. Key activities: + Continued engagement with NT Government agencies and private organisations on technical issues and/or collaborative opportunities. + Continued engagement with NT Government agencies and other relevant stakeholders for all secondary approvals associated with the Project and required prior to activities commencing + Notification to all stakeholders re proposed activities, schedule stakeholder communication and consultation process going forward. + Ongoing engagement with potential suppliers via ICN NT + Engage with key contractors who will be undertaking activities on Santos' behalf and the owners of land upon which activities will occur (e.g. Darwin Port, DIPL- East Arm, DLNG Management, Wickham Point Deed Reference Group) + Ongoing engagement with the following stakeholders on specific issues raised: – Opportunities for collaboration on dredging-related activities – NT DIPL, Inpex, Department of Defence – Pipelay activities within Reef Fish Protection Area – NT DITT – Fisheries, AFANT, NTSC	+ Stakeholder meetings + Presentations at stakeholder events (e.g. Darwin Port Users Group, Darwin Harbour Advisory Committee, Top End Tourism, Tourism NT, NT Chamber of Commerce, NT Energy Club) + Email, phone communication + Distribution of project update via email + Distribution of project fact sheets via email and stakeholder meetings + Distribution of project information via third parties (e.g. Darwin Port, Tourism NT) to their membership + Distribution of project information via paid advertorial in NT News + 24-hour telephone line available for stakeholder queries + Information posted to Santos website + Project page on ICN Gateway website + Santos ASX and media statements	Pending

Stage	Aims and Activities	Deliverables	Status
	– Indigenous consultation resulting from AAPA Clearance Certification – AAPA, NLC, Wickham Point Deed Reference Group, other identified Larrakia stakeholders – Opportunities for collaboration on environmental studies and modelling – NT DPEWS, Inpex, Darwin Harbour Advisory Group, Larrakia Rangers – Road traffic management – NT DIPL, other stakeholders identified – Darwin Harbour impacts management – NT DIPL, Darwin Port, DHAC, Tourism NT, Top End Tourism, AFANT, NTGFIA		
Stage 6 - Execution of activities in NT Waters Commencing Q1, 2024	Aims: To help ensure safe use by all users of locations where project activities are occurring. Ensure all identified stakeholders are kept regularly informed of aware of progress on current activities, pending activities, timeframes, how issues/concerns have been mitigated/are being managed, how complaints are being handled and ongoing communications process and contact points. Key activities: + Continued engagement with NT Government agencies and private organisations on technical issues and/or collaborative activities. + Continued engagement with NT Government agencies and other relevant stakeholders for the safe and efficient compliance of all secondary approvals (e.g. road traffic management, waste discharges, licence conditions) associated with the Project + Notification to all stakeholders re proposed activities, schedule stakeholder communication and consultation process going forward. + Ongoing engagement with potential suppliers via ICN NT	+ Stakeholder meetings + Presentations at stakeholder events (e.g. Darwin Port, Top End Tourism, Tourism NT, Chamber of Commerce, Energy Club) + Email, phone communication + 24-hour telephone line available for stakeholder queries + Distribution of project update via email + Distribution of project fact sheets via email and stakeholder meetings + Project fact sheets posted to Santos external website + Distribution of project information via third parties (e.g. Darwin Port, Tourism NT) to their membership + Distribution of project information via paid advertorial in NT News	Pending

Stage	Aims and Activities	Deliverables	Status
	+ Ongoing engagement with key contractors undertaking activities on Santos' behalf and the owners of land upon which activities will occur (e.g. Darwin Port, DIPL- East Arm, DLNG Management, Wickham Point Deed Reference Group) to ensure efficient communications and help maintain safe operations. + Ongoing engagement with the following stakeholders on specific issues raised: – Opportunities for collaboration on dredging-related activities – NT DIPL, Inpex, Department of Defence – Pipelay activities within Reef Fish Protection Area – NT DITT – Fisheries, AFANT, NTSC – Indigenous consultation resulting from AAPA Clearance Certification – AAPA, NLC, Wickham Point Deed Reference Group, other identified Larrakia stakeholders – Opportunities for collaboration on environmental studies and modelling – NT DPEWS, Inpex, Darwin Harbour Advisory Group, Larrakia Rangers – Road traffic management – NT DIPL – Darwin Harbour impacts management – NT DIPL, Darwin Port, DHAC, Tourism NT, Top End Tourism, AFANT, NTGFIA	+ Physical location on Darwin Harbour for distribution of project information and discussion of issues/concerns + Santos ASX and media statements	
Stage 7 – Pipeline Operations Ongoing from 2025	Aims: Ensure efficient, ongoing communication of any activities that may impact other users of the marine environment, e.g. pipeline maintenance; maintain ongoing liaison with DLNG Operations.	+ Email, phone communication + Distribution of activity updates via email + Activity fact sheets posted to Santos external website + Stakeholder meetings as required + Enquiries/complaints management via established Santos procedures	

Stage	Aims and Activities	Deliverables	Status
		+ 24-hour telephone line available for stakeholder queries Information posted to Santos website Santos ASX and media statements	
Stage 8 – Decommissioning Timeframe dependant on End of Pipeline Operations	Aim: Ensure early and ongoing consultation with all relevant stakeholders in compliance with legislative requirements and management of impacts on relevant communities.		Pending

5 References

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Appendix 1 Stakeholder List

Sector	Stakeholders
Commonwealth Government	+ Department of Climate Change, Energy, the Environment and Water (formerly Department of Agriculture, Water and the Environment) + Department of Defence (including Australian Hydrographic Office and HMAS Coonawarra, Darwin)
NT Government Regulators / Agencies	+ Aboriginal Areas Protection Authority (AAPA) + Department of Environment, Parks and Water Security + Department of Chief Minister and Cabinet + Department of Industry, Tourism and Trade - Fisheries + Department of Industry, Tourism and Trade - Energy + Department of Industry, Tourism and Trade - Tenure + Department of Industry, Tourism and Trade - Tourism + Department of Infrastructure, Planning & Logistics - Planning + Department of Infrastructure, Planning & Logistics - - Regional Harbourmaster + Department of Infrastructure, Planning & Logistics - Middle Arm Sustainable Development Precinct Project + Department of Infrastructure, Planning & Logistics - Darwin Ship-lift Project; Mandorah Ferry Project + Department of Infrastructure, Planning & Logistics - Transport + Department of Territory Families, Housing and Communities - Heritage + Environmental Protection Authority + NT Power and Water + Tourism NT
Indigenous Groups / Representative Bodies	+ Aboriginal Areas Protection Authority (also noted as agency above) + Larrakia Nation (including Larrakia Sea Rangers) + Northern Land Council + Tiwi Land Council + Wickham Point Deed Reference Group
Environmental Group Representatives	+ Australian Marine Science Association + Australian National University (individual) + Environment Centre NT + Sea Turtle Foundation
Fishing Representative Bodies	+ Amateur Fishermans' Association of the NT (recreational) + NT Seafood Council (commercial)
Other Community Organisations	+ Darwin Harbour Advisory Committee

Sector	Stakeholders
	+ NT Chamber of Commerce and Industry
Other Industry / Operators	+ Darwin Port + DLNG Pty Ltd + Eni Australia + INPEX + NT Guided Fishing Industry Association + Paspaley Pearling + Sea Darwin + Sun Cable + Telstra + Top End Tourism + Tourism NT

Santos

Appendix 2 Consultation Register

The following is a list of the consultation undertaken to date via meetings with key stakeholders to inform preparation of the Referral prior to its submittal and, following the NT EPA's assessment decision on 7 April 2022, to inform preparation of the required Supplementary Environmental Report. The list is not a complete record of consultation as it does not include all email and telephone engagement.

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Stakeholder(s)	Date	Description
Stage 1: Prior to submittal of referral to NT EPA		
Darwin Port/ NT Department of Infrastructure, Planning & Logistics (NT DIPL) - Regional Harbourmaster	3 August 2021	Meeting to discuss proposed route for Darwin Pipeline Duplication (DPD) and intention to submit a Referral to the NT EPA for the DPD section in NT Waters.
Darwin Port/ NT DIPL - Regional Harbourmaster)	21 August 2021	Further meeting to discuss proposed route for DPD in NT Waters in more detail.
NT Environment Protection Authority (NT EPA)	6 October 2021	Meeting with NT EPA Board to discuss intention to submit a Referral to the NT EPA for the DPD section in NT Waters.
Darwin Port/ NT-DIPL (Regional Harbourmaster)	8 October 2021	Further meeting to discuss proposed route for DPD in NT Waters in more detail.
ALL	8 October 2021	Direct distribution to all currently identified stakeholders via email of Barossa Project Quarterly Update, including information on the status of regulatory approvals including an additional Gas Export Pipeline section in Commonwealth Waters and the intention to submit a Referral to the NT EPA for the DPD section in NT Waters.
Tiwi Land Council (TLC)	19 October 2021	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to an additional Gas Export Pipeline section in Commonwealth Waters. The intention to submit a Referral to the NT EPA for the DPD section in NT Waters was also advised. Meeting is part of an ongoing Barossa engagement process.
Australia Bay Seafoods	20 October 2021	Meeting with commercial fishing company to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. Initial response from company was that there were unlikely to be major concerns. Following the meeting, Santos provided further specific information on the proposed pipeline route so any potential impacts on commercial fishing grounds in Commonwealth Waters and a Sea Gear Trial area in NT Waters can be considered by the company.
NT Department of Environment, Parks & Water Services (NT DEPWS)	21 October 2021	Meeting with department personnel who provide support services to the NT EPA to discuss content requirements and timeframe for submittal of Referral to the NT EPA and the separate regulatory process for other associated activities, i.e. secondary approval submissions for waste discharge, etc.

Stakeholder(s)	Date	Description
NT Department of Industry, Tourism & Trade – Fisheries (NT DITT – Fisheries)	21 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. Initial response from department was that there were unlikely to be major concerns related to commercial fishing or fish sustainability. The department requested that the route not pass over or close to a jewfish aggregation area within the Charles Point Reef Fish Protection Area (CPRFPA), that artificial reef areas are not impacted, and Santos consult with the Amateur Fisherman's Association of the NT to gain recreational fishing sector views. Following the meeting, Santos provided further information on the proposed pipeline route.
NT Guided Fishing Industry Association (NTGFIA)	21 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. The Association, which represents ~70 guided fishing/charter boat operations, provided initial advice that another pipeline was always welcome for fish attraction and artificial habitat creation and there should not be any major issues provided installation/trenching was of a relatively short duration and did not occur over known fishing spots or the artificial reefs. Following the meeting, Santos provided further information on the proposed pipeline route.
NT DITT - Energy	22 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters as well as processes involved with new NT pipeline licence applications and other associated secondary approvals, including Pipeline Management Plans. Department advised it was important to discuss the project with the Aboriginal Areas Protection Authority (AAPA).
Darwin Port	22 October 2021	Meeting to discuss DPD consultation process related to its users. Port advised that its preference will be for Santos to consult and communicate directly with all relevant stakeholders and keep the Port regularly informed. Consultation with the Darwin Harbour Advisory Committee is recommended. The Port will advise Santos if any briefings are required via its ongoing Port User Group consultation process.
Northern Prawn Fishing Pty Ltd (NPF Ltd)	25 October 2021	Meeting with representative organisation for all licence holders to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. Initial view of organisation is that there won't be any major concerns, however Santos was requested to provide further specific information on the proposed pipeline route and spoil disposal area plus the other subsea infrastructure required in the additional Commonwealth Waters Area so any potential impacts on commercial fishing grounds in Commonwealth Waters and a Sea Gear Trial area in NT Waters can be considered.
NT DITT - Tenure	25 October 2021	Meeting to discuss processes involved with new NT pipeline licence applications and other related approvals including Pipeline Management Plans, validations, consents to construct/operate

Stakeholder(s)	Date	Description
Sun Cable	25 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters, including potential future crossovers of cables and indicative activity schedules.
Aboriginal Areas Protection Authority (AAPA)	26 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters including process to apply for Clearance Certificate for activities in NT Waters.
Northern Land Council (NLC)	26 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. Legal Services section of the Council's Land and Law Division will continue to be engaged. Council agrees that Aboriginal Areas Protection Authority, Wickham Point Deed Reference Group and Tiwi Land Council are key stakeholders.
Amateur Fishers Association of the NT (AFANT)	27 October 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. AFANT is concerned at impact of planned activities on recreational fishing in Harbour which is already subject to many pressures as a result of varied and something conflicting uses. AFANT advised that Santos needs to explain how the scale of its project will be different to Inpex's Ichthys Project. In addition to mitigation measures, Santos should look at how it can offset this impact by working with the sector on other beneficial projects with positive impacts. Santos and AFANT exchanged information on the proposed pipeline route and recreational fishing spots in Darwin Harbour for further consideration of impacts.
Tiwi Resources	27 October 2021	Meeting to organise Santos' attendance at clan group meetings and Leaders Forum to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
NT DIPL - Executive	4 November 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters, as well as processes involved with other related approvals and consultation with project teams managing the department's ship-lift and Mandorah ferry activities in Darwin Harbour.
NOPSEMA/NOPTA	5 November 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters as well as process for licence variation of pipeline section within Commonwealth Waters. Santos also advised the intention to submit application for new pipeline licences in NT Waters to the NT DITT.

Stakeholder(s)	Date	Description
Inpex	8 November 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. Information shared re proposed activities in Darwin Harbour and the indicative schedules involved. Part of ongoing engagement process.
NT Heritage Branch	9 November 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. Meeting followed email and phone engagement conducted in August and October 2021 on Santos' intention to divert the proposed pipeline route around a submerged wreck site. The Heritage Branch will prepare scope of works for Santos to engage a contractor to conduct a desk-top assessment of its current pipeline route information.
NT DITT-Energy	10 November 2021	Meeting to further discuss processes involved with new NT pipeline licence applications and other related approvals including Pipeline Management Plans, Scope of Validation and Consents to Construct and Operate.
Commonwealth Director of National Parks / Commonwealth Department of Agriculture, Water & the Environment (DAWE)	11 November 2021	Meeting to discuss Santos' intention to submit a Referral on EPBC Act Matters to DAWE related to the DPD section in NT Waters. Focus of the meeting was the submittal and assessment process involved, including timeframes. The additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters was also discussed.
NT-DEPWS	17 November 2021	Meeting to further discuss additional information provided by Santos on recent habitat survey results, mapping to environmental assessment policy and framework of NT EPA Referral. DEPWS provided advice on information that would be required on range of matters including waste management, dredging methods and hydro-testing. DEPWS also advised that the EPA will be interested in how the pipeline relates to the overall management of greenhouse gas emissions at DLNG and the proposed Bayu-Undan to Darwin Gas Export Pipeline re-purposing for Carbon Capture and Storage (CCS). DEPWS will also provide specific information for Santos on applications of water and waste management and pollution control legislation and required secondary approvals.
HMAS Coonawarra Naval Base	17 November 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. The Navy advised it was planning to undertake dredging operations during 2023/24 and consultation should occur between Defence, NT DIPL, Santos and Inpex re their respective works in the Harbour and any potential collaboration that could occur. Santos also offered to brief the Defence Department's Capital Infrastructure Facilities Group in Canberra.
Environment Centre NT (ECNT)	17 November 2021	Meeting to discuss additional Gas Export Pipeline section in Commonwealth Waters and intention to submit a Referral to the NT EPA for the DPD section in NT Waters. ECNT believes approvals should be submitted and assessed based on the entire Barossa project, i.e., from extraction at Barossa Field right through treatment at DLNG, re-use

Stakeholder(s)	Date	Description
		of Bayu-Darwin pipeline and planned CCS at Bayu-Undan. Would like to meet with representatives who can speak about the company's overall plan, and this should also be covered in a presentation to the Darwin Harbour Advisory Committee.
Sun Cable	18 November 2021	Meeting to further discuss specific matters related to work schedules and potential crossovers of cables. Sun Cable advised it was planning to install cable starting in 2024/25 and was considering two potential routes, both of which would cross the existing Bayu-Undan to Darwin Pipeline and therefore the proposed additional pipeline. Following the meeting, Santos and Sun Cable have shared relevant information.
NT-DIPL – Darwin Ship-lift and Mandorah Ferry projects	18 November 2021	Meeting to further discuss Santos DPD Project and NT DIPL projects and share information with a view to any potential areas for collaboration. DIPL advised that a Darwin Harbour Dredge Management Strategy would assist projects going forward once it was developed. DIPL and Santos will continue to liaise re any potential collaboration via Santos' geophysical work in Harbour early next year and other future collaborative opportunities related to planned dredging works in Harbour.
Wickham Point Deed Reference Group (WPDRG)	19 November 2021	Meeting to discuss DPD Project in both NT and Commonwealth Waters and intention to submit a Referral to the NT EPA. Meetings of WPDRG, which represents the Larrakia Traditional Owners of the land upon which DLNG is located, are held on an ongoing basis with Barossa Project and DPD now a standing item for update. Representatives present advised there were no specific concerns related to the proposed operational area in the Harbour or shore crossing as they would be occurring in an already disturbed area. DLNG advised that civil works had commenced associated with the Life Extension project. Barossa will keep the committee members informed on the progress of the AAPA certification work
Tiwi landowner group - Malawu	23 November 2021	Meeting with Malawu clan group to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
Sea Darwin	24 November 2021	Phone discussion with owner/operator re DPD Project in both NT and Commonwealth Waters and intention to submit a Referral to the NT EPA. Owner/operator advised his main concern was the coordination of work programs in the Harbour that are being proposed by a range of organisations and how these relate to the NT Government's dredging strategy. Santos will be presenting to the DHAC on which Sea Darwin is represented.
Tiwi landowner group - Wurrumiyanga	25 November 2021	Meeting with Wurrumiyanga clan group to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.

Stakeholder(s)	Date	Description
AAPA Board meeting	2 December 2021	Meeting to provide update on intention to submit a Referral to the NT EPA for DPD Project in NT Waters and Santos' intention to applying for an AAPA Clearance Certification.
EPA Board	7 December 2021	Presentation by Santos summarising the content of the Referral that will be submitted shortly. The Board requested Santos provide additional detail on how the DPD Project relates to other Santos' activities, i.e., Barossa Project, DLNG Life Extension and Bayu-Undan CCS.
NT Power & Water Corporation (NT P&WC)	8 December 2021	Meeting to discuss DPD Project in both NT and Commonwealth Waters and intention to submit a Referral to the NT EPA. Discussions focused on the status of power and communications cables and crossings that will be required and may be required in the future. Santos advised the cables have recently been surveyed and their positions can be checked against the existing supplied position to determine any changes to their location. The latest survey data can also be supplied to PWC for their information. Santos and NT PWC to share detailed information and continue discussions.
TLC	15 December 2021	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
DAWE	20 December 2021	Meeting to advise the Department that Santos submitted an NT EPA referral for the DPD Project on 8 December 2021 and plans to submit an EPBC Act referral to align with the NT EPA's assessment process.
Darwin Port/ NT DIPL - Regional Harbourmaster	21 December 2021	Further meeting to discuss proposed route for Darwin Pipeline Duplication in NT Waters.
Stage 2: Following submission of referral to NT EPA		
DAWE	12 January 2022	Meeting to discuss whether any potential sea dumping legislative requirements apply to the DPD Project. Santos advised that approval is not required under the Commonwealth Sea Dumping Act as the material to be removed and disposed be wholly within the NT environment, i.e. no movement of materials between NT and Commonwealth Waters. DAWE's initial view was agreement and advice would follow if this was not the case. Note: no further advice or direction received.
ALL	18 January 2022	Direct distribution via email of information on DPD Project, notification that the Referral to the NT-EPA is now available for public comment and inviting discussion with Santos on the Project and Referral.
Paspaley Pearling	19 January 2022	Communication via phone, email and letter from Paspaley Pearling requesting Santos be mindful of pearling lease areas when undertaking project activities in the Beagle Gulf area, including within a proposed spoil disposal area.

Stakeholder(s)	Date	Description
		Paspaley requested that Santos not navigate through or anchor upon these areas. Santos advised it would consider internally and consult with the pipelay contractor.
NT DIPL - Regional Harbourmaster	21 January 2022	Further meeting to discuss proposed route for DPD in NT Waters.
NT DEPWS	31 January 2022	Meeting to discuss process for assessment and public comment associated with NT EPA Referral.
NT DITT - Energy	1 February 2022	Meeting to provide update on submittal of NT EPA Referral and discuss processes for submittal of associated secondary approvals that will also be required.
Paspaley Pealing	7 February 2022	Communication via phone and email by Santos with Paspaley Pearling to advise that the pipelay contractor had agreed that vessels traversing in NT Waters would not enter or anchor upon the identified lease areas.
AFANT	7 February 2022	Meeting to update AFANT on submittal of NT EPA Referral and further discuss issues and concerns raised by AFANT at the previous meeting held in October 2021. AFANT agreed that DPD was a significantly smaller and different project to Ichthys which was one of its main concerns and was pleased that trenching would not be occurring in the CPRFPA and spoil disposal would not occur within the Inpex spoil disposal area which had now become a recreational fishing spot. AFANT advised it would be providing a written submission during the public comment period and the cumulative impact on the Harbour from each project was an important factor in its thinking. AFANT was happy to continue a discussion on its research priorities and potential Santos' support.
NT DITT - Fisheries	9 February 2022	Meeting to update Department on submittal of NT EPA Referral and further discuss Department's views on range of environmental factors addressed in the Referral documentation. The Department's initial view was that the pipeline installation's local impact was unlikely to have any broader consequences for fisheries. Santos advised that the pipeline route within the Charles Point Reef Fish Protection Area would not be in close proximity to the jewfish aggregation area discussed at the last meeting with the Department held in October 2021.
DAWE	17 February 2022	Meeting with representatives of EPBC Referral Assessment Team to discuss required content and process surrounding submittal of EPBC Act referral for DPD Project in NT Waters.
NT DEPWS	2 March 2022	Meeting to discuss NT-EPA process for management and publication of submissions received during public comment period. DEPWS advised that a total of 311 had been received, including 284 as part of a campaign submission, and the main issues raised relate to GHG emissions management, how future CCS project relates to this approval, impacts to Harbour generally, Charles Point Reef Fish Protection Area and coastal areas near the spoil ground. The submissions will be published with the EPA's decision on the level of assessment.

Stakeholder(s)	Date	Description
WPDRG	3 March 2022	Meeting to provide update on submittal of NT EPA Referral and application for AAPA certification. Two members, one also representing Larrakia Nation, requested additional meetings with Santos.
TLC	4 March 2022	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
Darwin Harbour Advisory Committee (DHAC)	14 March 2022	Introductory meeting with new chair of Darwin Harbour Advisory Committee who explained its role and ways that Santos' DPD Project can link into the both the Committee's work and relevant personnel in NT DEPWS working with the Committee. Santos will present at the next DHAC meeting.
NT DITT - Fisheries	15 March 2022	Meeting to discuss the requirement for a fisheries licence under secondary approvals for the DPD Project and the process involved. Further discussion was held on CPRFPA with Fisheries advising while there is no heavy reef habitat in the area, the jewfish aggregation area needed to be avoided. Fisheries agreed that pipelines were generally beneficial to recreational fishing activities. It also did not see the DPD project causing problems for mud crab migration. Santos will provide the Department with data and imagery from its surveys in the harbour.
NT DITT - Tenure	15 March 2022	Meeting to discuss the process for submittal of secondary approvals for the DPD Project, i.e. pipeline licence, scope/statement of validation, consent to construct and operate and Pipeline Management Plans, including Dredge Management Plan.
NT DIPL	16 March 2022	Meeting to provide update on submittal of Referral and discuss process for submittal of secondary approvals.
Inpex	16 March 2022	Meeting to share information on respective projects involving future dredging in Darwin Harbour. Inpex has also commenced consultation on a five-year dredging maintenance program.
Darwin Harbour Advisory Committee (DHAC)	17 March 2022	Presentation to DHAC meeting on NT EPA Referral. Several members sought further information about how the pipeline factored into Santos' future greenhouse gas emissions management at DLNG and the proposal for CCS at Bayu-Undan. Barossa agreed to ask a representative from the CCS project team to attend a future meeting. AFANT member stressed that documents from proponents say things such as there are sparse corals and rocky areas in the Harbour as a reason to not be as concerned; but the sparse number also means their value is greater. Santos stated it was keen to get all feedback and to work with the committee going forward; the DPD trenching program will be quicker and less impactful than the program for Ichthys pipeline; and environmental information gained can be shared. Santos advised it would provide regular updates on the project.

Stakeholder(s)	Date	Description
Tiwi landowner group - Jikilaruwu	18 March 2022	Meeting with Jikilaruwu clan group to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
Northern Territory Seafood Council (NTSC)	18 March 2022	NTSC, which represents commercial fishing licence-holders, did not make a submission. NTSC confirmed that commercial fishers do not operate within the harbour, however, there is some fishing activities within other NT Waters jurisdictions. NTSC's two main requests were for Santos to not disturb the jewfish aggregation area within the CPRFPA and to mitigate against fishing gear being snagged around the pipeline. NTSC will provide contacts from Coastal Line Fishery or other fisheries if more information is required.
AFANT	18 March 2022	Meeting to provide update re submission of NT-EPA Referral and outcomes of discussions held with NT-DITT (Fisheries) on fish protection area and protection of jewfish aggregation site.
Stage 3: Preparation of SER prior to submittal to NT EPA		
Charles Darwin University	4 April 2022	Meeting with researcher to discuss issues related to presence and potential impacts on turtles in Darwin Harbour and NT Waters generally. An expert contact was also provided within NT DEPWS who was also contacted by Santos. The experts advised that the main issue impacting turtles on Darwin beaches is the presence of human traffic and resulting interaction, especially with other animals. Lighting from vessels at sea was considered less of a problem than lighting on land. In terms of the wider region, experts advised there was still a significant knowledge gap impacting the ability to fully understand the impacts on the overall health of the turtle population.
DAWE	4 April 2022	Further meeting to discuss submittal of EPBC Act referral for DPD Project in NT Waters with focus on noise and light impact from vessels in the harbour.
NT DITT- Energy	21 April 2022	Further discussion around construction activities associated with the DPD Project and information on secondary approvals to SER (e.g. construction plans and pipeline management plans).
NT P&WC	28 April 2022	Further meeting to discuss the status of power and communications cables and crossings that will be required and may be required in the future.
NT DIPL - Middle Arm Project	3 May 2022	Meeting to share information on DPD Project and Middle Arm Sustainable Development Project, including indicative timeframes and plans for activities in Darwin Harbour and current/planned environmental studies. Aim is to investigate potential areas for collaboration and management of cumulative impacts.

Stakeholder(s)	Date	Description
DAWE	3 May 2022	Further meeting to discuss EPBC referral, focusing on provision of additional information on noise and light impact assessments. Santos presented its progress on the referral and the department clarified questions related to how impact significance is determined. Santos is awaiting two more technical reports in order to finalise responses.
Tourism NT	3 May 2022	Meeting to discuss DPD Referral to NT EPA and stakeholder consultation undertaken to date with other users of Darwin Harbour and surrounds. Tourism NT assisted Santos with further identification of stakeholders, including Tourism Top End which represents charter boat operators along with the NT Guided Fishing Industry Association. Tourism NT advised that communication prior to and during the activities was critical and offered to assist by passing on communication via its monthly newsletter.
TLC	4 May 2022	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
Sea Darwin	4 May 2022	Meeting to discuss DPD Referral to NT EPA and stakeholder consultation undertaken to date with other users of Darwin Harbour and surrounds. The business owner/operator reiterated the importance of communication and need to liaise with Tourism NT and Top End Tourism. The owner/operator is also a member of the DHAC and will be kept informed through that membership as well as directly by Santos.
Larrakia Nation/Larrakia Sea Rangers	4 May 2022	Meeting to discuss DPD Referral and progress of application to AAPA for Clearance Certificate as well as consultation being undertaken with WPDRG, NLC and TLC. Further discussions to be held with Larrakia Sea Rangers re potential involvement in future environmental monitoring programs and other tasks associated with DPD Project.
Darwin Dive Shop/Academy	6 May 2022	Meeting to discuss DPD Referral to NT EPA and anecdotal advice received from NT DITT - Fisheries related to recreational diving in Darwin Harbour. Advice provided that the Darwin Harbour area is generally challenging for divers without the necessary experience, but particularly during specific periods of the year. Santos requested to ensure it mitigates any impact causing turbidity near to any identified dive wreck sites and keep stakeholders informed prior to and during the proposed activities.
NT DIPL - Darwin Ship-lift and Mandorah Ferry projects	13 May 2022	Meeting to share information on DPD Project and DIPL Ship-lift and Mandorah Ferry Project, including indicative timeframes and plans for planned activities in Darwin Harbour and current/planned environmental studies. Aim is to investigate potential areas for collaboration and management of cumulative impacts.
NT DEPWS	13 May 2022	Meeting to discuss sections of department's submission on DPD Referral on monitoring of water quality in Darwin Harbour. Santos provided information re proposed environmental management studies for the Project and committed to work closely with the department's aquatic group and within its integrated marine monitoring and

Stakeholder(s)	Date	Description
		research program. Santos also agreed to share sediment and water quality data that will be produced with associated studies of the Project. Once modelling results from some studies are finalised, Santos will further discuss with deportment opportunities for alignment and collaboration.
NT DEPWS	25 May 2022	Meeting to discuss NT EPA additional information requirements for the DPD Project Supplementary Environmental Report (SER) related to marine environmental quality, marine ecosystems and atmospheric processes.
Top End Tourism	27 May 2022	Meeting to discuss DPD Referral to NT EPA and stakeholder consultation undertaken to date with other users of Darwin Harbour and surrounds. Top End Tourism represents charter boat operators and has established relationships with Larrakia and Tiwi indigenous organisations. Has a board of management and advised that it would be happy for Santos to present on the DPD Project.
NT DIPL - Regional Harbourmaster	27 May 2022	Further meeting to discuss proposed route for Darwin Pipeline Duplication in NT Waters.
NT DEPWS	31 May 2002	Further meeting to discuss NT-EPA additional information requirements for the DPD Project Supplementary Environmental Report (SER).
ALL	17 June 2022	Direct distribution to All identified stakeholders via email of Barossa Project Quarterly Update, including information on Darwin Pipeline Duplication and NT EPA Referral.
NLC	2 June 2022	Meeting to provide update on EPA Referral, AAPA clearance certification process and submittal and public comment process for pipeline licence application for NT Waters.
NT DITT - Fisheries	3 June 2022	Meeting to discuss pipeline survey work in Darwin Harbour related to DPD Project and whether the department would like any specific locations included. Santos committed to sharing all information gained from the survey with the department.
NLC	10 June 2022	Meeting to provide update on EPA Referral, AAPA clearance certification process, the potential need for additional consultation with indigenous stakeholders and the public comment process for pipeline licence application in NT Waters.
WPDRG	10 June 2022	Meeting to provide update on EPA Referral, AAPA clearance certification process and submittal and public comment process for pipeline licence application in NT Waters.
DAWE	17 June 2022	Further meeting to discuss EPBC referral, focusing on provision of additional information on noise modelling and impact thresholds.

Stakeholder(s)	Date	Description
DHAC	22 June 2022	Presentation to committee meeting providing update on progress of SER preparation and information on completed and habitat surveys and planned noise and plume modelling.
NT DITT - Fisheries	28 June 2022	Discussion on CPRFPA. Fisheries confirmed that reference in its submission on the DPD Referral to an 'important subsea structure' is the jewfish aggregation area previously advised and that the rest of the protection area is believed to be flat mud bottom. Santos reiterated that the proposed pipeline route is further away from the aggregation area than the existing Ichthys and Bayu-Undan to Darwin pipelines.
NT DEPWS	29 June 2022	Meeting to discuss plume modelling thresholds to be used in development of trenching plans for incorporation in SER being prepared.
DAWE	30 June 2022	Further meeting to discuss EPBC referral, focusing on provision of additional information on noise modelling and impact thresholds.
Chief Minister's Office	4 July 2022	Meeting to provide update on Barossa Project activities, including preparation of SER. Santos advised that information on economic and social benefits/impacts, as requested by the Chief Minister's Department in its submission, would be included in the SER.
NT DIPL - Middle Arm Project	5 July 2022	Further meeting to share information on DPD Project and Middle Arm Sustainable Development Project, including indicative timeframes and plans for activities in Darwin Harbour and current/planned environmental studies. Aim is to investigate potential areas for collaboration and management of cumulative impacts. DIPL shared information on the progress of developing a working group to inform the government's plans for a Darwin Harbour Dredging Strategy.
AFANT	5 July 2022	Further meeting to discuss progress on preparation of SER and how Santos will be responding to issues raised in AFANT's submission to the Referral and AFANT's views of current and potential fish and habitat research in Darwin Harbour.
TLC	6 July 2022	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process.
Darwin Port	6 July 2022	Meeting to provide update on progress of all aspects of DPD planning as related to port operations, including future communication with key contracting companies for marine, wharf and road activities.
NT DIPL - Regional Harbourmaster	6 July 2022	Further meeting to discuss proposed route for DPD in NT Waters.

Stakeholder(s)	Date	Description
NT DIPL – Planning (Roads)	8 July 2022	Meeting to discuss progress on preparation of SER and DIPL submission requesting that a traffic impact assessment be included for movement of materials and personnel associated with the DPD Project. Santos advised that a specialist consultancy would undertake the assessment.
Department of Defence - Navy	8 July 2022	Meeting to discuss progress on preparation of SER and specifically share proposed schedules to discuss any potential cumulative impacts and/or collaboration that may be possible between the DPD Project and the Department's dredging plans. Based on the available documentation it is likely the respective dredging programs will not coincide as DPD will not be commencing until mid-2023 at the earliest. Santos also raised a query related to potential anchoring of some vessels within a corridor that traverses two areas of Naval Waters and what permitting process was involved. Defence (Navy) representatives suggested Santos should also contact the Department of Defence in Canberra to discuss its requirements and any potential restrictions during naval exercises to be conducted during 2023
NT DIPL	12 July 2022	Further information share between Santos on the DPD Project and NT DIPL's Ship-lift and Mandorah Ferry projects. Santos provided an update via email on the DPD Project and progress with environmental approvals and supporting studies, including drafts of environmental management plans for construction, trenching, spoil disposal marine fauna and acid sulphate soil. Santos advised it has completed modelling for underwater noise, sediment transport, contingency treated seawater discharge and oil spill and can share outputs and spatial layers. The interpretation of plume modelling and design of water quality monitoring programs and results from an ROV survey in Darwin Harbour of habitat/potential heritage targets can also be shared. Santos asked if both projects could also share specific information to ensure collaborative investigations, e.g. locations of water quality monitoring sites and other GIS information.
NT DITT – Energy; Tenure	27 July 2022	Meeting to provide the department with an update on AAPA Clearance Certification process and discuss whether there are any other requirements related to Native Title consultation. Department advised it was not aware of any issues that would trigger additional legislative requirements and consultation than Santos was already progressing.
Inpex	10 August 2022	Ongoing sharing of information on respective projects involving future dredging in Darwin Harbour. Inpex has also commenced consultation on a five-year dredging maintenance program.
NT DIPL – Regional Harbourmaster	26 August 2022	Further meeting to discuss proposed route for DPD in NT Waters

Stakeholder(s)	Date	Description
NT DEPWS	31 August 2022	Meeting discuss progress of EPBC Act referral for DPD Project and NT secondary approval queries. Santos advised the EPBC Referral for NT Waters has been withdrawn and is being revised to also include Commonwealth waters section of pipeline. DEPWS advised that its SER additional information requirements will continue to await the outcome of the EPBC Act referral assessment. Discussion also held re accredited assessment process, SER submittal date and further public comment period and waste discharge licence requirements for dredging, treated seawater discharge and filter backflushing activities.
WPDRG	1 September 2022	Santos provided update on all Barossa-related activities, including progress on preparation of SER for DPD Project and AAPA Certificate Certification process. Specific information was requested on status of some DPD work contracts and this was provided following the meeting.
Commonwealth Department of Climate Change, Energy, the Environment & Water (DCCEW). Note: formerly DAWE.	7 September 2022	Meeting with representatives of EPBC Referral Assessment Team to discuss required content and process surrounding submittal of EPBC Act referral for DPD Project in NT and Commonwealth Waters. Santos advised that no additional MNES species have been identified for the for 23km section in Commonwealth Waters. The submission will include specific activities related to the additional 23km section including treated seawater and MEG discharge plus spool, PLET and mattress installation.
NLC	12 September 2022	Further meeting to discuss progress on DPD Project and AAPA Clearance Certificate, role of the NLC and other groups in Darwin Harbour and opportunity to engage with ranger groups for any project related compliance requirements.
TLC	12 September 2022	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process. Discussion also focussed on the organisation of further clan group meetings to discuss installation of the pipeline.
Inpex	14 September 2022	Ongoing sharing of information on respective projects involving future dredging in Darwin Harbour.
NT-DIPL	19 September 2022	Further meeting, with Santos' consultant also involved, to discuss preparation of Traffic Impact Assessment for DPD Project and information required. Santos confirmed the assessment attached to the SER document will include movement of both materials and personnel.
Inpex	21 September 2022	Ongoing sharing of information on respective projects involving future dredging in Darwin Harbour.
NT DITT - Energy; Tenure	6 October 2022	Meeting to further discuss preparation and submittal of secondary approvals related to DPD Project.
NT DIPL - Planning	6 October 2022	Meeting to further discuss preparation and submittal of secondary approvals related to DPD Project.

Stakeholder(s)	Date	Description
TLC	6 October 2022	Meeting to discuss Barossa Project activities and potential areas for collaboration on environmental projects with relevance to the DPD section in Commonwealth Waters. Part of ongoing Barossa engagement process. Removal of ghost nets, feral pests and turtle monitoring are ongoing focusses for Tiwi Land and Sea Rangers and provide opportunities to support. Meeting focussed on organisation of further clan group meetings to discuss installation of the pipeline and how information is provided. Santos also advised that it was resubmitted the DPD EPBC Act Referral to DCCEEW which will also now include the 23km section in Commonwealth Waters south of the Tiwi Islands.
AAPA	6 October 2022	Meeting to provide update re progress of DPD referrals to NT-EPA and Commonwealth Government, DPD NT (new) and Commonwealth (variation) pipeline licence applications and consultation with TLC and NLC
Inpex	12 October 2022	Ongoing sharing of information on respective projects involving future dredging in Darwin Harbour
NT-DIPL - Planning	18 October 2022	Further discussion with the relevant department personnel on the process for submittals of an Exceptional Development Permit (EDP) under the Planning Act 1999 (NT) and Planning Regulations 2000 (NT), for the dredging/trenching in Darwin harbour (pipeline up to the beach valve) and an Occupational Licence under the NT Crown Lands Act 1992 and Crown Lands Regulation 1992 (NT) for the activities to be undertaken in the dredge disposal area.
Department of Defence	8 November 2022	Meeting to discuss anchoring requirements in sections of Darwin Harbour identified for defence activities and schedules for future defence exercises and DPD activities in the event they coincide.
NT DIPL	8 November 2022	Further information share between Santos on the DPD Project and NT DIPL's Ship-lift and Mandorah Ferry projects. Topics included progress with environmental approvals and supporting studies, suitability of spoil materials for potential reuse and coordination of land traffic management in event that rock transport for projects is occurring simultaneously.
NT-DPIL Middle Arm	8 November 2022	Provision of status update to Middle Arm project management with emphasis on planning and progress of environmental studies and sharing of results.
NT-DIPL – Regional Harbourmaster	8 November 2022	Ongoing discussion re final route of pipeline in Darwin Harbour.
Tourism NT	9 November 2022	Provision of update on project approvals and proposed schedule of works in Darwin Harbour. Particular focus on consultation with guided fishing industry and other groups representing other users of the harbour and plans for future consultation in lead-up to and during execution phase.

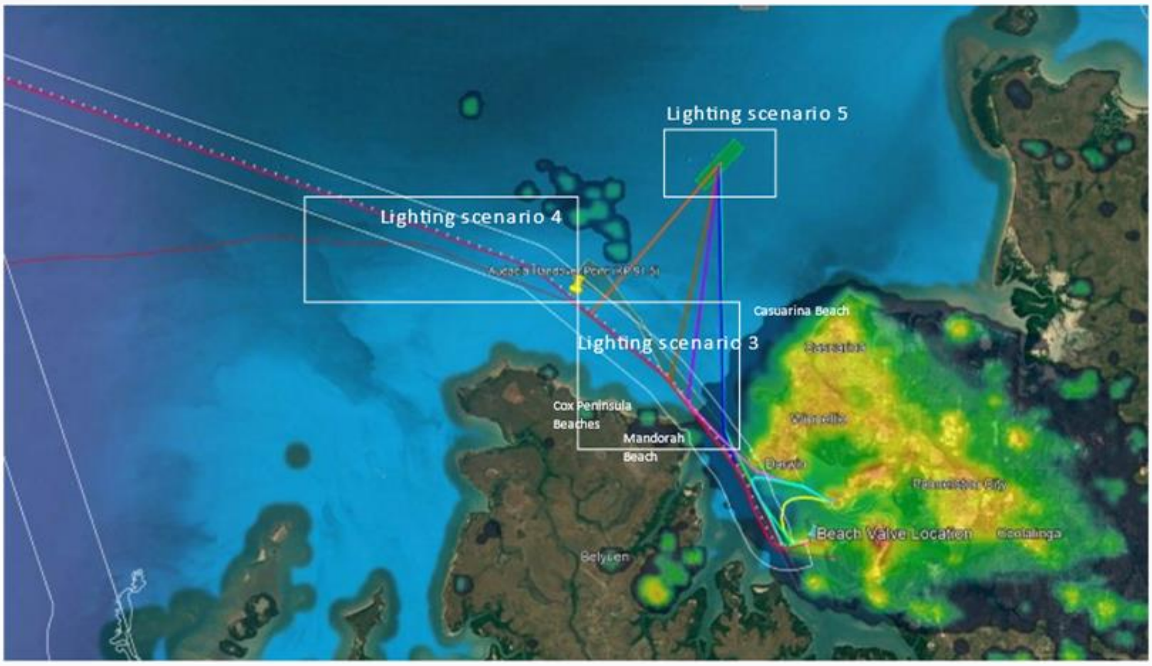
Stakeholder(s)	Date	Description
DHAC	10 November 2022	Presentation by Santos, as requested by DHAC members, on the process of Carbon Capture and Storage, Santos' current CCS-related projects in Australia and the proposed Bayu-Undan CCS Project.
AFANT	10 November 2022	Provision of update on project approvals and proposed schedule of works in Darwin Harbour with particular focus on progress of environmental studies as related to issues previously raised by AFANT in its Referral submission.
WPDRG	18 November 2022	Provision of update on project approvals, including AAPA investigation for Clearance Certificate, and proposed schedule of works in Darwin Harbour and DLNG shore crossing.
NLC	2 December 2022	Provision of update on project approvals, including AAPA investigation for Clearance Certificate, and proposed schedule of works in Darwin Harbour and DLNG shore crossing.
Inpex	14 December 2022	Ongoing sharing of information on respective projects involving future dredging in Darwin Harbour.
Department of Territory Families, Housing & Communities - Heritage	20 December 2022	Provision of update on completed archaeological survey work in NT Waters and proposed process for further survey in Darwin Harbour.
NTGFIA	23 January 2023	Provision of update on progress of environmental approvals with particular focus on schedule for proposed works, mitigation of impacts on existing habitat, including in Charles Point Reef Fish Protection Area, consultation efforts that will occur in lead-up to and during execution of works in order to manage impacts on other users.
Paspaley Pearling	24 January 2023	Provision of update on progress of environmental approvals with particular focus on schedule for proposed works. Topics included avoidance of offshore pearl lease areas by transiting vessels, management of potential impacts due to spoil disposal activities, mitigation of impacts to aquaculture operations at Channel Island and nature and extent of exclusion zones during pipelay activities.
DITT – Mines & Energy	24 January 2023	Provision of update on progress of environmental approvals with particular focus on required secondary approvals via the Department, timing of approvals and progress on final pipeline route.
DITT - Fisheries	27 January 2023	Provision of update on progress of environmental approvals with specific discussion on avoidance of fish aggregation area in Charles Point Reef Fish Protection Area, extent of trenching and rock dumping required, progress of discussions with other fishing stakeholders on issues raised in Referral submissions and process for required Fisheries Permits for some activities.
DIPL	27 January 2023	Further information share between Santos on the DPD Project and NT DIPL's Ship-lift and Mandorah Ferry projects. Topics included progress with environmental approvals and supporting studies, suitability of spoil materials for

Stakeholder(s)	Date	Description
		potential reuse and coordination of land traffic management in event that rock transport for projects is occurring simultaneously.
DITT -Fisheries	1 March 2023	Presentation to NT Department of Fisheries and users of the Darwin Aquaculture Centre re progress of environmental documentation for EPA assessment, proposed activities and indicative schedule with specific focus on the outcomes of sediment dispersion modelling for planned trenching in closest proximity to Channel Island, potential for impacts from mobilisation and accumulation of heavy metals and proposed environmental monitoring program.

Appendix 14: Darwin Harbour Lighting Impact Assessment

SANTOS

BAROSSA PIPELAY, DARWIN HARBOUR LIGHTING TECHNICAL NOTE



Prepared by

Pendoley Environmental Pty Ltd

For

Santos

27 May 2022

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DOCUMENT CONTROL INFORMATION

TITLE: BAROSSA PIPELAY, DARWIN HARBOUR LIGHTING TECHNICAL NOTE

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Document History

Revision	Description	Date	Personnel
Draft	Draft	19/05/2022	Dr K Pendoley
Rev IA	Internal Review	24/05/2022	B Moore
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Name of project:	Barossa Pipelay, Darwin Harbour Lighting Technical Note
Client	Santos
Client representative:	Lachlan MacArthur
Report number:	J06063
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1 BACKGROUND

Santos proposes to construct and operate the Darwin Pipeline Duplication (DPD) Project, to allow gas from the Barossa gas field in the Timor Sea to be transported to Darwin LNG facility. As part of the referral process to obtain approval to dredge and install the Barossa pipeline , the Department of Agriculture, Water and the Environment (DAWE) has requested Santos provide further information on listed threatened and migratory species in the Darwin region, in particular, marine turtles nesting on beaches potentially exposed to lighting from Project vessels in the Darwin Harbour.

Santos has requested a Subject Matter Expert (SME) desktop assessment to determine the presence and significance of marine turtle nesting activity on beaches surrounding Darwin Harbour. This Technical Note compiles the available information on regional marine turtle nesting and assesses the likely level of impact the DPD Project will have on the Arafura Sea genetic stock of flatback turtles (*Natator depressus*).

1.1 Data sources

Information on the local (Darwin environs) and regional (Northern Territory) has been derived from several sources including:

- Online
  - Northern Territory Natural Resource Maps: https://nrmaps.nt.gov.au/
  - Atlas of Living Australia: https://www.ala.org.au/
- Grey Literature
  - Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017)
  - Proceedings of the Australian Marine Turtle Conservation Workshop (ANCA 1994)
  - Marine Turtle Conservation and Management in Northern Australia (Centre for Indigenous Natural and Cultural Resource Management 1998)
  - A Biological Review of Australian Marine Turtles (QEPA 2009)
- Published, peer-reviewed literature.

1.2 Review on Darwin area nesting

Potential impact beaches with evidence of marine turtle nesting activity that are likely to be exposed to Project vessel lighting include Casuarina Beach in Darwin, and beaches on Cox Peninsula, including Wagait Beach and Mandorah (**Figure 1**).

The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017) identifies the known important habitat critical to the survival of all marine turtle species in Australia. The Arafura Sea genetic stock, which includes the Darwin area nesting beaches, is the largest genetic stock for flatback turtles in Australia and covers the largest geographic area (FitzSimmons et al 2020). The Recovery Plan does not recognise any of the potential impact beaches as significant nesting sites for the Arafura Sea genetic stock.

The threats identified for this stock include: marine debris entanglement (very high); climate change, terrestrial predators and indigenous take (high); international take, fisheries bycatch, noise, dredging, disease and pathogens, habitat modification and human recreation (low) (Commonwealth of Australia 2017). Light pollution was not identified as a threat for the Arafura Sea stock. Unlike smaller and more geographically constrained genetic stocks, the size and wide geographic distribution of the Arafura Sea flatback stock provides greater resilience to threats or impacts on the stock.

A number of species reviews and nesting distribution studies for Northern Territory stocks have been conducted which consistently identify regional rookeries remote from the Darwin Harbour as significant nesting sites, while the beaches surrounding Darwin Harbour, when they are acknowledged at all, are reported as supporting a relatively insignificant nesting effort (Chatto 1998; Chatto and Baker 2008; Guinea 1994a; Guinea 1994b; Parmenter 1994).

Chatto (1998) conducted a series of aerial surveys to identify hotspot nesting sites for subsequent ground truthing found flatback turtles are the most common nesting species in the Northern Territory and were widespread on island and mainland beaches. He identified low-level flatback nesting (1 – 10 track/nests) on Cox Peninsula and at Casuarina Beach near Darwin (**Figure 1**). This finding was further confirmed in Chatto and Baker (2008) who reported on data from regional snap shot surveys between 1990 and 2004 which also found turtle activity (tracks and nests) fell into the 1 – 10 range and were not recognised as significant rookeries. Significant flatback rookeries nearest to Darwin Harbour are located at Quail Island and Bare Sand Island off the western coast of the Cox Peninsula and ~40 km west of Darwin (**Figure 1**). Nest/track activity ranged from 100 – 200 events over the same sampling period at these locations (1991 – 2004). Whiting and Guinea (2003), reporting on systematic tagging surveys at Bare Sand Island, found 6 – 10 nests per night over a 14-day standardised survey period.

Chatto and Baker (2008) have identified the most important turtle nesting areas in the Northern Territory as: Turtle Point in Joseph Bonaparte Gulf, Bare Sand and Quail Islands near Darwin, the southwest of Bathurst Island, a number of beaches along the northern coastline of Melville Island, the Smith Point area of Cobourg Peninsula, islands to the north and east of Croker Island, the Goulburn Islands, NW Crocodile Island, many of the outer islands of the numerous island chains off northeast Arnhem Land, the mainland coast and islands between Cape Arnhem and Blue Mud Bay, the eastern part of Groote Eylandt and its associated islands, and some of the outer islands in the Sir Edward Pellew Group.

No systematic tagging or census surveys have been carried out on Cox Peninsula. Records held by the Atlas of Living Australia (ALA) include records submitted by the public and reports by local rangers between 2011 and 2019. Nine records exist for flatback turtles on the Cox Peninsula, and include one nesting event, three reports of individual hatchlings found on the beach, one floating animal unable to dive and four miscellaneous records with no further detail. These records further support the low level of nesting activity reported for beaches, including Wagait Beach and Mandorah beaches, on the peninsula. Furthermore, eight records exist for hawksbill (three records) and green turtles (five records) in the area, all of which were reports of stranded animals either found floating or washed ashore emaciated, with boat strike injuries or entangled in marine debris. No hawksbill or green turtle nesting has been reported at potential impact beaches. While the records are likely limited by several factors including low survey effort, low reporting effort and the lack of a systemic approach, the results are consistent with the reported low levels of nesting effort for this area (Chatto and Baker 2008), who also acknowledge similar limitations in their survey methods and data.

ALA records from the Casuarina Beach section of coastline show a similar result. Of the 10 hawksbill and 15 green turtle records, none were for nesting activity, and all were attributed to strandings (eight hawksbill, two green) and indigenous take (two hawksbill, 13 green). Flatback activity dominated the records over the nine years between 2011 and 2020, with a total of 47 records ranging from 1 – 12 reports per year for flatback turtles within 5 km of Lee Point, including Casuarina Beach. Given Casuarina is a popular beach for recreation, we can conclude this survey effort is consistently high, particularly in the southern half of the beach.

Systemic and intensive turtle monitoring conducted on Casuarina Beach between 1997 and 2006 recorded 107 nests along 8 km of beach: 104 flatback, two olive ridley and one green (Chatto and Baker 2008). The number of nests recorded ranged from 7 to 20 each year, peaking between May and October, and confirms this as a low-density nesting beach (Chatto and Baker 2008). This beach is recognised for its value as a public education program and not as a significant turtle nesting site (Chatto and Baker 2008).

No data is available on the orientation of hatchlings leaving beaches on the Cox Peninsula, or Casuarina Beach. The ALA database does not address this, nor is this data collected by the Northern Territory Department of Environment Parks and Water Security. Hatchlings use several cues to find the ocean, including horizon elevation and brightness, and beach slope. In the absence of orientation data, it can be assumed that some misorientation would be occurring as a result of the urban lights from the City of Darwin (**Figure 2**). Vehicle headlights and campfires on beaches may also misorient hatchlings under certain conditions.

Available records covering at least the last 30 years are consistent in demonstrating the low importance of beaches surrounding Darwin Harbour to nesting turtles, including Wagait Beach and Mandorah on Cox Peninsula, and Casuarina Beach in Darwin, to nesting turtles and specifically to flatback turtles within the wider Arafura Sea genetic stock. Current pressures on the few flatback turtles that use the potential impact beaches for nesting include substantial light pollution from Darwin (**Figure 2**), disturbance from recreational beach use, and indigenous take of turtles or eggs. Local aboriginals harvest eggs of all species from accessible mainland beaches throughout the Northern Territory (Chatto 1998), which are highly sought after for food (Kennett, Munungurritj, Yunupingu 1998, Winderlich, 1998). Illegal turtle egg harvest by non-Aboriginal people has also been reported in the Northern Territory (Risk and Browne 1998). Green turtles are the most hunted turtle species in Australia as they are the most favoured for food, whilst flatback turtles are not as well favoured and so not targeted by indigenous hunters (Kowarsky, 1982; Kennett, Munungurritj, Yunupingu 1998). The ALA includes records of turtle carcass dumps in Darwin which are dominated by green turtles and confirms the local indigenous take.

Human recreation, including presence of people, campfires and vehicles, will disturb turtles. Females coming ashore to nest can be forced to go elsewhere when exposed to human activity onshore, vehicles can crush nests or hatchlings, and tyre ruts can obstruct the hatchlings seaward crawl (Lutcavage et al , 1997). Furthermore, campfires have been known to attract emerging hatchlings, which have been observed to crawl into the flames. High recreational use of Casuarina Beach has been confirmed by R Chatto (Northern Territory Department of Environment Parks and Water Security), in communications with Santos staff on 4 April 2022, who provided the following advice on turtle nesting at Casuarina Beach:

- Artificial lighting is considered less of a problem than the amount of human (and dog) traffic on Casuarina Beach – Casuarina Beach is a very popular recreational area for Darwin residents.
- At least half of the turtle nests encountered are relocated to other areas like Lee Point.
- Artificial lighting at sea is considered less of a problem than lighting on land.
- R Chatto could not comment on the specifics of turtle nesting at Mandorah and Cox Peninsula but believed they attracted fewer numbers of nesting turtles than Casuarina Beach
- Information on the number of turtles, nests and re-locations, are available from the Northern Territory Fauna Atlas.

J06063 Barossa Pipelay, Darwin Harbour Lighting

Figure 1: Location Map

Drawn: B. Moore
Date: 25/05/2022
Drawing File Ref: PENV-J06063-1181-A
Coordinate System: GDA 1994 MGA Zone 52

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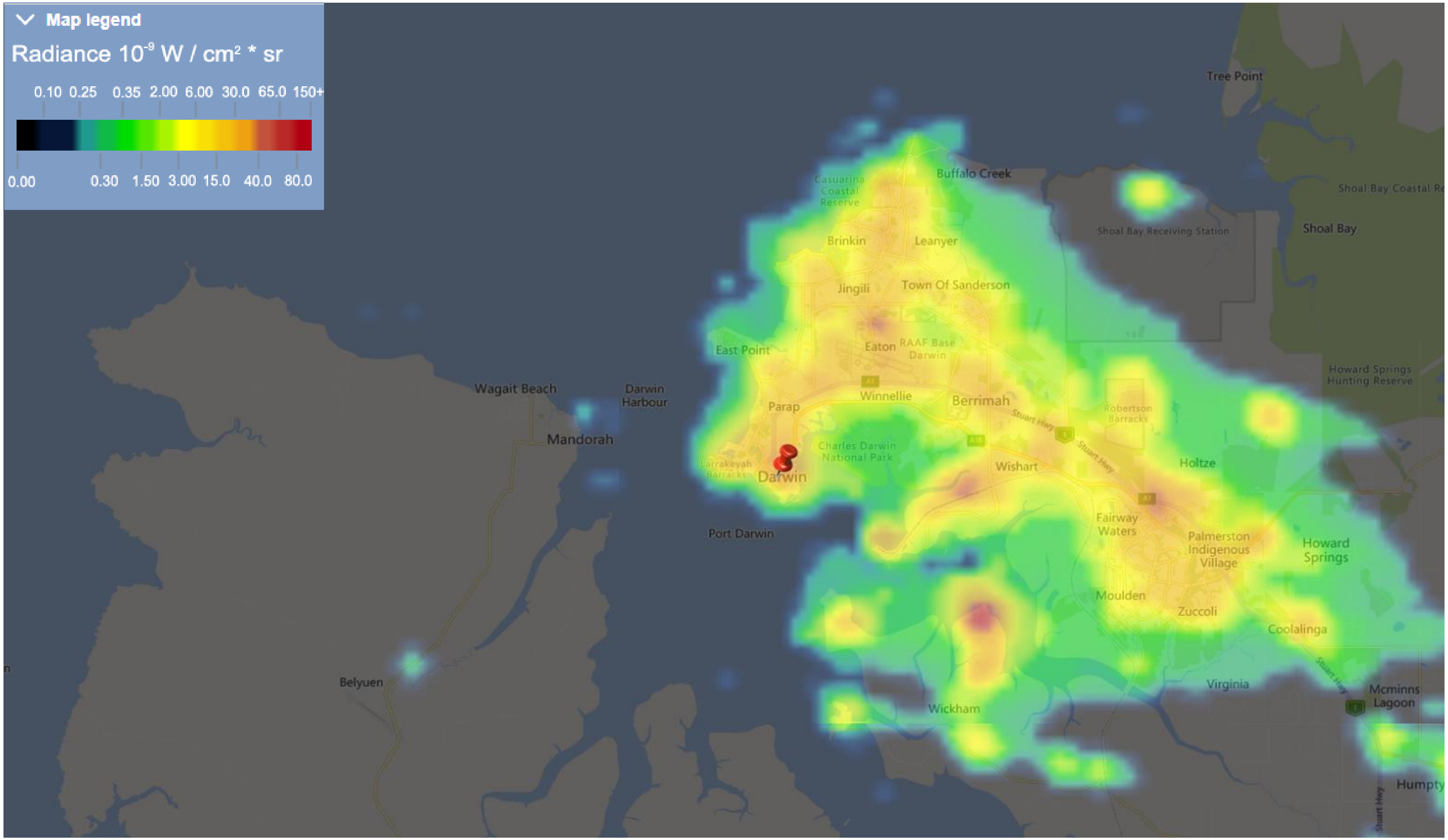

Figure 2: Current light pollution in the Darwin region, 2021. Source: lightpollutionmap.info

1.3 Assessment of dredge vessel impact

The location of dredge vessel activity proposed for the DPD Project in Darwin Harbour has been broken into five zones (**Figures 3 and 4**). Project activity is proposed to occur during a single marine turtle nesting season, including the May to October peak of flatback turtle nesting for the region.

It is clear from **Figure 3** that turtles using Casuarina and Wagait beaches will not have line-of-sight visibility of vessels within the harbour (scenarios 1 and 2) and so are at little to no risk from exposure to vessel lighting. Turtles that use beaches at Mandorah on the Cox Peninsula will be at low risk of impact from vessel lighting, due to the low number of turtles, nests and hatchlings likely to be present on these beaches, the short duration of dredging (i.e. limited to one nesting season), and the amount of existing light pollution from Darwin Harbour and City. To a marine turtle, vessel lighting is unlikely to be distinguishable from the background city lighting.

Offshore, the outer harbour approach (scenario 4, **Figure 4**) and spoil disposal area (Scenario 5, **Figure** 4) are 10 – 20 km from potential impact beaches. Over that distance, vessel lights will produce a relatively small amount of sky glow, similar in appearance to the vessels that currently use the offshore vessel anchorage area. If impact is not being currently observed from the vessel anchorage area, then it is unlikely Project vessels will cause any additional detectable impact.

The greatest risk of exposure is likely to occur when vessels are operating in the harbour mouth (scenario 3, **Figure 4**) during the May to October nesting season peak. Vessels at this location will be ~12 km away from Casuarina Beach and 2 – 8 km from the Wagait and Mandorah beaches. However, the risk of impact is again considered low due to the low number of turtles, nests and successfully emerged hatchlings on theses beaches, the short duration of dredging (i.e. limited to one nesting season), the large amount of urban and City light between the vessels and Casuarina Beach which is likely to mask the vessel lighting rendering it indistinguishable from the onshore lighting. Furthermore the vessels lights are likely to merge with large amount of light from Darwin and the harbour when viewed from Mandorah and Wagait, also rendering them indistinguishable from the onshore lighting.

Overall, there is no discernible risk of the project causing a significant impact to the Arafura Sea flatback turtle genetic stock based on presently and publicly available data. This is due to the short-term nature of the project, the low nesting effort on potential impact beaches, and their low reproductive value relative to other rookeries within the wider genetic stock.

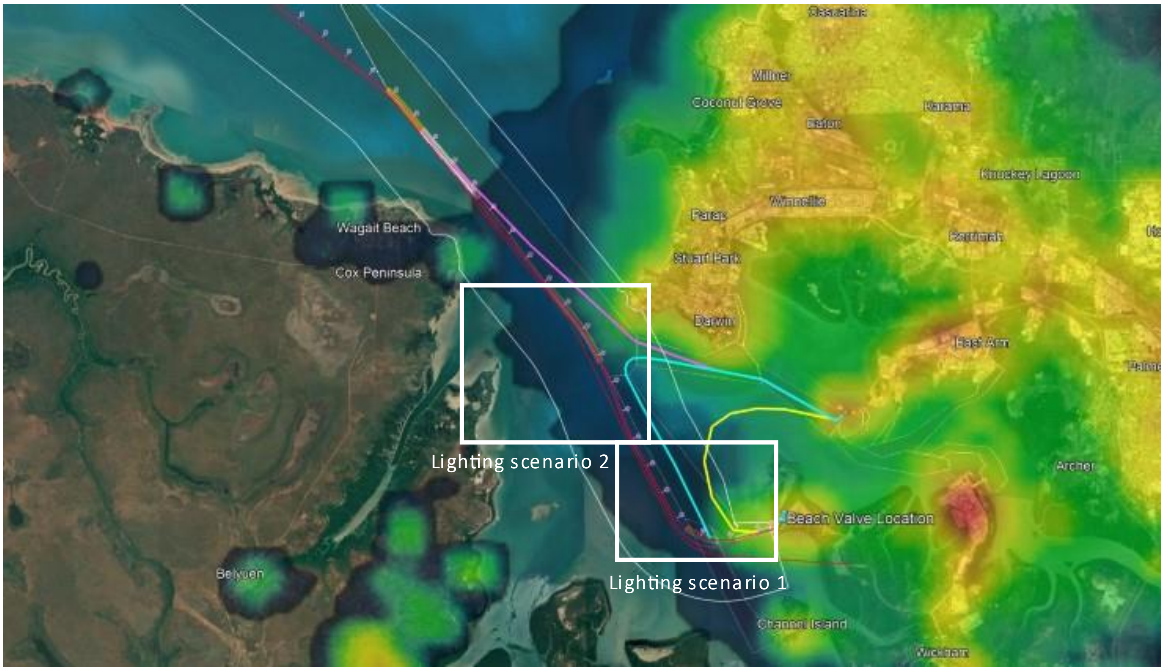

Figure 3: Vessel presence zones in Darwin Harbour

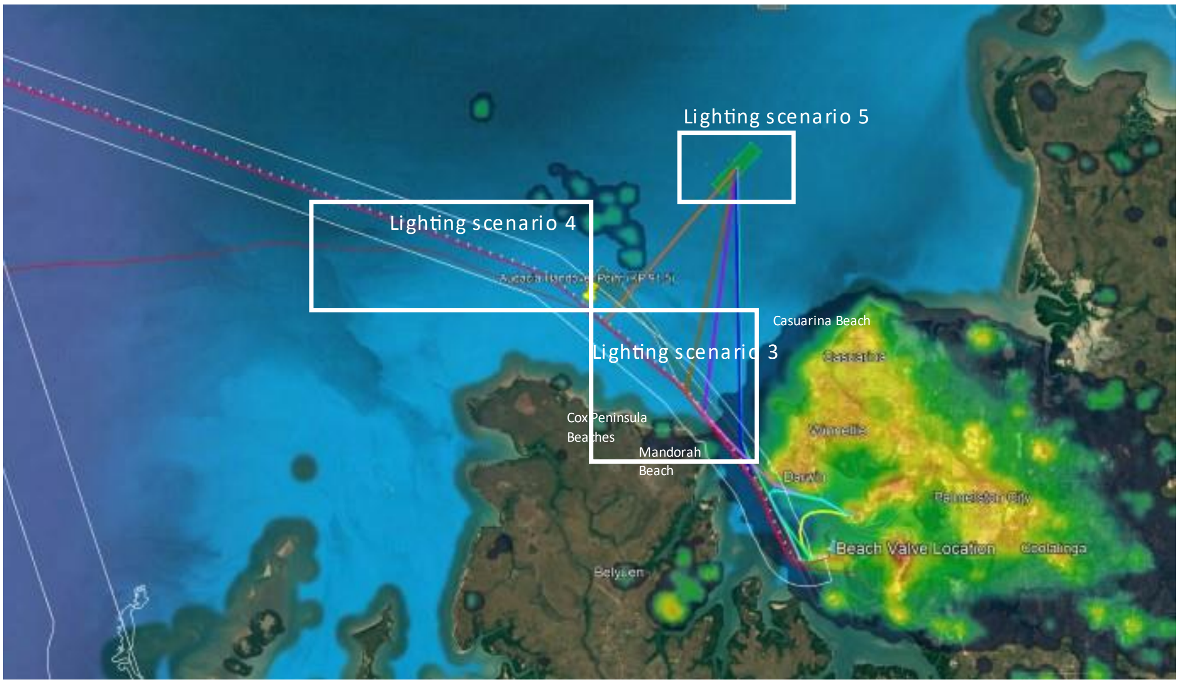

Figure 4: Vessel presence zones approaching Darwin Harbour

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Santos

Appendix 15: Hydrocarbon Spill Modelling Report

SANTOS DARWIN PIPELINE DUPLICATION (DPD) PROJECT

Oil spill modelling study report

MAW1077J.002
Rev2
11 November 2022

REPORT

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Contents

TERMS AND ABBREVIATIONS **1**

EXECUTIVE SUMMARY **4**
Background 4
Methodology 4
Oil Properties 5
Results 5

1 INTRODUCTION **8**
1.1 Background 8
1.2 What is Oil Spill Modelling? 10
1.2.1 Stochastic Modelling (Multiple Spill Simulations) 10
1.2.2 Deterministic Modelling (Single Spill Simulation) 11

2 SCOPE OF WORK **12**

3 CURRENTS **13**
3.1 Development of Regional Current Data 13
3.2 Grid Setup 13
3.3 Boundary Conditions 14
3.3.1 Overview 14
3.4 Surface Currents 15

4 WIND DATA **19**

5 WATER TEMPERATURE AND SALINITY **23**

6 OIL SPILL MODEL – SIMAP **24**

7 OIL PROPERTIES **26**

8 FLOATING, SHORELINE AND IN-WATER THRESHOLDS **27**
8.1 Floating Oil Exposure Thresholds 27
8.2 Shoreline Accumulation Thresholds 28
8.3 In-water Exposure Thresholds 29
8.3.1 Dissolved Hydrocarbons 29
8.3.2 Entrained Hydrocarbons 30

9 RECEPTORS **31**

10 MODEL SETTINGS **38**

11 CALCULATION OF EXPOSURE RISK **40**

12 SCENARIO 1 RESULTS – OFFSHORE PIPELAY VESSEL FUEL TANK RUPTURE AT KP91.5 ..... **41**
12.1 EMBA 41
12.2 Stochastic Analysis 43
12.2.1 Floating Oil Exposure 43
12.2.2 Shoreline Accumulation 47
12.2.3 In-water exposure 51
12.3 Deterministic Analysis 64

13 SCENARIO 2 RESULTS – VESSEL FUEL TANK RUPTURE AT KP114 ..... **69**
13.1 EMBA 69
13.2 Stochastic Analysis 71
13.2.1 Floating Oil Exposure 71
13.2.2 Shoreline Accumulation 75
13.2.3 In-water exposure 79

13.3 Deterministic Analysis 88

14 SCENARIO 3 RESULTS – VESSEL TO VESSEL REFUELLING AT KP114 93
14.1 EMBA 93
14.2 Stochastic Analysis 95
14.2.1 Floating Oil Exposure 95
14.2.2 Shoreline Accumulation 99
14.2.3 In-water exposure 103
14.3 Deterministic Analysis 108

15 SCENARIO 4 RESULTS – VESSEL FUEL TANK RUPTURE AT KP114 112
15.1 EMBA 112
15.2 Stochastic Analysis 114
15.2.1 Floating Oil Exposure 114
15.2.2 Shoreline Accumulation 118
15.2.3 In-water exposure 123
15.3 Deterministic Analysis 132

16 REFERENCES 137

Tables

Table 1.1 Release locations for the Barossa DPD oil spill modelling study. 8
Table 3.1 Summary of the predicted average and maximum surface current speeds adjacent to the KP91.5 and KP 114 release locations, derived from the modelled 2019 – 2020 dataset. 16
Table 4.1 Summary of the predicted average and maximum winds for the nearest CFSR wind nodes to the KP91.5 and KP 114 release locations, derived from CFSR hindcast model from 2019 – 2020 (inclusive). 20
Table 5.1 Monthly average sea surface temperature and salinity adjacent to the KP91.5 and KP114 release locations. 23
Table 7.1 Physical properties of the MDO 26
Table 7.2 Boiling point ranges of the MDO 26
Table 8.1 The Bonn Agreement Oil Appearance Code. 27
Table 8.2 Floating oil exposure thresholds used in the Barossa DPD oil spill modelling study (in alignment with NOPSEMA, 2019). 28
Table 8.3 Shoreline accumulation thresholds used in the Barossa DPD oil spill modelling study (in alignment with NOPSEMA, 2019). 29
Table 8.4 Dissolved and entrained hydrocarbon exposure thresholds assessed over a 1-hour time step used in the Barossa DPD oil spill modelling study (in alignment NOPSEMA 2019). 30
Table 9.1 Summary of receptors used to assess floating oil, shoreline, and in-water exposure to hydrocarbons in the Barossa DPD oil spill modelling study. 31
Table 10.1 Summary of the oil spill scenarios and model settings used in the Barossa DPD oil spill modelling study. 39
Table 12.1 Maximum distances and directions travelled by floating oil from an offshore pipelay vessel fuel tank rupture at KP91.5 for each season. Results were calculated from 100 spill simulations per season. 43
Table 12.2 Summary of the potential exposure by floating oil to individual receptors from an offshore pipelay vessel fuel tank rupture at KP91.5 for each season. Results were calculated from 100 spill simulations per season. 44
Table 12.3 Summary of oil accumulation on any shoreline from an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season. 47

Table 12.6 Maximum distances and directions travelled by dissolved hydrocarbons (0 – 10 m depth layer) from an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season. 51
Table 12.7 Summary of dissolved hydrocarbon exposure for each receptor in the 0 – 10 m depth layer for an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season. 52
Table 12.8 Summary of dissolved hydrocarbon exposure for each receptor in the 10 – 20 m depth layer for an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season. 52
Table 13.8 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from the release location vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season. 83
Table 13.9 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season. 84
Table 14.1 Maximum distances and directions travelled by floating oil from a vessel to vessel refuelling incident at KP114 at each threshold for each season. Results were calculated from 100 spill simulations per season. 95
Table 14.2 Summary of the potential exposure by floating oil to individual receptors from a vessel to vessel refuelling incident at KP114 for each season. Results were calculated from 100 spill simulations per season. 96
Table 14.3 Summary of oil accumulation on any shoreline from a vessel to vessel refuelling incident at KP114 during each season. Results were calculated from 100 spill simulations per season. 99
Table 14.4 Summary of oil accumulation on individual shoreline sectors from a vessel to vessel refuelling incident at KP114 for the dry season. Results were calculated from 100 spill simulations per season. 100
Table 14.5 Summary of oil accumulation on individual shoreline sectors from a vessel to vessel refuelling incident at KP114 for the wet season. Results were calculated from 100 spill simulations per season. 100
Table 14.6 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from the release location for a vessel to vessel refuelling incident at KP114 during each season during each season. Results were calculated from 100 spill simulations per season. 103
Table 14.7 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer from a vessel to vessel refuelling incident at KP114 during each season. Results were calculated from 100 spill simulations per season. 104
Table 15.8 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from the release location vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season. 127
Table 15.9 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season. 128

Figures

Figure 1.1 Release locations for the Barossa DPD oil spill modelling study. 9
Figure 1.2 Examples of four individual spill trajectories (four replicate simulations) predicted by SIMAP for a spill scenario. The frequency of contact with given locations is used to calculate the probability of impacts during a spill. Essentially, all model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability. 10

Figure 1.3 Example of an individual spill trajectory predicted by SIMAP for a spill scenario. Note, this image represents surface oil and does not take any thresholds into consideration. 11
Figure 3.1 Detail of the hydrodynamic model grid. 14
Figure 3.2 Monthly surface current rose distributions from 2019 – 2020 (inclusive), for the closest current nodes to the KP91.5 (left) and KP 114 (right) release locations, derived from the modelled dataset. 17
Figure 3.3 Total surface current rose distributions from 2019 – 2020 (inclusive), for the closest current nodes to the KP91.5 (left) and KP 114 (right) release locations, derived from the modelled dataset. 18
Figure 4.1 Monthly wind rose distributions from 2019 – 2020 (inclusive), for the closest wind node to KP91.5 release location, derived from CFSR hindcast model. 21
Figure 4.2 Total wind rose distributions from 2019 – 2020 (inclusive), for the closest wind node to KP91.5 release location, derived from CFSR hindcast model. 22
Figure 8.1 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015). 28
Figure 9.1 Receptor map for Australian Marine Parks (AMP), Marine Parks (MP) and Key Ecological Features (KEFs). 32
Figure 9.2 Receptor map for the reef fish protection areas (RFPA) and restricted areas. 33
Figure 9.3 Receptor map for the reefs, shoals and banks (RSB). 34
Figure 9.4 Receptor map for the shipwrecks. 35
Figure 9.5 Receptor map for the shoreline sections. 36
Figure 9.6 Receptor map for the water quality zones (WQ Zones). 37
Figure 12.1 Predicted low threshold risk EMBA from an offshore pipelay vessel fuel tank rupture at KP91.5. The annualised results were calculated from 200 spill simulations. 42
Figure 12.2 Zones of potential floating oil exposure from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations. 45
Figure 12.3 Zones of potential floating oil exposure from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations. 46
Figure 12.4 Maximum potential shoreline loading from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations. 49
Figure 12.5 Maximum potential shoreline loading from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations. 50
Figure 12.6 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations. 53
Figure 12.7 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations. 54
Figure 12.8 Zones of potential dissolved hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations. 55
Figure 12.9 Zones of potential dissolved hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations. 56
Figure 12.10 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations. 60

Figure 12.11 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations. 61
Figure 12.12 Zones of potential entrained hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations. 62
Figure 12.13 Zones of potential entrained hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations. 63
Figure 12.14 Zones of potential exposure on the sea surface and shoreline accumulation (over the 50 days) for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season. 65
Figure 12.15 Zones of potential entrained hydrocarbon exposure 0 – 10 m below the sea (over the 50-days) for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season. 66
Figure 12.16 Time series of the area of floating oil exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season. 67
Figure 12.17 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season. 67
Figure 12.18 Predicted weathering and fates for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season. 68
Figure 13.1 Predicted low threshold risk EMBA from a vessel fuel tank rupture at KP114. The annualised results were calculated from 200 spill simulations. 70
Figure 13.2 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 73
Figure 13.3 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 74
Figure 13.4 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 77
Figure 13.5 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 78
Figure 13.6 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 81
Figure 13.7 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 82
Figure 13.8 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 86
Figure 13.9 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 87
Figure 13.10 Zones of potential exposure on the sea surface and shoreline accumulation (over the 20-days) for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season. 89
Figure 13.11 Zones of potential entrained hydrocarbon exposure 0 – 10 m below the sea (over the 20-days) for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season. 90

Figure 13.12 Time series of the floating oil surface area exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season. 91
Figure 13.13 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season. 91
Figure 13.14 Predicted weathering and fates graph for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season. 92
Figure 14.1 Predicted low threshold risk EMBA from a vessel to vessel refuelling incident at KP114. The annualised results were calculated from 200 spill simulations. 94
Figure 14.2 Zones of potential floating oil exposure from a vessel to vessel refuelling incident at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 97
Figure 14.3 Zones of potential floating oil exposure from a vessel to vessel refuelling incident at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 98
Figure 14.4 Maximum potential shoreline loading from a vessel to vessel refuelling incident at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 101
Figure 14.5 Maximum potential shoreline loading from a vessel to vessel refuelling incident at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 102
Figure 14.6 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel to vessel refuelling incident at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 106
Figure 14.7 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel to vessel refuelling incident at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 107
Figure 14.8 Zones of potential exposure on the sea surface and shoreline accumulation (over the 10 days) for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season. 109
Figure 14.9 Time series of the area of floating oil exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season. 110
Figure 14.10 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season. 110
Figure 14.11 Predicted weathering and fates graph for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season. 111
Figure 15.1 Predicted low threshold risk EMBA from a vessel fuel tank rupture at KP114. The annualised results were calculated from 200 spill simulations. 113
Figure 15.2 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 116
Figure 15.3 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 117
Figure 15.4 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 121
Figure 15.5 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 122
Figure 15.6 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 125
Figure 15.7 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 126

Figure 15.8 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations. 130
Figure 15.9 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations. 131
Figure 15.10 Zones of potential exposure on the sea surface and shoreline accumulation (over the 30-days) for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season. 133
Figure 15.11 Zones of potential entrained hydrocarbon exposure 0 – 10 m below the sea (over the 30-days) for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season. 134
Figure 15.12 Time series of the floating oil surface area exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season. 135
Figure 15.13 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season. 135
Figure 15.14 Predicted weathering and fates graph for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season. 136

TERMS AND ABBREVIATIONS

°	Degrees
‘	Minutes
“	Seconds
µm	Micrometre (unit of length; 1 µm = 0.001 mm)
Actionable oil	Oil which is thick enough for the effective use of mitigation strategies
AMP	Australian Marine Park
AMSA	Australian Maritime Safety Authority
API	American Petroleum Institute gravity. A measure of how heavy or light a petroleum liquid is compared to water.
ASTM	American Society for Testing and Materials
Biodegradation	Decomposition of organic material by microorganism
Bonn Agreement	An agreement for cooperation in dealing with pollution of the North Sea by oil and other harmful substances, 1983, includes: Governments of the Kingdom of Belgium, the Kingdom of Denmark, the French Republic, the Federal Republic of Germany, the Republic of Ireland, the Kingdom of the Netherlands, the Kingdom of Norway, the Kingdom of Sweden, the United Kingdom of Great Britain and Northern Ireland and the European Union.
BP	Boiling point
BTEX	Benzene, toluene, ethylbenzene, and xylenes
BU	Bayu-Undan
°C	degree Celsius (unit of temperature)
CFSR	Climate Forecast System Reanalysis
cP	Centipoise (unit of dynamic viscosity)
Decay	The process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions.
Dissolved hydrocarbons	Hydrocarbon droplets which are dissolved in water.
DPD	Darwin Pipeline Duplication
Dry Season	May to October
Dynamic viscosity	The dynamic viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.
EMBA	Environment that may be affected
Entrained hydrocarbons	Hydrocarbon droplets that are suspended into the water column, though not dissolved.
Evaporation	The process whereby components of the oil mixture are transferred from the sea-surface to the atmosphere as vapours.
g/m^2	Grams per square meter (unit of surface area density)
GDA	Geocentric Datum of Australia
GEBCO	General Bathymetric Chart of the Oceans
GEP	Gas Export Pipeline

GODAE	Global Ocean Data Assimilation Experiment
HYCOM	Hybrid Coordinate Ocean Model. A data-assimilative, three-dimensional ocean model.
ITOPF	International Tankers Owners Pollution Federation
KEF	Key Ecological Feature
km	Kilometre (unit of length)
km^2	Square Kilometres (unit of area)
Knots	unit of speed (1 knot = 0.514 m/s)
KP	Kilometre point. Refers to the surveyed distance along the main line or lateral line of a pipeline.
LC_{50}	Median lethal dose required for mortality of 50% of a tested population after a specified exposure duration.
m	Meter (unit of length)
m/s	Meter per Second (unit of speed)
m^3	Cubic meter (unit of volume)
MAHs	Monoaromatic hydrocarbons
MDO	Marine diesel oil
MGA	Map Grid of Australia
MNR	Marine Nature Reserve
MP	Marine Park
NASA	National Aeronautics and Space Administration
NCEP	National Centres for Environmental Prediction
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration
NOPP	National Ocean Partnership Program
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NR	Nature Reserve
NRC	National Research Council
PAHs	Polynuclear aromatic hydrocarbons
ppb	parts per billion (concentration)
Pour point	The pour point of a liquid is the temperature below which the liquid loses its flow characteristics.
psu	Practical salinity units
Ramsar site	A site listed under the Ramsar Convention on wetlands which is an international intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources.
RFPA	Reef Fish Protected Areas
RSB	Reefs, shoals and banks
Sea surface exposure	Contact by floating oil on the sea surface at concentrations equal to or exceeding defined threshold concentrations. The consequence will vary depending on the threshold and the receptors.

Shoreline contact	Arrival of oil at or near shorelines at on-water concentrations equal to or exceeding defined threshold concentrations. Shoreline contact is judged for floating oil arriving within a 1 km buffer zone from any shoreline as a conservative measure
SIMAP	Spill Impact Model Application Package. SIMAP is designed to simulate the fate and effects of spilled hydrocarbons for surface or subsea releases
Single Oil spill modelling	Oil spill modelling involving a computer simulation of a single hypothetical oil spill event subject to a single sequence of wind, current and other sea conditions over time. Single oil spill modelling, also referred to as "deterministic modelling" provides a simulation of one possible outcome of a given spill scenario, subject to the metocean conditions that are imposed. Single oil spill modelling is commonly used to consider the fate and effects of 'worst-case' oil spill scenarios that are carefully selected in consideration of the nature and scale of the offshore petroleum activity and the local environment (NOPSEMA, 2018). Because the outcomes of a single oil spill simulation can only represent the outcome of that scenario under one sequence of metocean conditions, worst-case conditions are often identified from stochastic modelling. It is impossible to calculate the likelihood of any outcome from a single oil spill simulation. Single oil spill modelling is generally used for response planning, preparedness planning and for supporting oil spill response operations in the event of an actual spill.
Stochastic Oil spill modelling	Stochastic oil spill modelling is created by overlaying and statistically analysing the outcomes of many single oil-spill simulations of a defined spill scenario, where each simulation was subject to a different sequence of metocean conditions, selected objectively (typically by random selection) from a long sequence of historic conditions for the study area. Analysis of this larger set of simulations provides a more accurate indication of the area that maybe affected (EMBA) and also indicates which particular locations are more likely to be affected (as well as other statistics). Stochastic oil spill modelling avoids biases that affect single oil spill modelling (due to the reliance on only one possible sequence of conditions). However, when interpreting stochastic modelling, which is based on a wide range of potential conditions that might happen to occur, it is essential to understand that calculations for the Risk EMBA will enclose a much larger area than could be affected in any single spill event, where a more limited set of conditions will occur. Consequently, it is misleading to imply that the Risk EMBA contours derived from stochastic modelling indicate the outcomes expected from a single spill event (NOPSEMA, 2018). Stochastic modelling is generally used for risk assessment and preparedness planning by indicating locations that could be exposed and may require response or subsequent impact assessment.
TOPEX/Poseidon	A joint satellite mission between NASA and CNES to map ocean surface topography using an array of satellites equipped with detailed altimeters
USCG	United States Coast Guard
US EPA	United States Environmental Protection Agency
USA	United States of America
Weathered oil	Oil that no longer contains volatile or soluble components
Wet season	November to April
World Ocean Atlas	A collection of objectively analysed quality controlled physicochemical parameters (e.g., temperature, salinity, oxygen, phosphate, silicate, and nitrate) based on profile data from the World Ocean Database (NCEI, 2021) established by NOAA's National Centers for Environmental Information (NCEI)

EXECUTIVE SUMMARY

Background

Santos is assessing environmental impacts and risks associated with the Darwin Pipeline Duplication (DPD) Project. The DPD Project involves the installation of a gas export pipeline (GEP) from a point (kilometre point (KP) 0) in Commonwealth waters (25km from the Commonwealth/ NT waters boundary) to the Darwin LNG (DLNG) facility on Wickham Point in Darwin Harbour (KP122.2). The pipeline will transfer dry gas from the offshore Barossa field to the DLNG facility. The new pipeline (nearshore Barossa GEP) would run alongside the existing Bayu-Undan (BU) to Darwin GEP, typically within 50-100m, thereby effectively duplicating that pipeline.

To support the environmental risk assessment and approval requirements for the DPD Project, including the development of management plans, an oil spill modelling study was undertaken which considered the following four scenarios:

- **Scenario 1** – An offshore pipelay vessel fuel tank rupture at KP91.5 resulting in the release of 700 m^3 of marine diesel oil (MDO) on the surface over 6 hours;
- **Scenario 2** – A vessel fuel tank rupture at KP114 resulting in the release of 87.5 m^3 MDO on the surface over 6 hours;
- **Scenario 3** – An instantaneous surface spill of 10 m^3 of MDO due to a vessel to vessel refuelling incident within the harbour at KP114; and
- **Scenario 4** – A vessel fuel tank rupture at KP114 resulting in the release of 300 m^3 MDO on the surface over 6 hours.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for wet (November to April) and dry (May to October) seasons.

The purpose of the modelling is to provide an understanding of the conservative 'outer envelope' of the potential area that may be affected in the unlikely event of a vessel-based spill. Since the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill, the results presented herein are conservative.

Methodology

The modelling study was carried out in stages. Firstly, two-years (2019 – 2020) of wind and high-resolution current data covering Darwin Harbour and Beagle Gulf was generated. Secondly, the currents, winds and detailed hydrocarbon characteristics were used as inputs in the three-dimensional oil spill model (SIMAP) to simulate the drift, spread, weathering and fate of the spilled oil.

As spills can occur during any set of wind and current conditions, modelling was conducted using a stochastic (or statistical) approach, which involved running 100 spills modelled for each scenario, per season, with each simulation having the same information (i.e., spill volume, duration and MDO composition) and randomly selected start times. This ensured that each simulation was subjected to different wind and current conditions and, in turn, movement and weathering of the MDO. The results from the simulations were combined to determine the potential exposure to the surrounding waters, shorelines and sensitive receptors based on established exposure thresholds endorsed by NOPSEMA (NOPSEMA 2019).

The SIMAP system, methods and analysis presented herein, use modelling algorithms which have been anonymously peer reviewed and published in international journals. Further, RPS warrants that this work meets and exceeds the ASTM Standard F2067-13 "*Standard Practice for Development and Use of Oil Spill Models*".

Oil Properties

MDO has a density of 829.1 kg/m^3 (API gravity of 37.6) and a dynamic viscosity of 4.0 cP at 25ºC, classifying it as a Group II light persistent oil according to the International Tankers Owners Pollution Federation (ITOPF, 2014) and USEPA/USCG classifications. MDO is characterised by a high percentage of volatile components (95%), which will evaporate when on the sea surface. It also contains 5% persistent hydrocarbons, which will not evaporate and decay slowly over time. It is important to note that some heavy components contained in MDO have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e., >12 knots) and breaking waves but can re-float to the surface when the winds ease.

Results

Scenario 1 – Offshore Pipelay Vessel Fuel Tank Rupture at KP91.5 (700 m^3 of marine diesel oil)

- The KP91.5 stochastic modelling results showed that due to the location, the predominant movement of the oil would be in a northwest and south easterly direction. This was largely due to the sweep of the ebb and flood tide.
- The maximum distances of floating oil exposure zones to the release location at the low (≥1 g/m^2), moderate (≥10 g/m^2) and high (≥ 50 g/m^2) thresholds were 26.4 km (southeast), 19.9 km (southeast) and 14 km (west northwest).
- Floating oil exposure was greatest (100% at the low threshold for both seasons) at Charles Point Wide Reef Fish Protected Area (RFPA and Outer Harbour Water Quality (WQ) Zone) due the proximity of the release location (1.11 km east and 0.65 km north, respectively). Otherwise, exposure at the low and moderate thresholds were predicted at Restricted Area 5 and Middle Harbour WQ Zone with all probabilities ≤10%.
- The probability of oil accumulating on any shoreline at, or above, the low threshold (≥10 g/m^2) was highest for spills commencing during the wet season conditions (50%) and lower during the dry season months (25%) conditions. The quickest time for oil to accumulate on shorelines at, or above, the low threshold was 0.96 days during the wet. The greatest volume of oil ashore from a single spill during dry and wet conditions was 28.1 m^3 and 59.7 m^3, respectively. The wet season simulation resulting in the highest volume ashore took 2 days to initially reach the shorelines.
- The greatest probabilities of oil accumulation at, or above, the low threshold were predicted for the East Arm (16% dry and 33% wet conditions), Outer Harbour East (4% dry and 20% wet seasons) and Outer Harbour West (9% dry and 10% wet seasons). The greatest volume (peak) of oil accumulation during the dry and wet seasons was predicted occurred along Outer Harbour West (22.2 m^3) and Outer Harbour East shorelines (43.8 m^3), respectively. The minimum time for an oil spill simulation to reach a shoreline (at the low threshold) was 1.50 days (Outer Harbour West) during the dry season and 0.96 days (Cox-Finniss) during the wet season conditions.
- Dissolved hydrocarbon exposure at, or above, the low (10 ppb) and moderate (≥ 50 ppb) thresholds were 16.9 km (west) and 13.7 km (southeast), respectively, from the release location during both seasons. No exposure predicted for either season at the high threshold (≥ 400 ppb).
- Not including Charles Point Wide RFPA and Outer Harbour WQ Zone receptors due the proximity of the release location (1.11 km east and 0.65 km north, respectively) Booya shipwreck and Middle Harbour were predicted to be exposed to dissolved hydrocarbons at the low threshold in the 0 – 10 m depth during the dry and wet seasons with probabilities ranging from 1% to 7%. The maximum instantaneous concentrations were 23 ppb predicted at Middle Harbour WQ Zone during the dry season and 38 ppb at Booya shipwreck during the wet season.
- The maximum distances from the release location within the 0 – 10 m depth layer to the low (at the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds, ranged between 182.3 km northeast (wet conditions) and 51.3 km east northeast (wet conditions) from the release location, respectively.

- Due to that the proximity of the release location to Charles Point Wide RFPA (1.11 km east) and Outer Harbour WQ Zone (0.65 km north), the probability of exposure was greatest for these receptors (100% at the low threshold for both seasons) and would take 1 hour for a spill to reach the boundaries of the receptors.

Scenario 2 – Vessel Fuel Tank Rupture at KP114 (87.5 m^3 of marine diesel oil)

- Results indicated that the predominant movement for the spilt diesel oil was in a north and south easterly direction, in line with the major tidal axis. Due to the high energy environment, the oil spills were predicted to spread rapidly across the water surface within various reaches of the port.

- The maximum distances to the low, moderate and high floating oil exposure zones were 29.3 km (west northwest), 14.9 km (southeast) and 0.1 km (west northwest), respectively.

- The probability of oil accumulation at, or above, the low threshold was 94% (dry season) and 83% (wet season). The quickest time for a spill to reach a shoreline and for oil accumulation to occur at, or above, the low threshold ranged between 0.21 days (dry season) and 0.17 days (wet season). The maximum volume ashore for a single spill ranged between 24.8 m^3 (dry season) and 24.7 m^3 (wet season). The maximum length of shoreline contacted at the low threshold was 29.6 km (dry season).
- The highest probability of oil accumulation at the low threshold was predicted along the West Arm (78% dry and 47% wet seasons) and East Arm (32% dry and 48% wet conditions) shorelines. The highest volume of oil accumulation during the dry and wet seasons occurred along the West Arm shoreline (24.2 m^3 (dry season) and 24.6 m^3 (wet season)). The minimum time for oil accumulation at the low threshold was 0.21 days (East Arm) for the dry season and 0.17 days (East Arm) during the wet season conditions.
- There was no exposure predicted for the moderate and high dissolved hydrocarbon thresholds. The maximum distances to the low threshold exposure zones during the dry and wet seasons were 3.9 km and 12.2 km north northwest, respectively. Exposure was limited to the 0 – 10 m depth layer.
- There was no exposure to any receptor during the dry season. Under wet season conditions, 3 receptors had recorded exposure at the low threshold (Ham Luong and Mauna Loa USAT shipwreck, and Outer Harbour WQ Zone) and the probabilities ranged between 1 and 6%. The maximum instantaneous dissolved concentrations were 9 ppb and 21 ppb predicted at the Mauna Loa USAT shipwreck during dry and wet seasons, respectively.

- The maximum distances travelled by entrained hydrocarbons within the 0 – 10 m depth layers at the low and moderate thresholds, which ranged between 36.1 km and 23.9 km northwest from the release location.

- For both seasons assessed, the Charles Point Wide RFPA and four Restricted Areas (1, 4, 5 and 6) were predicted to be exposed to entrained hydrocarbons at the low threshold with probabilities ranging from 45 – 97% and 5 – 69% during the dry and wet seasons, respectively. During both seasons Restricted Area 6 was predicted to have the greatest probability of low threshold exposure (97% and 69%). The maximum instantaneous concentrations were predicted at Outer Harbour during both the dry (436 ppb) and wet (677 ppb) seasons.

Scenario 3 – Vessel to Vessel Refuelling at KP 114 (10 m^3 of marine diesel oil)

- Floating oil exposure zones to the low and moderate thresholds were limited to 22.9 km (northwest) and 12.5 km (northwest), respectively during dry season conditions. There was no exposure predicted for the high threshold.
- During the dry and wet seasons the probability of oil accumulation at the low threshold was 58%, and the minimum time was 0.25 days and 0.29 days, respectively. The maximum volume ashore for a single spill ranged between 3.9 m^3 (dry season) and 4.3 m^3 (wet season). The maximum length of shoreline contacted at the low threshold was 9 km for the two seasons.
- The West Arm (49% dry and 28% wet conditions) and East Arm (8% dry and 26% wet seasons) shorelines recorded the highest probability of oil accumulation at the low threshold. The minimum time

before the accumulation was 0.29 days (Middle Arm and West Arm) during the dry season and 0.25 days (East Arm and Wickham Point) during the wet season conditions.

- There was no dissolved hydrocarbon exposure predicted for any spills during this scenario at or above the low threshold (≥ 10 ppb).
- Entrained hydrocarbons within the 0 – 10 m depth layers for the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds, were predicted to range between 32 km and 19.6 km northwest.
- The highest probability of entrained hydrocarbon exposure was predicted at Ham Luong (61%) and Mauna Loa USAT (64%) shipwrecks during dry and wet seasons conditions. The maximum entrained concentrations were also predicted Ham Luong (745 ppb) and Mauna Loa USAT (639 ppb) shipwrecks for the two seasons. Also, there were four WQ Zones predicted to be exposed to entrained hydrocarbons at the low threshold during both seasons with probabilities ranging from 6% (East Arm) and 36% (Outer Harbour) during the dry season and 7% (Middle Arm) and 30% (Outer Harbour) during the wet season.

Scenario 4 – Vessel Fuel Tank Rupture at KP114 (300 m^3 of marine diesel oil)

- Floating oil exposure zones to the low, moderate and high thresholds were limited to 33.4 km (northwest; wet season), 19.6 km (northwest; dry season) and 10.2 km (north-northwest; dry season), respectively.
- The probability of shoreline accumulation at, or above, the low threshold (10 g/m^2) was 100% (dry season) and 91% (wet season). The minimum time before oil accumulation at, or above, the low threshold was 0.21 days during dry and wet seasons. The maximum volume ashore for a single spill during the dry and wet season was 114.8 m^3 and 115.5 m^3, respectively, and the maximum length of shoreline contacted at the low threshold was 57.7 km (dry season) and 54.2 km (wet season).
- The highest probability of oil accumulation at the low threshold was predicted along the West Arm (88% dry and 49% wet seasons) and East Arm (44% dry and 60% wet conditions) shorelines. The highest volume of oil accumulation during the dry and wet seasons occurred along the West Arm shoreline (103.5 m^3 (dry season) and 111.7 m^3 (wet season)).
- The maximum distances travelled by dissolved hydrocarbons from the release location to the low (≥ 10 ppb) exposure zone was 12.8 km (dry season) and 20.0 km (wet season), whilst distances were reduced to 0.6 km (dry season) and 7.3 km (wet season) for the moderate (≥ 50 ppb) exposure threshold. Exposure was limited to the 0 – 10 m depth layer. No exposure was predicted for the high (≥ 400 ppb) threshold.
- Dissolved hydrocarbon exposure at the low threshold was also predicted at shipwreck receptors during the dry (3) and wet seasons (5) with dry season probabilities ranging from 1 – 10% and wet season probabilities of exposure ranging between 2 – 17%. The greatest probability of low threshold exposure during the dry and wet season was predicted for Ham Luong and Mauna Loa USAT, respectively.
- The maximum distances travelled by entrained hydrocarbons from the release location to the low (≥ 10 ppb) exposure zone was 41.7 km (dry season) and 48.3 km (wet season), whilst distances were reduced to 30.3 km (dry season) and 32.4 km (wet season) for the moderate exposure threshold.
- During both seasons the Charles Point Wide RFPA and four Restricted Areas (1, 4, 5 and 6) were predicted to be exposed to entrained hydrocarbons at the low threshold with probabilities ranging from 14 – 99% and 50 – 94% during the dry and wet seasons, respectively. During both seasons, Restricted Area 6 was predicted to have the highest probability of exposure (99% and 94%).
- Exposure at the low threshold was predicted at 18 and 19 shipwreck receptors during the dry and wet season, respectively, with probabilities ranging from 5% (East Arm Vietnamese Refugee Boat 1) and 100% (Ham Luong, Mauna Loa USAT and Yu Han 22) during the dry season and 4% (Elizabeth River - unidentified wreck) and 95% (Ham Luong) during the wet season.

1 INTRODUCTION

1.1 Background

Santos is assessing environmental impacts and risks associated with the Darwin Pipeline Duplication (DPD) Project. The DPD Project involves the installation of a gas export pipeline (GEP) from a point (kilometre point (KP) 0) in Commonwealth waters (25km from the Commonwealth/ NT waters boundary) to the Darwin LNG (DLNG) facility on Wickham Point in Darwin Harbour (KP122.2). The pipeline will transfer dry gas from the offshore Barossa field to the DLNG facility. The new pipeline (nearshore Barossa GEP) would run alongside the existing Bayu-Undan (BU) to Darwin GEP, typically within 50-100m, thereby effectively duplicating that pipeline.

To support the environmental risk assessment and approval requirements for the DPD Project, including the development of management plans, an oil spill modelling study was undertaken which considered the following four scenarios:

- **Scenario 1** – An offshore pipelay vessel fuel tank rupture at KP91.5 resulting in the release of 700 m^3 of marine diesel oil (MDO) on the surface over 6 hours;
- **Scenario 2** – A vessel fuel tank rupture at KP114 resulting in the release of 87.5 m^3 MDO on the surface over 6 hours;
- **Scenario 3** – An instantaneous surface spill of 10 m^3 of MDO due to a vessel to vessel refuelling incident within the harbour at KP114; and
- **Scenario 4** – A vessel fuel tank rupture at KP114 resulting in the release of 300 m^3 MDO on the surface over 6 hours.

Table 1.1 presents the coordinates of each location and Figure 1.1 is the location map.

The potential risk of exposure to the surrounding waters and contact to shorelines was assessed for wet (November to April) and dry (May to October) seasons.

The purpose of the modelling is to provide an understanding of the conservative ‘outer envelope’ of the potential area that may be affected in the unlikely event of a vessel-based spill. Since the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities that would be implemented in response to the spill, the results presented herein are conservative.

The spill modelling was performed using an advanced three-dimensional trajectory and fates model; Spill Impact Mapping and Assessment Program (SIMAP). The SIMAP model calculates the transport, spreading, entrainment and evaporation of spilled hydrocarbons over time, based on the prevailing wind and current conditions and the physical and chemical properties.

Note that the oil spill model, method and analysis presented herein uses modelling algorithms which have been anonymously peer reviewed and published in international journals. Furthermore, RPS warrants that this work meets and exceeds the American Society for Testing and Materials (ASTM) Standard F2067-13 “*Standard Practice for Development and Use of Oil Spill Models*” (ASTM, 2013).

Table 1.1 Release locations for the Barossa DPD oil spill modelling study.

Scenario	Identifier	Easting (S)	Northing (E)	Water Depth (LAT m)
1	KP91.5	681,788.21	8,635,852.42	17.1
2, 3 & 4	KP114	696,972.89	8,619,537.48	19.44

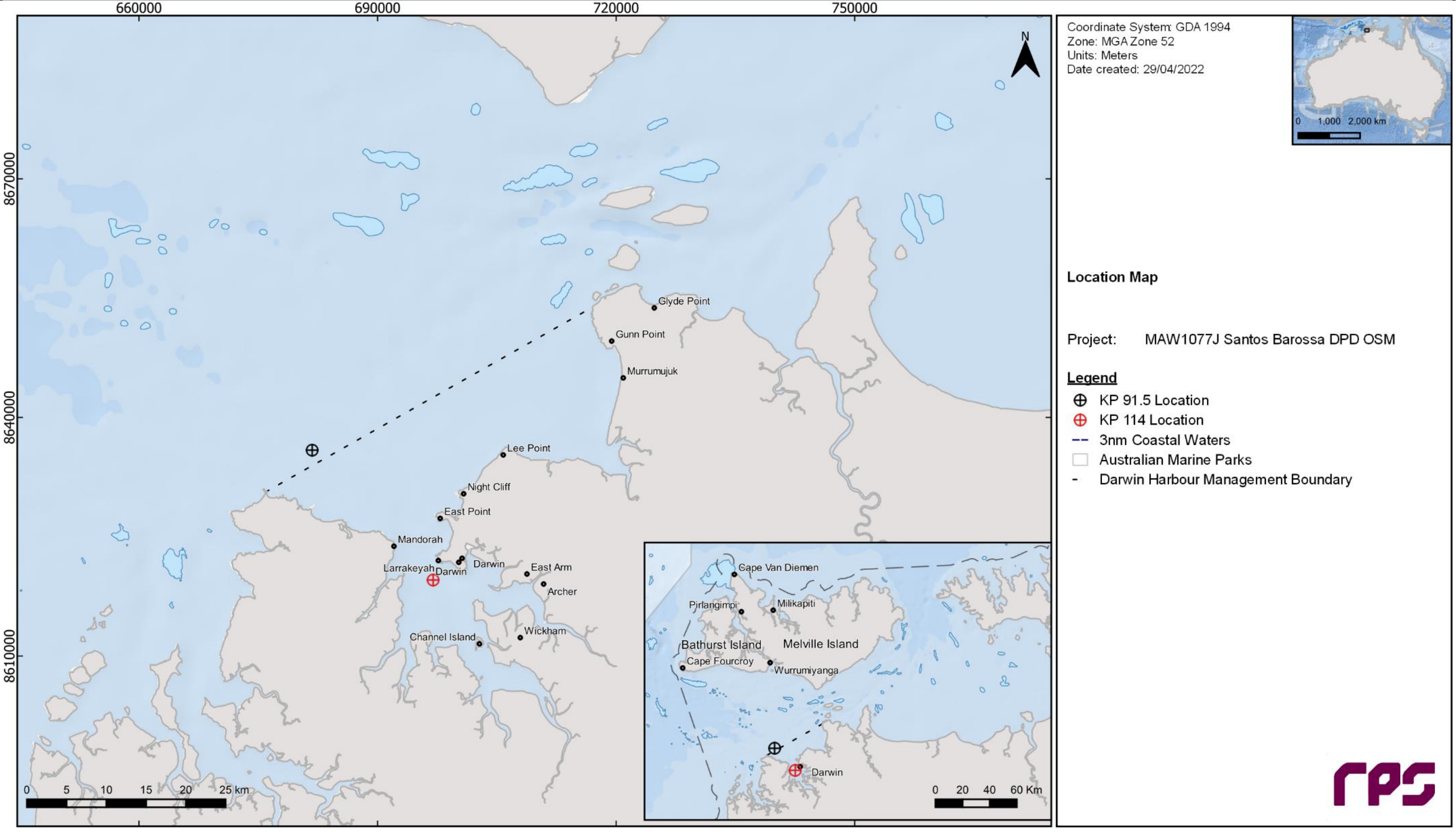


Figure 1.1 Release locations for the Barossa DPD oil spill modelling study.

1.2 What is Oil Spill Modelling?

Oil spill modelling is a valuable tool widely used for risk assessment, emergency response and contingency planning where it can be particularly helpful to proponents and decision makers. By modelling a series of the most likely oil spill scenarios, decisions concerning suitable response measures and strategic locations for deploying equipment and materials can be made, and the locations at most risk can be identified. The two types of oil spill modelling often used are stochastic (Section 1.2.1) and deterministic (Section 1.2.2) modelling.

1.2.1 Stochastic Modelling (Multiple Spill Simulations)

Stochastic oil spill modelling is created by overlaying a great number (often hundreds) of individual, computer-simulated hypothetical spills (NOPSEMA, 2018; Figure 1.2).

Stochastic modelling is a common means of assessing the potential risks from oil spills related to new projects and facilities. Stochastic modelling typically utilises hydrodynamic data for the location in combination with historic wind data. Typically, 100 iterations of the model will be run utilising the data that is most relevant to the season or timing of the project.

The outcomes are often presented as a probability of exposure and is primarily used for risk assessment purposes in view to understand the range of environments that may be affected or impacted by a spill. Elements of the stochastic modelling can also be used in oil spill preparedness and planning.

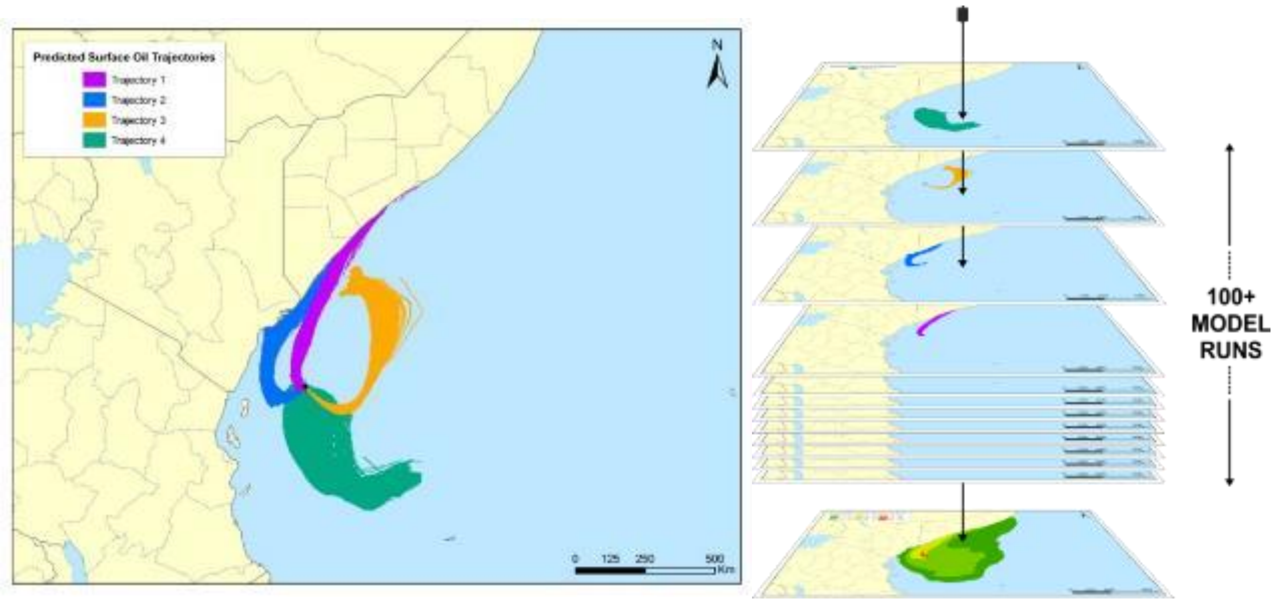


Figure 1.2 Examples of four individual spill trajectories (four replicate simulations) predicted by SIMAP for a spill scenario. The frequency of contact with given locations is used to calculate the probability of impacts during a spill. Essentially, all model runs are overlain (shown as the stacked runs on the right) and the number of times that trajectories contact a given location at a concentration is used to calculate the probability.

1.2.2 Deterministic Modelling (Single Spill Simulation)

Deterministic modelling is the predictive modelling of a single incident subject to a single sample of wind and weather conditions over time (NOPSEMA, 2018; Figure 1.3).

Deterministic modelling is often paired with stochastic modelling to place the large stochastic footprint into perspective. This deterministic analysis is generally a single run selected from the stochastic analysis and serves as the basis for developing the plans and equipment needs for a realistic spill response. Deterministic spills can be selected based on parameters such as minimum time to shoreline, largest swept area, maximum volume ashore and longest length of shoreline contacted by oil.

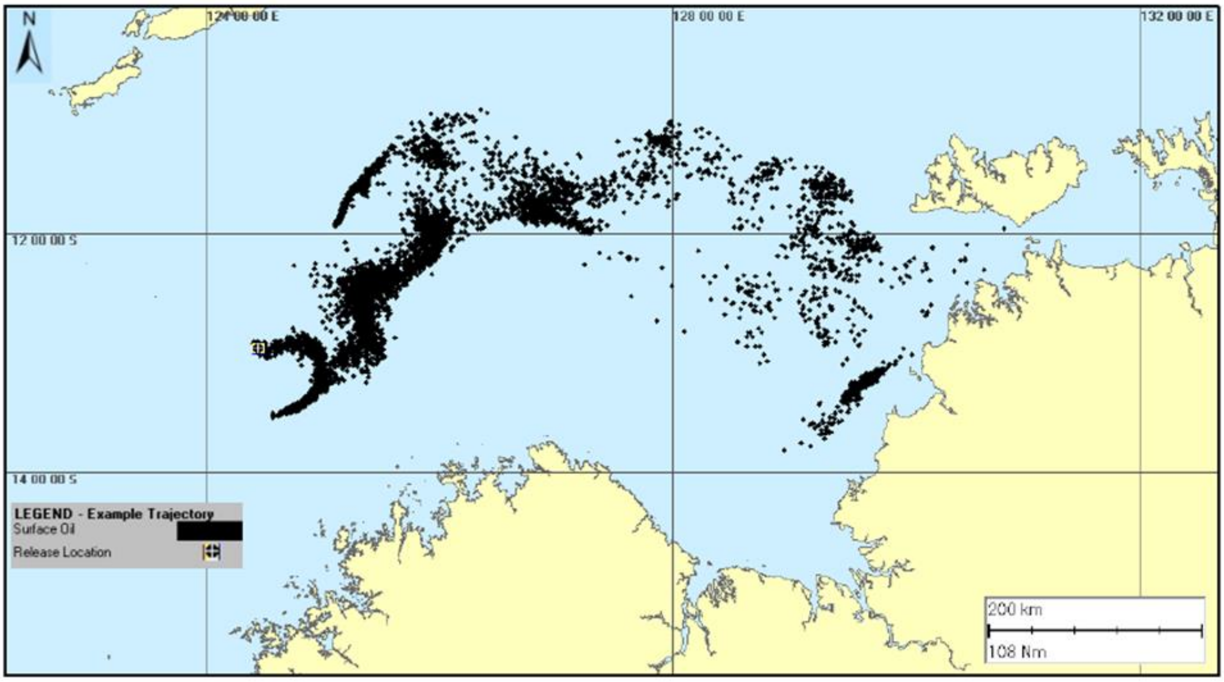


Figure 1.3 Example of an individual spill trajectory predicted by SIMAP for a spill scenario. Note, this image represents surface oil and does not take any thresholds into consideration.

2 SCOPE OF WORK

The scope of work included the following components:

1. Generate 2 years (2019 – 2020) of wind and high-resolution current data covering Darwin Harbour and the Beagle Gulf representing the complex tidal flows, in addition to the tidal wetting and drying of intertidal zones;
2. Include the wind and current data and the MDO characteristics as input into the three-dimensional oil spill model, SIMAP, to model the movement, spreading, weathering and shoreline accumulation by hydrocarbons over time;
3. For each scenario, run 100 oil spill simulations per season (200 total per scenario), with each simulation having the same spill information (spill volume, duration and composition of hydrocarbons) but varying start times. This ensured that each spill trajectory was subjected to a unique set of wind and current conditions;
4. Combine the results from the 100 spill trajectories (per season) to determine the probability and level of exposure to the waters and shorelines for defined thresholds;
5. Present the combined results from the 200 spill simulations, per scenario, to assess the low threshold environment that maybe affected (EMBA); and
6. From the 200 simulations modelled for each scenario, identify and present the “worst case” deterministic run resulting in the maximum volume of oil ashore.

3 CURRENTS

3.1 Development of Regional Current Data

To simulate the hydrodynamics within Darwin Harbour and Beagle Gulf, a three-dimensional model was setup which accounted for tidal and oceanic currents, bathymetry, bottom roughness and wind stress. The model framework was developed through the combination of a large-scale regional model with smaller refined regions, or sub-domains. The D-FLOW model is ideally suited to represent the hydrodynamics of complex coastal waters, including regions where the tidal range creates large intertidal zones.

The three-dimensional simulations were generated using a rectangular grid in the horizontal with a series of interconnected (two-way, dynamically-nested) grids of varying resolution; a technique referred to as “domain decomposition”. This allows for the generation of a series of grids with progressively increasing spatial resolution, down to an appropriate scale for accurate resolution of the hydrodynamics to resolve flows more accurately along the coastline, around islands and over regions with more complex bathymetry. The main advantage of domain decomposition over traditional one-way, or static, nesting systems is that the model domains interact seamlessly, allowing transport and feedback between the regions of different scales. The ability to dynamically couple multiple model domains offer a flexible framework for hydrodynamic model development. In the vertical, a sigma-coordinate approach was employed to divide the water column into a series of layers.

D-FLOW allows for the establishment of a:

- Detailed bathymetry of the study area with wetting and drying of the intertidal zones simulated in applicable areas;
- Boundary elevation forcing data in the form of water levels representing the tides was sourced from the TPXO8.0 database, which is derived from sea-surface topography measurement by the TOPEX/Poseidon satellite-borne radar altimeters; TOPEX). While elevation data representing the ocean currents sourced from Hybrid Coordinate Ocean Model (HYCOM); and
- Spatially-varying surface wind data.

3.2 Grid Setup

To optimise the computational effort required for a large, multi-layered model domain, and to achieve adequate horizontal and temporal resolution, a multiple-grid (domain-decomposition) strategy was applied using five sub-domains of varying horizontal grid cell size (Figure 3.1). The horizontal resolution within Darwin Harbour was 80 m (sub-grid 4), 240 m for the intermediate region (sub-grid 3), 720 m, 2.2 km and 6.5 km for the outer domains (sub-grids 2, 1 and 0, respectively).

A combination of datasets was used and merged to describe the shape of the seabed within Darwin Harbour and the intermediate area, including spot depths and contours which were digitised from nautical charts released by the hydrographic offices. For the outer domains, depths extracted from the General Bathymetric Chart of the Oceans (GEBCO) dataset on a 15 arc-second interval grid was used.

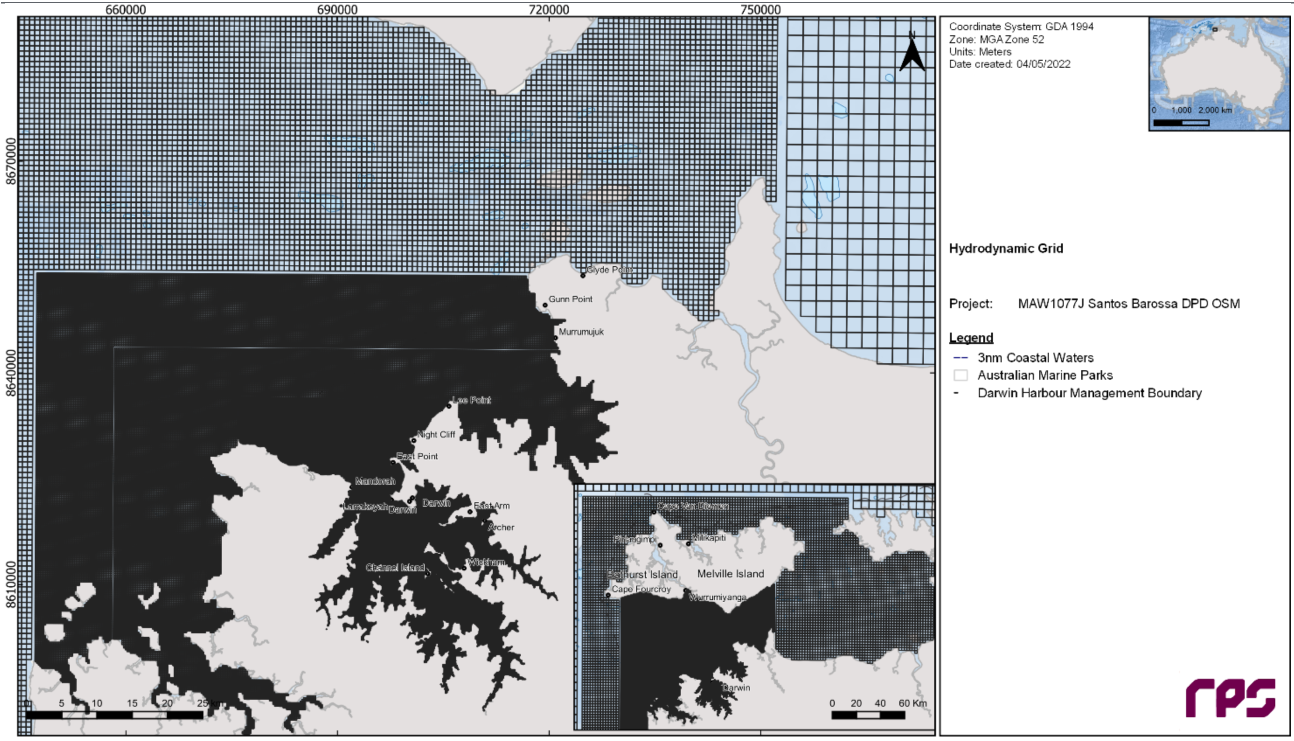


Figure 3.1 Detail of the hydrodynamic model grid.

3.3 Boundary Conditions

3.3.1 Overview

While the hydrodynamics in Darwin Harbour are controlled primarily by tidal flows, oceanic and wind forcing were explicitly included to account for the conditions beyond the port limits.

The model was forced on the open boundaries of the outer sub-domain with time series of water elevation obtained for the chosen simulation period. Spatial and temporal variation in wind forcing across the entire domain was accounted for by applying spatially-varying wind speed and wind direction data that varied over time.

3.3.1.1 Water Elevation

Water elevations at hourly intervals were obtained from the TPXO8.0 database, which is derived from measurements of sea-surface topography by the TOPEX/Poseidon satellite-borne radar altimeters. Tides are provided as complex amplitudes of earth-relative sea-surface elevation for eight primary (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1), two long-period (M_f, M_m) and three non-linear (M_4, MS_4, MN_4) harmonic constituents at a spatial resolution of 0.25°.

The tidal sea level data was augmented with non-tidal (or oceanic) sea level elevation data from the global Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet *et al.*, 2007, 2009; Halliwell, 2004), created by the USA's National Ocean Partnership Program (NOPP) as part of the Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite instrumentation, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density, sea height variations and the rotation of the Earth. The model has a global coverage with a horizontal resolution of 1/12th of a degree (~7 km at mid-latitudes) and a temporal resolution of 24 hours.

3.3.1.2 Wind Forcing

Wind forcing was included in the hydrodynamic model as a boundary condition to capture its effect on water currents. For this model, wind data was sourced from the National Center for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha *et al.*, 2010). The CFSR wind model includes observations from many data sources: surface observations, upper-atmosphere air balloon observations, aircraft observations and satellite observations. The model is capable of accurately representing the interaction between the earth’s oceans, land and atmosphere. The gridded wind data output is available at a horizontal resolution of 0.25° (~33 km) and a temporal resolution of 1 hour.

3.4 Surface Currents

Table 3.1 displays the predicted monthly average and maximum combined surface current speeds adjacent to the release locations. The surface modelled current speeds were relatively consistent ranging from 0.39 m/s to 0.42 m/s at KP91.5 and 0.33 m/s to 0.36 m/s (KP114). The dominant current directions at KP91.5 and KP114 were along the east-southeast to west-northwest axis and south-southeast to north-northwest axis, respectively. In addition, the maximum monthly current speeds ranged from 1.08 m/s to 1.23 m/s (KP91.5) and 1.07 m/s and 1.33 m/s (KP114).

Figure 3.2 and Figure 3.3 present the monthly and total surface current rose distributions from 2019 – 2020 (inclusive), respectively. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. The rose branches are each divided into segments of different colour according to speed intervals of 0.1 m/s, which represent current speeds within the monthly or seasonal datasets, respectively. The length of each coloured segment (indicative of speeds) is relative to the proportion of time the currents flow in that direction.

Table 3.1 Summary of the predicted average and maximum surface current speeds adjacent to the KP91.5 and KP 114 release locations, derived from the modelled 2019 – 2020 dataset.

Season		KP91.5 (Scenario 1)			KP114 (Scenario 2, 3 and 4)		
	Month	Average current speed (m/s)	Maximum current speed (m/s)	General direction(s) (towards)	Average current speed (m/s)	Maximum current speed (m/s)	General direction(s) (towards)
Wet	January	0.39	1.17	East-southeast and west-northwest	0.33	1.18	South-southeast and north-northwest
	February	0.41	1.14		0.35	1.20	
	March	0.40	1.16		0.35	1.26	
	April	0.41	1.15		0.35	1.33	
Dry	May	0.39	1.19		0.33	1.27	
	June	0.39	1.13		0.33	1.16	
	July	0.39	1.08		0.33	1.07	
	August	0.40	1.12		0.34	1.15	
	September	0.41	1.15		0.36	1.29	
	October	0.42	1.19		0.36	1.30	
Wet	November	0.40	1.23		0.34	1.31	
	December	0.39	1.16		0.33	1.21	
	Minimum	**0.39**	**1.08**		**0.33**	**1.07**	
	Maximum	**0.42**	**1.23**		**0.36**	**1.33**	

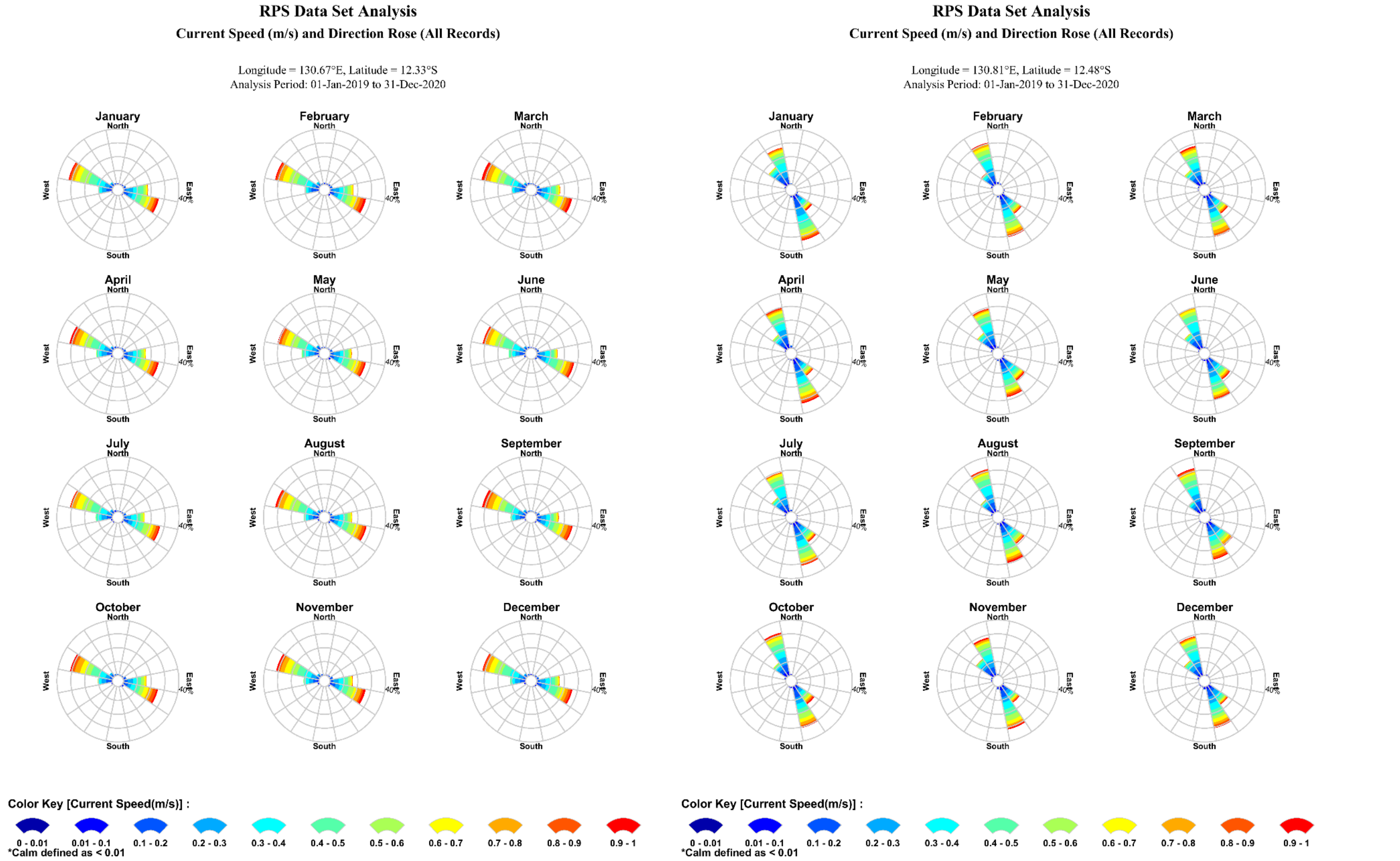
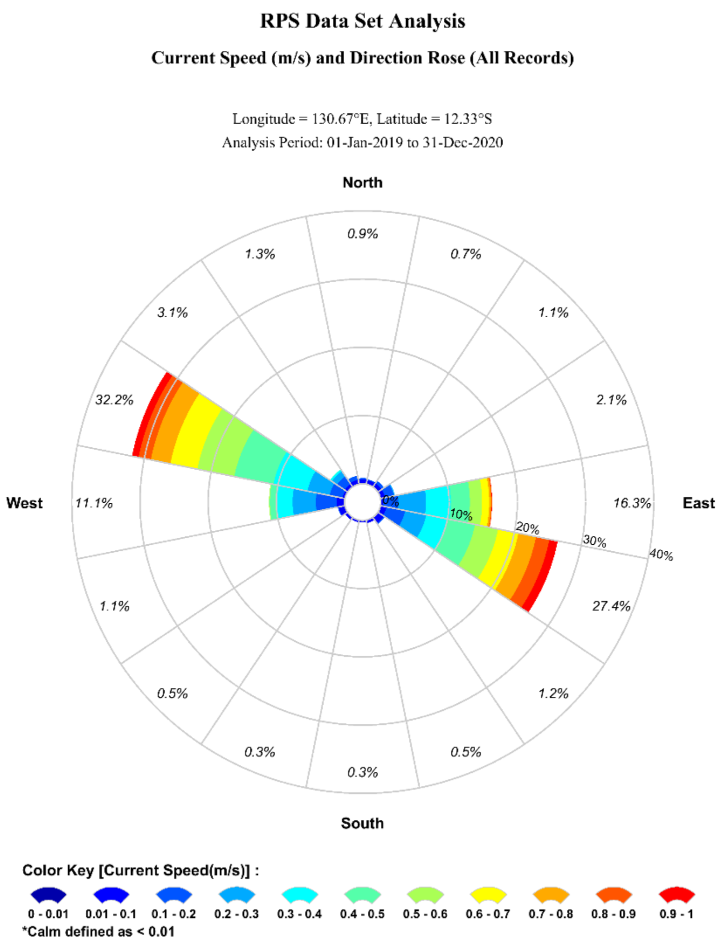


Figure 3.2 Monthly surface current rose distributions from 2019 – 2020 (inclusive), for the closest current nodes to the KP91.5 (left) and KP 114 (right) release locations, derived from the modelled dataset.



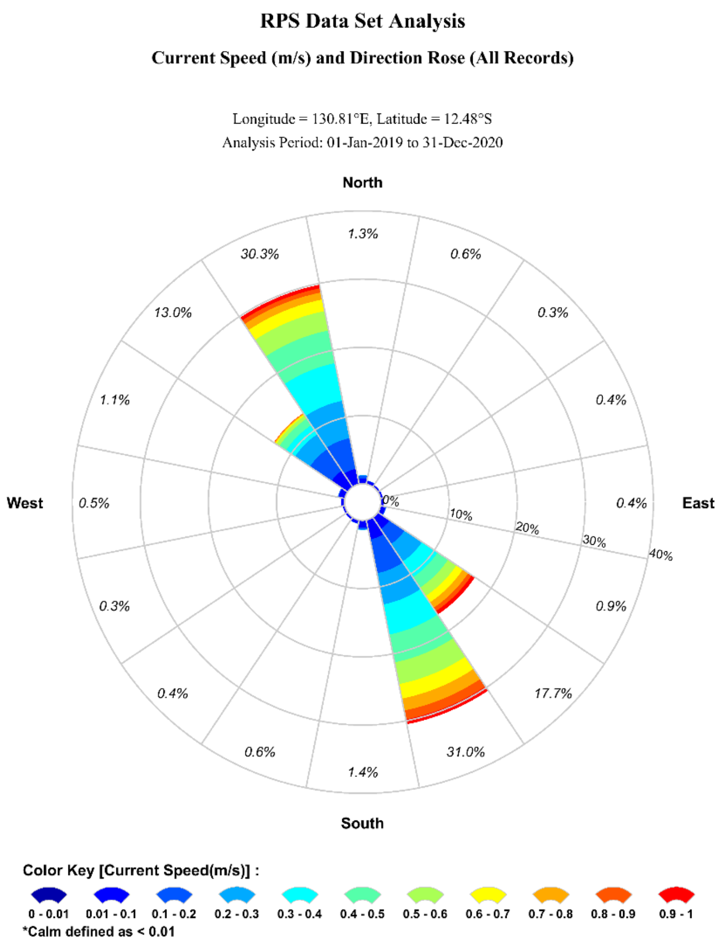


Figure 3.3 **Total surface current rose distributions from 2019 – 2020 (inclusive), for the closest current nodes to the KP91.5 (left) and KP 114 (right) release locations, derived from the modelled dataset.**

4 WIND DATA

To account for the influence of the wind on the floating oil, the wind conditions between 2019 – 2020 (inclusive) was sourced from the CFSR model (see Section 3.3.1.2). Table 4.1 presents the monthly average and maximum winds derived from a CFSR wind node closest to the release locations. Monthly average wind speeds ranged from 7.1 to 13.5 knots at KP91.5 and 17.5 to 28.2 knots at KP114, while monthly maximums ranged from 17.3 to 29.2 knots at KP91.5 and 17.5 to 28.2 knots at KP114. The wind direction varied between the months, with the winds blowing generally from the west during the wet season and east-southeast during the dry season at both locations.

Figure 4.1 and Figure 4.2 show the monthly and total wind rose distributions derived from the nearest wind node to the KP91.5 release location. Plots for KP114 are not presented as they are identical to KP91.5. Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows from, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent wind speed ranges from that direction. Speed ranges of 3 knots are predominantly used in these wind roses. The length of each segment within a branch is proportional to the frequency of winds blowing within the corresponding range of speeds from that direction.

Table 4.1 Summary of the predicted average and maximum winds for the nearest CFSR wind nodes to the KP91.5 and KP 114 release locations, derived from CFSR hindcast model from 2019 – 2020 (inclusive).

Season	Month	KP91.5 (Scenario 1)			KP114 (Scenario 2, 3 and 4)		
		Average wind speed (knots)	Maximum wind speed (knots)	General direction (from)	Average wind speed (knots)	Maximum wind speed (knots)	General direction (from)
Wet	January	11.9	29.2	West	11.3	28.2	West
	February	13.5	28.5	West	12.9	27.4	West
	March	8.3	22.9	West	7.9	22.0	West
	April	7.9	28.2	East	7.6	25.7	East
Dry	May	10.8	25.0	East-southeast	10.2	23.5	East-southeast
	June	9.9	23.2	East-southeast	9.4	21.7	East-southeast
	July	8.9	24.3	East-southeast	8.5	22.9	East-southeast
	August	7.9	22.2	Variable	7.6	21.1	Variable
	September	7.1	17.6	Variable	6.9	18.2	Variable
	October	7.2	17.3	West	6.8	17.5	West
Wet	November	7.9	18.5	West	7.4	19.4	West
	December	8.5	22.9	West	8.1	21.7	West
	Minimum	**7.1**	**17.3**		**6.8**	**17.5**	
	Maximum	**13.5**	**29.2**		**12.9**	**28.2**	

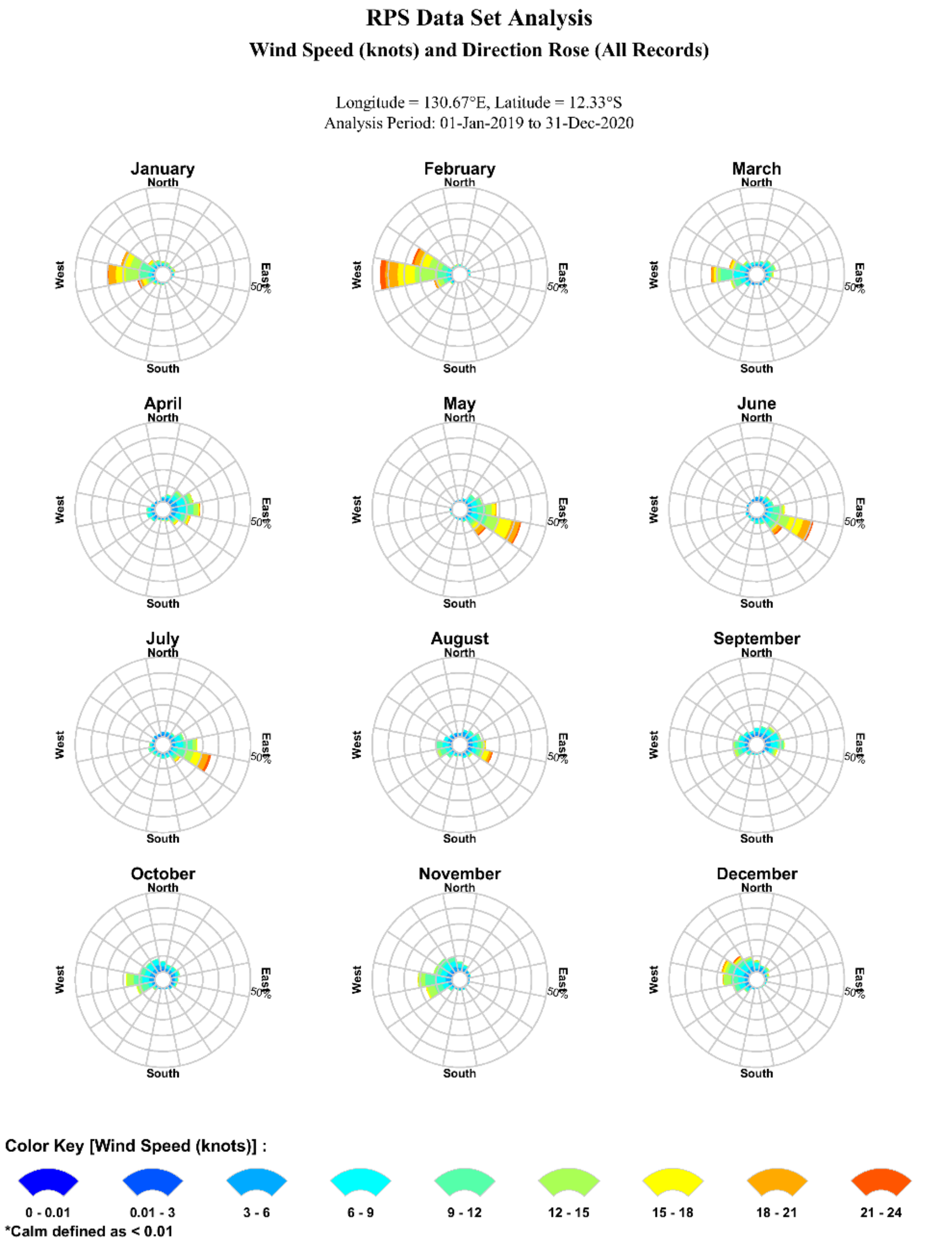


Figure 4.1 Monthly wind rose distributions from 2019 – 2020 (inclusive), for the closest wind node to KP91.5 release location, derived from CFSR hindcast model.

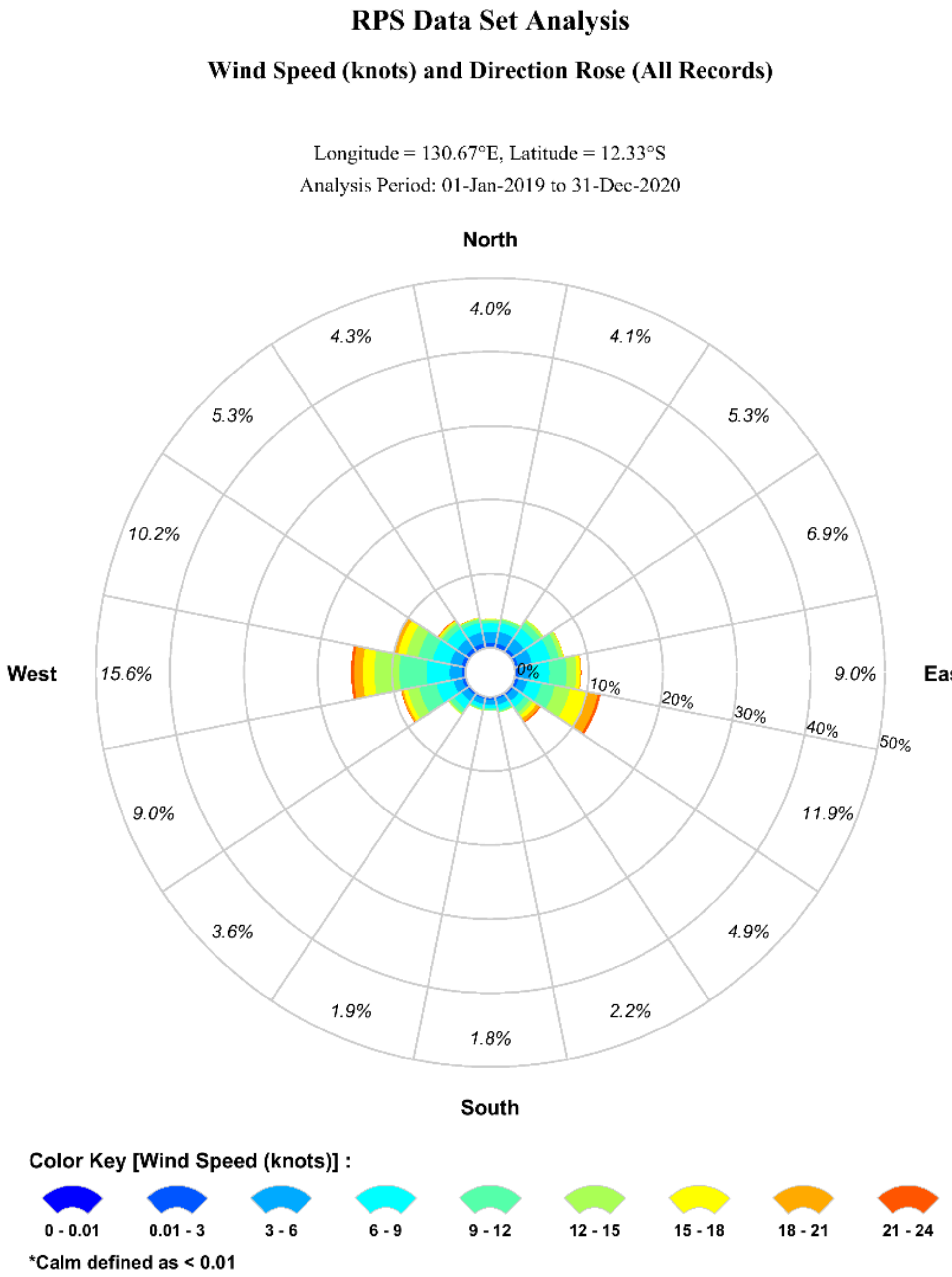


Figure 4.2 Total wind rose distributions from 2019 – 2020 (inclusive), for the closest wind node to KP91.5 release location, derived from CFSR hindcast model.

5 WATER TEMPERATURE AND SALINITY

Table 5.1. provides a summary of the monthly mean sea surface temperature and salinity values in the 0 – 5 m depth layer at the release locations. The temperature and salinity data throughout the water column was obtained from the World Ocean Atlas 2018 database produced by the National Oceanographic Data Centre (National Oceanic and Atmospheric Administration, NOAA) and its co-located World Data Centre for Oceanography (Levitus *et al.*, 2013). The data is used to inform the weathering, movement and evaporative loss of hydrocarbon spills in the surface and subsurface layers.

The monthly average sea surface temperatures ranged between 26.0°C (July) and 30.9°C (December) at KP91.5. While the sea surface temperatures at KP114 ranged between 24.4°C (June) and 31.0°C (December). The monthly average salinity values remain relatively consistent between the two locations (between 33.6 psu to 34.7 psu at KP91.5; and between 32.9 psu to 34.8 psu at KP114). The data align with the Darwin Harbour water quality monitoring program (https://depws.nt.gov.au/water/water-management/darwin-harbour/darwin-harbour-region-report-cards/2018-report-cards).

Table 5.1 Monthly average sea surface temperature and salinity adjacent to the KP91.5 and KP114 release locations.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
KP91.5	Temperature (ºC)	30.1	30.6	30.6	30.3	28.7	26.3	26.0	26.7	28.7	30.1	30.4	30.9
	Salinity (psu)	33.7	33.7	33.6	33.6	34.1	34.5	34.5	34.5	34.2	34.5	34.7	34.7
KP114	Temperature (ºC)	29.9	30.6	30.5	30.1	28.2	24.4	25.2	26.2	28.8	30.2	30.6	31.0
	Salinity (psu)	33.1	33.0	32.9	33.5	34.2	34.5	34.5	34.6	34.2	34.5	34.8	34.6

6 OIL SPILL MODEL – SIMAP

The spill modelling was carried out using a purpose-developed oil spill trajectory and fates model, SIMAP. This model is designed to simulate the transport and weathering processes that affect the outcomes of hydrocarbon spills to the sea, accounting for the specific oil type, spill scenario, and prevailing wind and current circulation patterns.

SIMAP is the evolution of the United States Environmental Protection Agency (US EPA) Natural Resource Damage Assessment model (French & Rines, 1997; French *et al.*, 1999) and is designed to simulate the fate and effects of spilled oils and fuels for both the surface slick and the three-dimensional plume that is generated in the water column. SIMAP includes algorithms to account for both physical transport and weathering processes. The latter are important for accounting for the partitioning of the spilled mass over time between the water surface (surface slick), water column (entrained oil and dissolved compounds), atmosphere (evaporated compounds) and land (stranded oil). The model also accounts for the interaction between weathering and transport processes.

The physical algorithms calculate transport and spreading by physical forces, including surface tension, gravity and wind and current forces for both surface slicks and oil within the water column. The fates algorithms calculate all the weathering processes known to be important for oil spilled to marine waters. These include droplet and slick formation, entrainment by wave action, emulsification, dissolution of soluble components, sedimentation, evaporation, bacterial and photo-chemical decay and shoreline interactions. These algorithms account for the specific oil type being considered.

Entrainment is the physical process where globules of oil are transported from the sea surface into the water column by wind and wave-induced turbulence or be generated subsea by a pressurised discharge at depth. It has been observed that entrained oil is broken into droplets of varying sizes. Small droplets spread and diffuse into the water column, while larger ones rise rapidly back to the surface (Delvigne & Sweeney, 1988; Delvigne, 1991).

Dissolution is the process by which soluble hydrocarbons enter the water from a surface slick or from entrained droplets. The lower molecular weight hydrocarbons tend to be both more volatile and more soluble than those of higher molecular weight.

The formation of water-in-oil emulsions, or mousse, which is termed ‘emulsification’, depends on oil composition and sea state. Emulsified oil can contain as much as 80% water in the form of micrometre-sized droplets dispersed within a continuous phase of oil (Daling & Brandvik, 1991; Bobra, 1991; Daling *et al.*, 1997; Fingas, 1995, 1997).

Entrainment, dissolution and emulsification rates are correlated to wave energy, which is accounted for by estimating wave heights from the sustained wind speed, direction and fetch (i.e. distance downwind from land barriers) at different locations in the domain. Dissolution rates are dependent upon the proportion of soluble, short-chained hydrocarbon compounds, and the surface area at the oil/water interface of slicks. Dissolution rates are also strongly affected by the level of turbulence. For example, dissolution rates will be relatively high at the site of the release for a deep-sea discharge at high pressure.

Evaporation can result in the transfer of large proportions of spilled oil from the sea surface to the atmosphere, depending on the type of oil (Gundlach & Boehm, 1981). Evaporation rates vary over space and time dependent on the prevailing sea temperatures, wind and current speeds, the surface area of the slick and entrained droplets that are exposed to the atmosphere as well as the state of weathering of the oil. Evaporation rates will decrease over time, depending on the calculated rate of loss of the more volatile compounds. By this process, the model can differentiate between the fates of different oil types.

Decay (degradation) of hydrocarbons may occur as the result of photolysis, which is a chemical process energised by ultraviolet light from the sun, and by biological breakdown, termed biodegradation. Many types of marine organisms ingest, metabolise and utilise oil as a carbon source, producing carbon dioxide and water as by-products.

The SIMAP weathering algorithms include terms to represent these dynamic processes. Technical descriptions of the algorithms used in SIMAP and validations against real spill events are provided in French (1998), French *et al.*, (1999) and French-McCay (2004).

Input specifications for oil types include density, viscosity, pour-point, distillation curve (volume of oil distilled off versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges. The model calculates a distribution of the oil by mass into the following components:

- Surface-bound or floating oil;
- Entrained oil (non-dissolved oil droplets that are physically entrained by wave action);
- Dissolved hydrocarbons (principally the aromatic and short-chained aliphatic compounds);
- Evaporated hydrocarbons;
- Sedimented hydrocarbons; and
- Decayed hydrocarbons.

7 OIL PROPERTIES

Table 7.1 and Table 7.2 present the physical properties and boiling point ranges of the MDO used in this study. It has a density of 829.1 kg/m³ (API of 37.6) and a low pour point of -14°C. The low viscosity (4 cP) indicates that this oil will spread quickly when released and will form a thin to low thickness film on the sea surface, increasing the rate of evaporation.

Generally, about 6.0% of the MDO mass should evaporate within the first 12 hours (Boiling point (BP) < 180°C); a further 34.6% should evaporate within the first 24 hours (180°C < BP < 265°C); and an additional 54.4% should evaporate over several days (265°C < BP < 380°C). Approximately 5% (by mass) of MDO will not evaporate though will decay slowly over time.

The oil is categorised as a group II oil (light-persistent) according to the International Tankers Owners Pollution Federation (ITOPF, 2014) and US EPA/USCG classifications. The classification is based on the specific gravity of hydrocarbons in combination with relevant boiling point ranges.

It is important to note that some heavy components contained in MDO have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but can re-float to the surface if these energies abate.

Table 7.1 Physical properties of the MDO

Characteristic	Marine Diesel Oil (MDO)
Density (kg/m³)	829.1 (at 25 °C)
API	37.6
Dynamic viscosity (cP)	4.0 (at 25 °C)
Pour point (°C)	-14
Hydrocarbon property category	Group II
Hydrocarbon property classification	Light - Persistent

Table 7.2 Boiling point ranges of the MDO

Oil Type	Component	Volatile (%)	Semi-volatile (%)	Low-volatility (%)	Residual (%)
	Boiling point (°C)	<180 C_4 to C_{10}	180-160 C_{11} to C_{15}	160-380 C_{16} to C_{20}	>380 >C_{20}
Marine diesel oil (MDO)	% of total	6.0	34.6	54.4	5.0

8 FLOATING, SHORELINE AND IN-WATER THRESHOLDS

The thresholds and their relationship to exposure for the sea surface, shoreline, and water column (entrained and dissolved hydrocarbons) are presented in Sections 8.1 to 8.3. Supporting justifications of the adopted thresholds applied during the study and additional context relating to the area of influence are also provided. It is important to note that the thresholds herein are based on NOPSEMA (2019).

8.1 Floating Oil Exposure Thresholds

The modelling results can be presented to any levels; therefore, thresholds have been specified (based on scientific literature) to record floating oil exposure to the sea-surface at meaningful levels only, described in the following paragraphs.

The low threshold to assess the potential for floating oil exposure, was 1 g/m^2, which equates approximately to an average thickness of 1 µm, referred to as visible oil. Oil of this thickness is described as rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement, 2009; AMSA, 2014) (see Table 8.1). Table 8.1 provides a description of the appearance in relation to exposure zone thresholds used to classify the zones of floating oil exposure. Figure 8.1 shows photographs highlighting the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen. The low threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to its visibility on the sea surface and potential to trigger temporary closures of areas (i.e., fishing grounds) as a precautionary measure.

Ecological impact has been estimated to occur at 10 g/m^2 (a film thickness of approximately 10 µm or 0.01 mm) (French *et al.*,1996 and French-McCay 2009) as this level of fresh oiling has been observed to mortally impact some birds through adhesion of oil to their feathers, exposing them to secondary effects such as hypothermia. The appearance of oil at this average thickness has been described as a metallic sheen (Bonn Agreement, 2009). Concentrations above 10 g/m^2 is also considered the lower actionable threshold, where oil may be thick enough for containment and recovery as well as dispersant treatment (AMSA, 2015).

Oil concentrations on the sea surface of 25 g/m^2 (or greater) would be harmful for all birds that have landed in an oil film due to potential contamination of their feathers, with secondary effects such as loss of temperature regulation and ingestion of oil through preening (Scholten *et al.*, 1996 and Koops *et al.*, 2004). The appearance of oil at this thickness is also described as metallic sheen (Bonn Agreement, 2009). For this study the high exposure threshold was set to 50 g/m^2 and above based on NOPSEMA (2019). This threshold can also be used to inform response planning.

Table 8.2 defines the thresholds used to classify the zones of floating oil exposure reported herein.

Table 8.1 The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (g/m^2 or µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	≥ 200	≥ 200,000

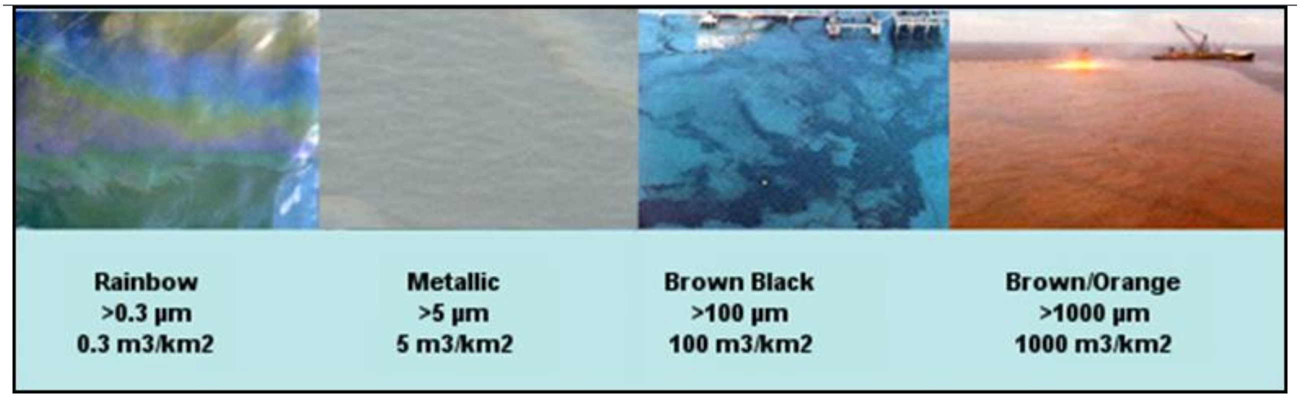


Figure 8.1 Photographs showing the difference between oil colour and thickness on the sea surface (source: adapted from Oil Spill Solutions, 2015).

Table 8.2 Floating oil exposure thresholds used in the Barossa DPD oil spill modelling study (in alignment with NOPSEMA, 2019).

Threshold level	Floating oil (g/m^2)	Description
Low	1	Approximates range of socio-economic effects and establishes planning area for scientific monitoring
Moderate	10	Approximates lower limit for harmful exposures to birds and marine mammals
High	50*	Approximates surface oil slick and informs response planning

* 50 g/m^2 also used to define the threshold for actionable floating oil.

8.2 Shoreline Accumulation Thresholds

There are many different types of shorelines, ranging from cliffs, rocky beaches, sandy beaches, mud flats and mangroves, and each of these influences the volume of oil that can remain stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow oil to percolate through the sand, thus increasing its ability to hold more oil ashore over tidal cycles and various wave actions than an equivalent area of water; hence oil can increase in thickness onshore over time. A sandy beach shoreline was assumed as the default shoreline type for the modelling in this study, as it allows for the highest carrying capacity of oil (of the available open/exposed shoreline types). Hence the results are considered conservative (i.e., worst-case) given that a large part of the shoreline in the study area (especially the western part of the Joseph Bonaparte Gulf) is characterised by exposed rocky shorelines, with southern parts characterised by tidal mudflats and mangroves and eastern shorelines containing more sandy beaches.

Previous risk assessment studies used a threshold of 10 g/m^2 to assess the potential for shoreline accumulation (French-McCay *et al.*,2005a; 2005b). This is a conservative threshold used to define regions of socio-economic impact, such as triggering temporary closures of adjoining fisheries or the need for shore clean-up on beaches or man-made features/amenities (breakwaters, jetties, marinas, etc.). It would equate to approximately 2 teaspoons of hydrocarbon per square meter of shoreline accumulation. The appearance is described as a stain/film. On that basis, the 10 g/m^2 shoreline accumulation threshold has been selected to define the zone of potential “low shoreline accumulation”.

French *et al.* (1996) and French-McCay (2009) define a shoreline oil accumulation threshold of 100 g/m^2, or above, would potentially harm shorebirds and wildlife (fur-bearing aquatic mammals and marine reptiles on or along the shore) based on studies for sub-lethal and lethal impacts. This threshold has been used in previous environmental risk assessment studies (see French-McCay, 2003; French-McCay *et al.*, 2004, French-McCay *et al.*, 2011; 2012; NOAA, 2013). Additionally, a shoreline concentration of 100 g/m^2, or above, is the minimum concentration that the oil can be effectively cleaned according to AMSA (2015). This threshold equates to approximately ½ a cup of oil per square meter of shoreline accumulation. The appearance is described as a thin oil coat. Therefore, 100 g/m^2 has been selected to define the zone of potential "moderate shoreline accumulation".

Observations by Lin & Mendelssohn (1996) demonstrated that loadings of more than 1,000 g/m^2 of hydrocarbon during the growing season would be required to impact marsh plants significantly. Similar thresholds have been found in studies assessing hydrocarbon impacts on mangroves (Grant *et al.*, 1993; Suprayogi & Murray, 1999). This loading equates to approximately 1 litre of hydrocarbon per square meter of shoreline accumulation and the appearance is described as a hydrocarbon cover. A loading of 1,000 g/m^2 has been selected to define the zone of potential "high shoreline accumulation".

These shoreline accumulation thresholds derived from extensive literature review (outlined in Table 8.3) align with the threshold values for oil spill modelling specified in NOPSEMA (2019).

Table 8.3 Shoreline accumulation thresholds used in the Barossa DPD oil spill modelling study (in alignment with NOPSEMA, 2019).

Threshold level	Shoreline loading(g/m^2)	Description
Low (socioeconomic/sublethal)	10	Predicts potential for some socio-economic impact
Moderate	100*	Loading predicts area likely to require clean-up effort
High	1,000	Loading predicts area likely to require intensive clean-up effort

* 100 g/m^2 also used to define the threshold for actionable shoreline oil.

8.3 In-water Exposure Thresholds

Oil is a mixture of thousands of hydrocarbons of varying physical, chemical, and toxicological characteristics, and therefore, demonstrate varying fates and impacts on organisms. As such, for in-water exposure, the SIMAP model provides separate outputs for dissolved and entrained hydrocarbons from oil droplets. The consequences of exposure to dissolved and entrained components will differ because they have different modes and magnitudes of effect.

Entrained hydrocarbon concentrations were calculated based on oil droplets that are suspended in the water column, though not dissolved. The composition of this oil would vary with the state of weathering (oil age) and may contain soluble hydrocarbons when the oil is fresh. Calculations for dissolved hydrocarbons specifically calculates oil components which are dissolved in water, which are known to be the primary source of toxicity exerted by oil.

A complicating factor that should be considered when assessing the consequence of dissolved and entrained oil distributions is that there will be some areas where both physically entrained oil droplets and dissolved hydrocarbons co-exist. Higher concentrations of each will tend to occur close to the source where sea conditions can force mixing of relatively unweathered oil into the water column, resulting in more rapid dissolution of soluble compounds.

8.3.1 Dissolved Hydrocarbons

Laboratory studies have shown that dissolved hydrocarbons exert most of the toxic effects of oil on aquatic biota (Carls *et al.*, 2008; Nordtug *et al.*, 2011; Redman, 2015). The mode of action is a narcotic effect, which is positively related to the concentration of soluble hydrocarbons in the body tissues of organisms (French-McCay, 2002). Dissolved hydrocarbons are taken up by organisms directly from the water column by absorption through external surfaces and gills, as well as through the digestive tract. Thus, soluble hydrocarbons are termed "bioavailable".

Hydrocarbon compounds vary in water-solubility and the toxicity exerted by individual compounds is inversely related to solubility, however bioavailability will be modified by the volatility of individual compounds (Nirmalakhandan & Speece, 1988; Blum & Speece, 1990; McCarty, 1986; McCarty *et al.*, 1992a, 1992b; McCarty & Mackay, 1993; Verhaar *et al.*, 1992, 1999; Swartz *et al.*, 1995; French-McCay, 2002; McGrath & Di Toro, 2009). Of the soluble compounds, the greatest contributor to toxicity for water-column and benthic organisms are the lower-molecular-weight aromatic compounds, which are both volatile and soluble in water.

Although they are not the most water-soluble hydrocarbons within most oil types, the polynuclear aromatic hydrocarbons (PAHs) containing 2 – 3 aromatic ring structures typically exert the largest narcotic effects because they are semi-soluble and not highly volatile, so they persist in the environment long enough for significant accumulation to occur (Anderson *et al.*, 1974, 1987; Neff & Anderson, 1981; Malins & Hodgins, 1981; McAuliffe, 1987; NRC, 2003). The monoaromatic hydrocarbons (MAHs), including the BTEX compounds (benzene, toluene, ethylbenzene, and xylenes), and the soluble alkanes (straight chain hydrocarbons) also contribute to toxicity, but these compounds are highly volatile, so that their contribution will be low when oil is exposed to evaporation and higher when oil is discharged at depth where volatilisation does not occur (French-McCay, 2002).

French-McCay (2002) reviewed available toxicity data, where marine biota was exposed to dissolved hydrocarbons prepared from oil mixtures, finding that 95% of species and life stages exhibited 50% population mortality (LC_{50}) between 6 and 400 ppb (with an average of 50 ppb) total PAH concentration after 96 hrs exposure. Therefore, concentrations lower than 6 ppb total PAH value should be protective of 97.5% of species and life stages even with exposure periods of days (at least 96 hours). Early life-history stages of fish appear to be more sensitive than older fish stages and invertebrates.

Exceedances of 10, 50 or 400 ppb over a 1-hour timestep (see Table 8.4) were applied in this study to indicate the increasing potential for sub-lethal to lethal toxic effects (or low to high), based on NOPSEMA (2019).

8.3.2 Entrained Hydrocarbons

Entrained hydrocarbons consist of oil droplets that are suspended in the water column and insoluble. Insoluble compounds in oil cannot be absorbed from the water column by aquatic organisms, therefore they are not bioavailable through absorption of compounds from the water. Exposure to these compounds would require routes of uptake other than absorption of soluble compounds. The route of exposure of organisms to whole oil alone include direct contact with tissues of organisms and uptake of oil by direct consumption, with potential for biomagnification through the food chain (NRC, 2003).

Thresholds of 10 ppb and 100 ppb were applied over a 1-hour time exposure (Table 8.4) as per NOPSEMA (2019).

The 10-ppb threshold exposure zone is not considered to be of significant biological impact and is therefore outside the adverse exposure zone. This exposure zone represents the area contacted by the spill.

Table 8.4 Dissolved and entrained hydrocarbon exposure thresholds assessed over a 1-hour time step used in the Barossa DPD oil spill modelling study (in alignment NOPSEMA 2019).

	Exposure level	In-water threshold (ppb)	Description
Dissolved hydrocarbons	Low	10	Establishes planning area for scientific monitoring based on potential for exceedance of water quality triggers
	Moderate	50	Approximates potential toxic effects, particularly sublethal effects to sensitive species
	High	400	Approximates toxic effects including lethal effects to sensitive species
Entrained hydrocarbons	Low	10	Establishes planning area for scientific monitoring based on potential for exceedance of water quality triggers
	Moderate	100	As appropriate given oil characteristics for informing risk evaluation

9 RECEPTORS

A range of receptors and shorelines were assessed for floating oil exposure, shoreline contact and water column exposure (entrained and dissolved) as part of the study (Figure 9.1 to Figure 9.6). Receptor categories (see Table 9.1) include sections of shorelines and within the Harbour the shorelines have been sectorised to closely aligned with the nine water quality zones. Also included in the assessment were the nine water quality reporting zones in the Harbour. Risks of exposure were separately calculated for each receptor and have been tabulated in the respective sections. It should be noted, that given that the release location for Scenarios 2 and 3 resides within the Middle Harbour WQ Zone receptor, there is no tabulated results presented for the floating oil and water column.

Table 9.1 Summary of receptors used to assess floating oil, shoreline, and in-water exposure to hydrocarbons in the Barossa DPD oil spill modelling study.

Receptor Category	Acronym	Hydrocarbon Exposure Assessment		
		Water Column	Floating oil	Shoreline
Australian Marine Park	AMP	✓	✓	✗
Conservation Reserve	CR	✓	✓	✗
Key Ecological Feature	KEF	✓	✓	✗
Marine Park	MP	✓	✓	✗
National Park	NP	✓	✓	✗
Nature Reserves	NR	✓	✓	✗
Reefs, Shoals and Banks	RSB	✓	✓	✗
Reef Fish Protected Areas	RFPA	✓	✓	✗
Restricted areas	Restricted areas	✓	✓	✗
Shipwrecks	Shipwrecks	✓	✗	✗
Shorelines	Shore	✗	✓ (reported as nearshore waters)	✓
Water Quality Zones	WQ Zones	✓	✓	✗

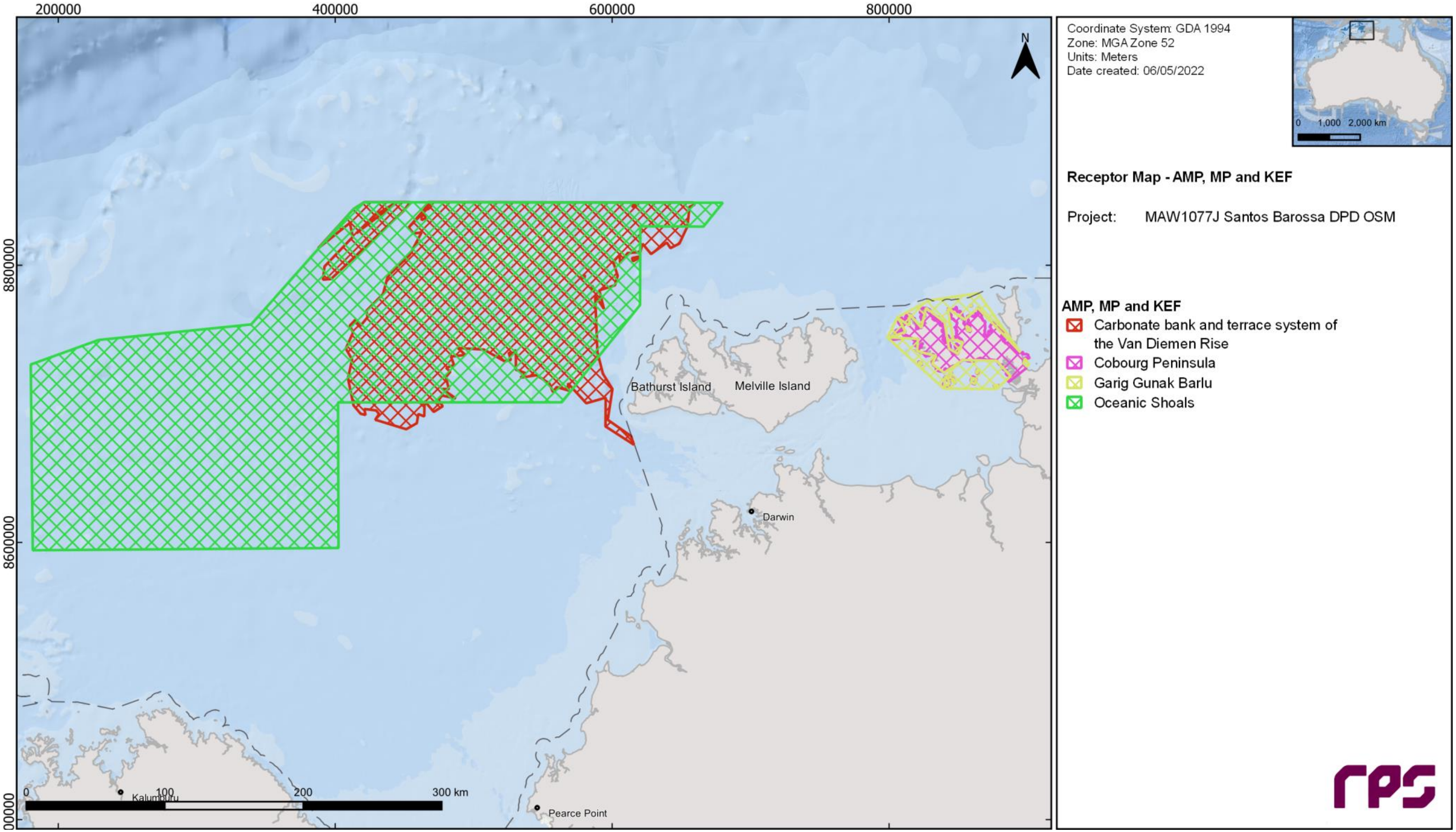


Figure 9.1 Receptor map for Australian Marine Parks (AMP), Marine Parks (MP) and Key Ecological Features (KEFs).

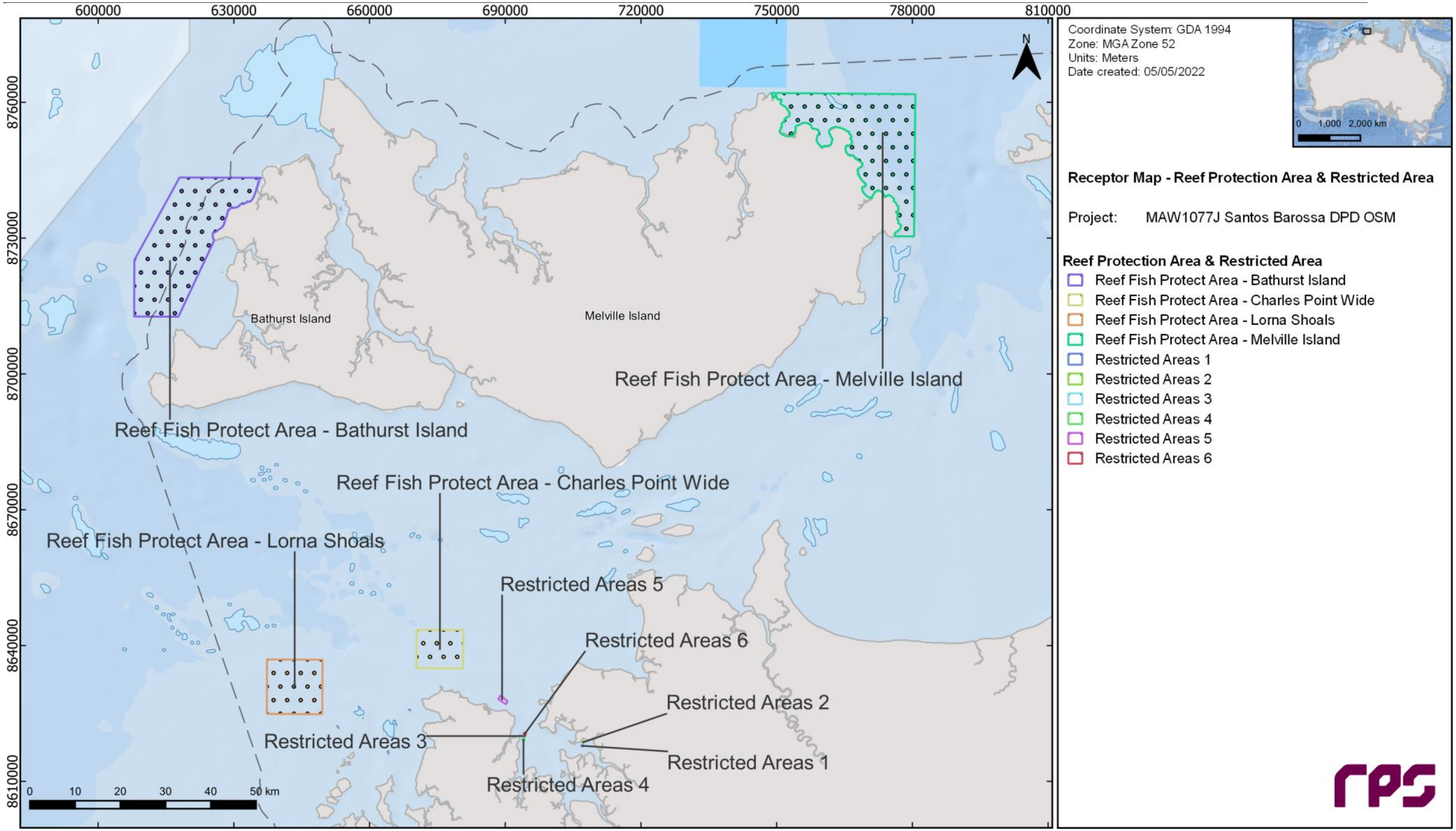


Figure 9.2 Receptor map for the reef fish protection areas (RFPA) and restricted areas.

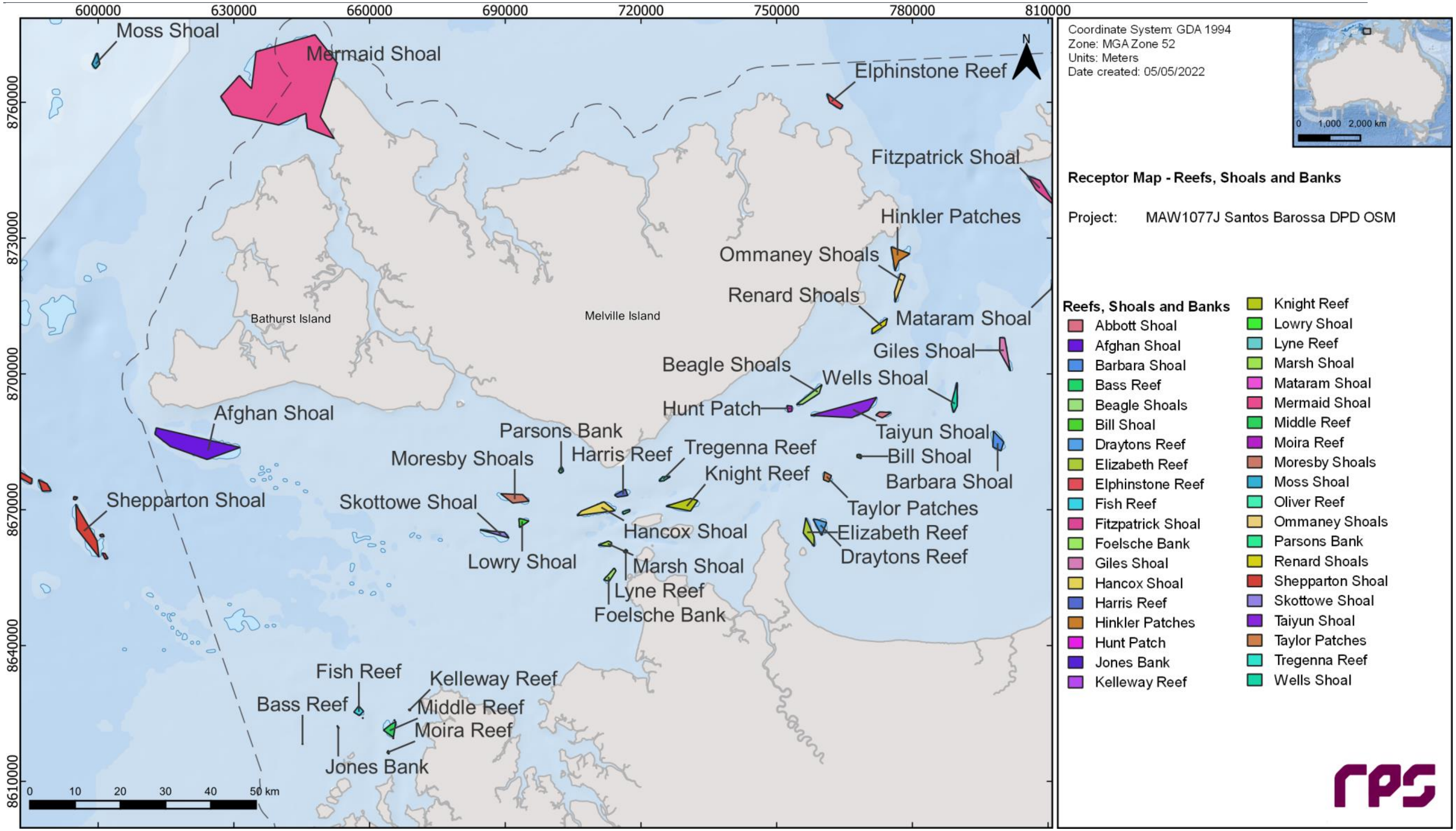


Figure 9.3 **Receptor map for the reefs, shoals and banks (RSB).**

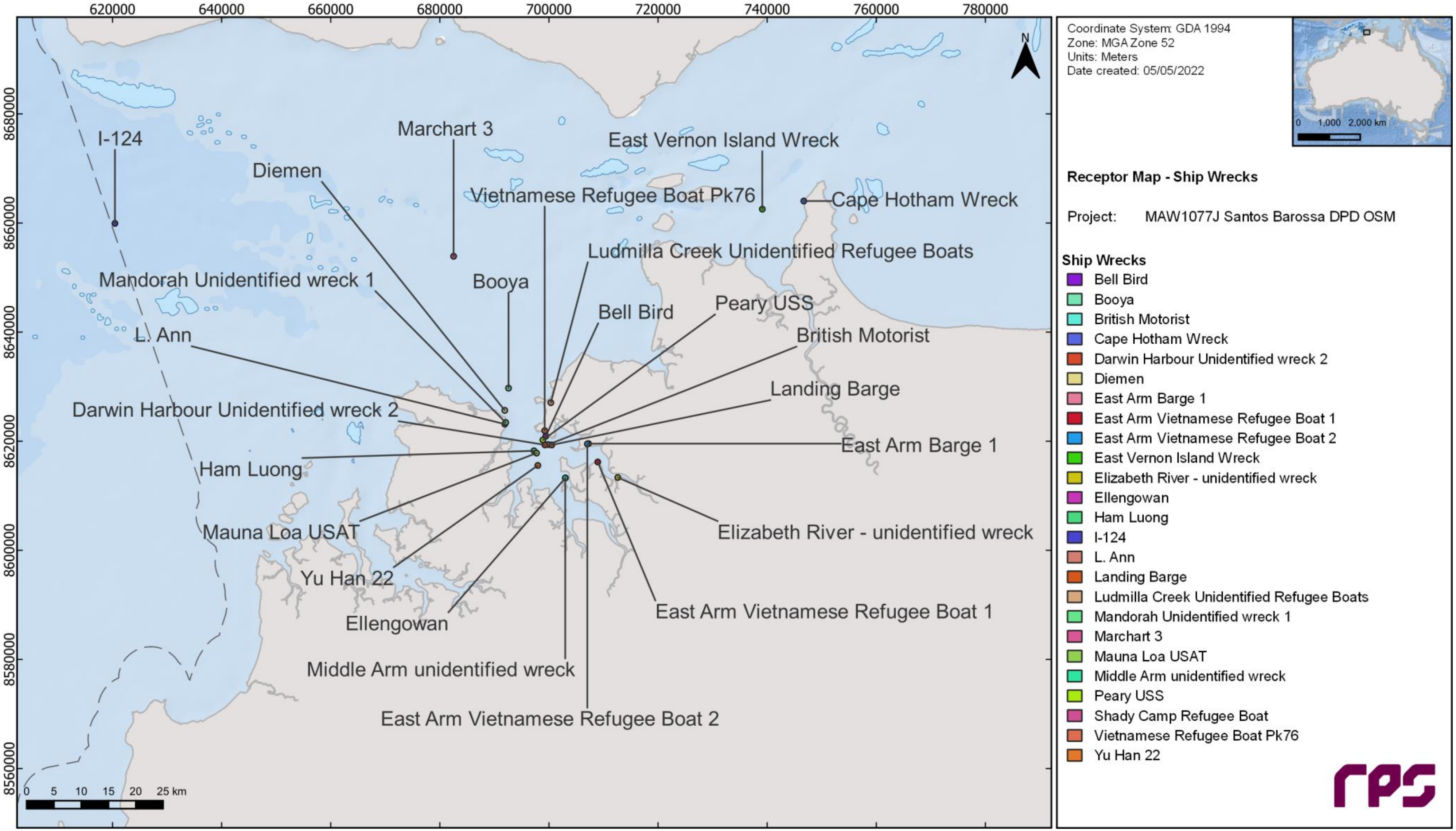


Figure 9.4 Receptor map for the shipwrecks.

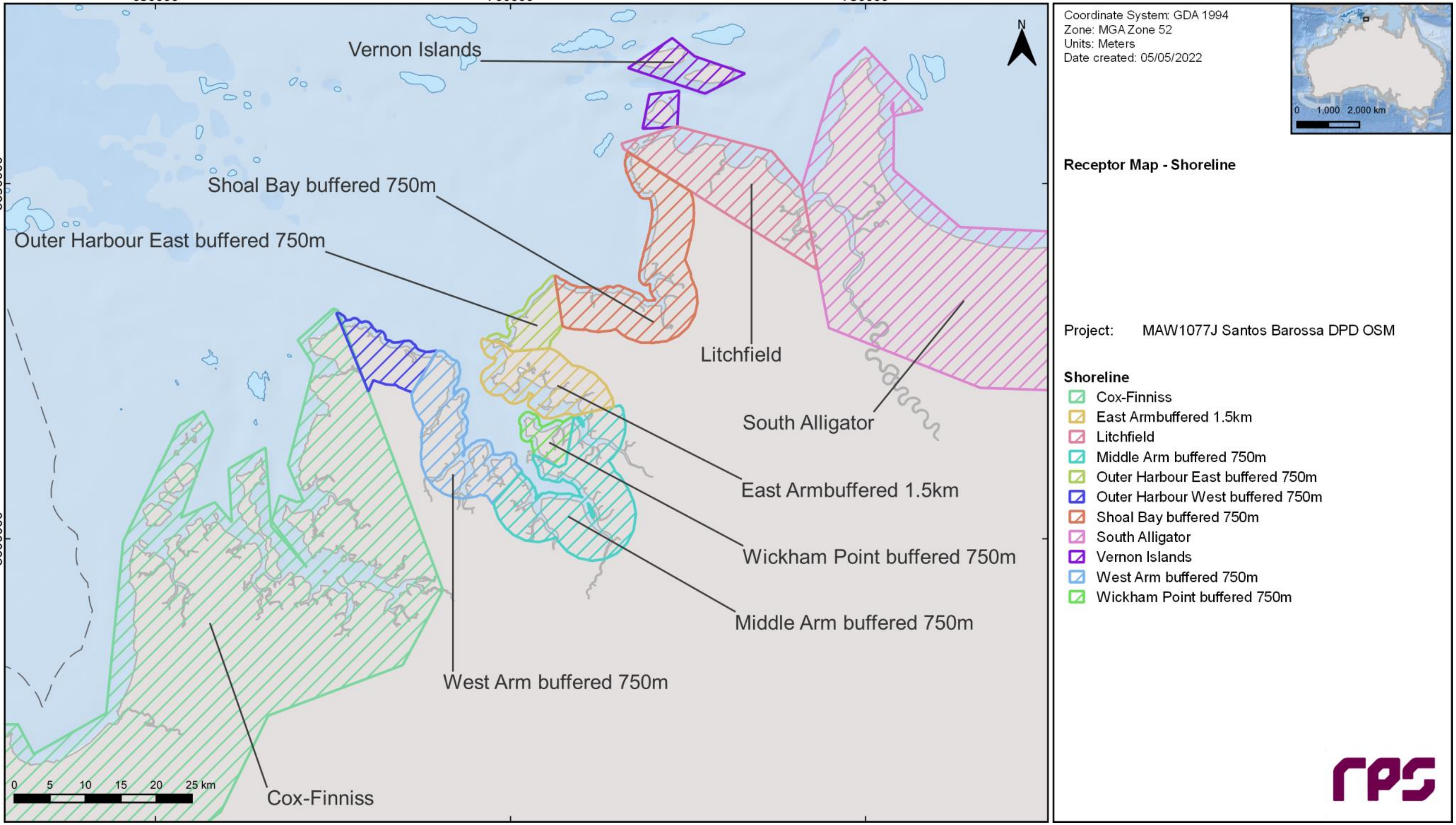


Figure 9.5 Receptor map for the shoreline sections.

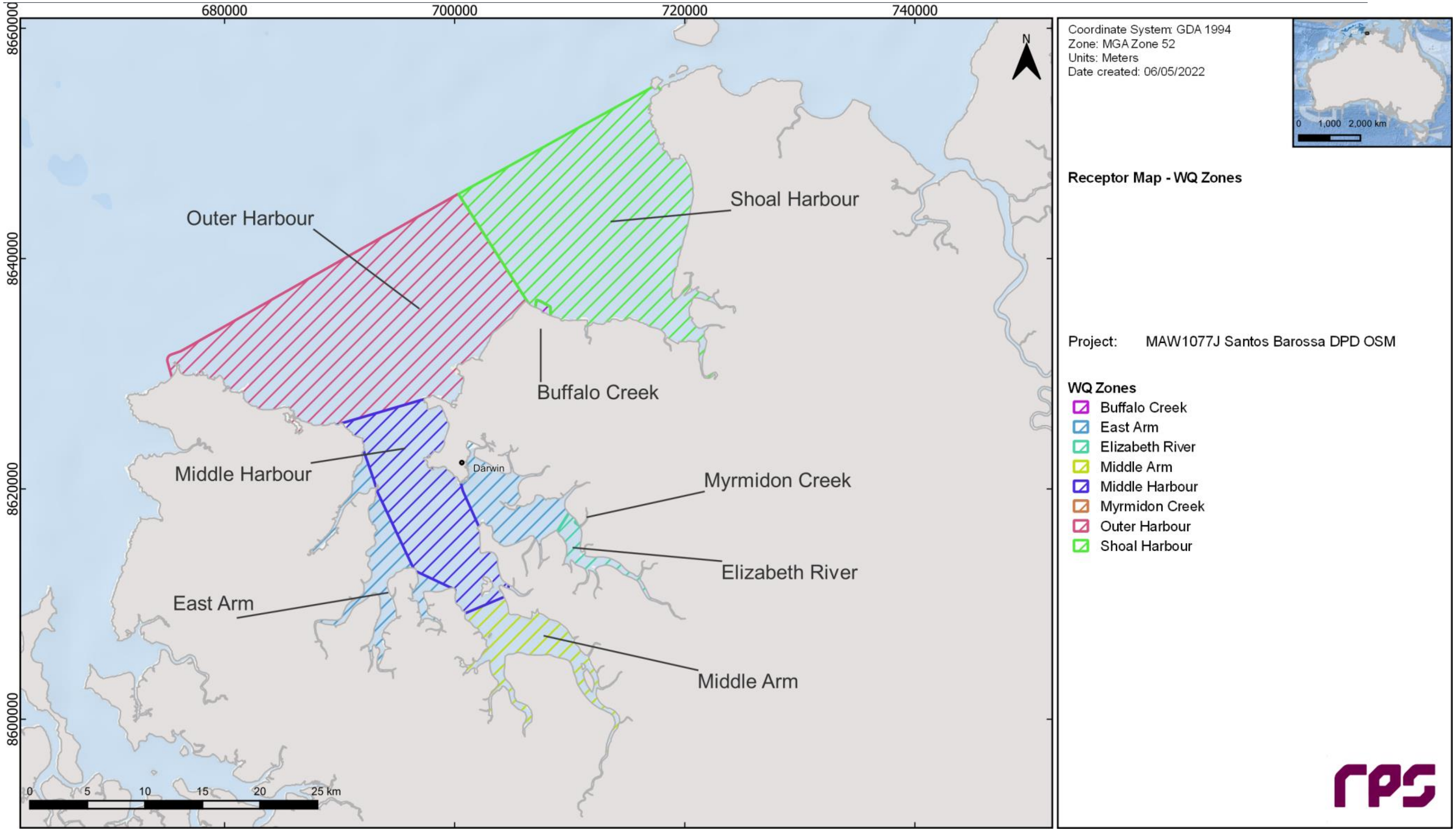


Figure 9.6 Receptor map for the water quality zones (WQ Zones).

10 MODEL SETTINGS

Table 10.1 provides a summary of the oil spill scenarios and model settings used in the assessment. The table also shows the thresholds that were used. The simulation lengths for each scenario were carefully selected based on extensive sensitivity testing. During the sensitivity testing process, sample spill simulations were run for longer than intended durations. Upon completion of the spill simulations, the results were carefully assessed to examine the persistence of the MDO (i.e., whether the maximum evaporative loss has been achieved for the period modelled; and whether a substantial volume of hydrocarbons remain in the water column (if any)) in conjunction with the extent of floating oil exposure based on reporting thresholds. Once there was agreement between the two factors (i.e., the final fate of hydrocarbon is accounted for, and the full exposure area is identified) the simulation length was deemed appropriate.

Table 10.1 Summary of the oil spill scenarios and model settings used in the Barossa DPD oil spill modelling study.

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Description	Offshore pipelay vessel fuel tank rupture	Vessel fuel tank rupture	Vessel to vessel refuelling	Vessel fuel tank rupture
Location Name	KP91.5	KP114	KP114	KP114
Spill volume (m^3)	700	87.5	10	300
Release duration (hours)	6	6	Instantaneous	6
Simulation length (days)	50	20	10	30
Number of randomly selected spill start times per season	100			
Model period	Wet season (November to April) and dry season (May to October).			
Oil type	MDO			
Release type	Surface			
Floating oil exposure thresholds (g/m^2)	1 (low exposure) 10 (moderate exposure) 50 (high exposure)			
Shoreline accumulation thresholds (g/m^2)	10 (low potential exposure) 100 (moderate potential exposure) 1,000 (high potential exposure)			
Dissolved hydrocarbon exposure thresholds (ppb)	10 (10 ppb x 1 hr, potential low exposure) 50 (50 ppb x 1 hr, potential moderate exposure) 400 (400 ppb x 1 hr, potential high exposure)			
Entrained hydrocarbon exposure thresholds (ppb)	10 (10 ppb x 1 hr, potential low exposure) 100 (100 ppb x 1 hr, potential moderate exposure)			

11 CALCULATION OF EXPOSURE RISK

The stochastic sampling approach provides an objective measure of the possible outcomes of a spill because randomly selected environmental conditions with more simulations will tend to use the most commonly occurring conditions, while more unusual conditions will be represented less frequently.

During each simulation, the SIMAP model records the location (by latitude, longitude and depth) of each of the particles (representing a given mass of oil) on or in the water column, at regular time steps. For any particles that contact a shoreline, the model records the accumulation of oil mass that arrives on each section of shoreline over time, less any mass that is lost to evaporation and/or subsequent removal by current and wind forces.

The collective records from all simulations are then analysed by dividing the study region into a three-dimensional grid. For oil particles that are classified as being at the water surface (floating oil), the sum of the mass in all oil particles (including accounting for spreading and dispersion effects) located within a grid cell, divided by the area of the cell provides estimates of the concentration of oil in that grid cell, at each time step. For entrained and dissolved hydrocarbons particles, concentrations are calculated at each time step by summing the mass of particles within a grid cell and dividing by the volume of the grid cell.

The concentrations of oil calculated for each grid cell, at each time step, are then analysed to determine whether concentration estimates exceed defined threshold concentrations over time.

Risks are then summarised as follows:

- The probability of exposure to a location is calculated by dividing the number of spill simulations where any contact occurred above a specified threshold at that location by the total number of replicate spill simulations. For example, if contact occurred at a location (above a specified threshold) during 21 out of 100 simulations, a probability of exposure of 21% is indicated;
- The minimum potential time to a shoreline location is calculated by the shortest time over which oil at a concentration above a threshold was calculated to travel from the source to the location in any of the replicate simulations;
- The maximum potential concentration of oil predicted for each shoreline section is the greatest mass per m^2 of shoreline calculated to strand at any location within that section during any of the replicate simulations; and
- Similar treatments were undertaken for entrained and dissolved hydrocarbon exposures.

Thus, the minimum time to shoreline and the maximum potential concentration estimates indicate the worst potential outcome of the modelled spill scenario for each section of shoreline. However, the average over the replicates presents an average of the potential outcomes, in terms of oil that could strand.

Note also that results quoted for sections of shoreline are derived for any individual location within that section, as a conservative estimate. Locations will represent shoreline lengths of the order of ~1 km for Scenario 1 and 0.5 km for Scenario 2 & 3, while sections or regions will represent shorelines spanning tens to hundreds of kilometres. The maximum potential concentrations quoted will not necessarily occur over the full extent of each section, therefore multiplying the maximum concentration estimates by the full area of the section is not recommended as this will greatly overestimate the total volume expected on that section.

12 SCENARIO 1 RESULTS – OFFSHORE PIPELAY VESSEL FUEL TANK RUPTURE AT KP91.5

This scenario examined the potential exposure following a 700 m^3 surface release of MDO over 6 hours in the event of an offshore pipelay vessel fuel tank rupture at KP91.5. A total of 200 spill trajectories were simulated (i.e., 100 spills per season) and tracked for 50 days.

Section 12.1 presents the low threshold environment that may be affected (EMBA), resulting from the 200 spill simulations. Section 12.2 shows the seasonal (or stochastic) analysis, while Section 12.3 presents in more detail the results for the simulation resulting in the largest volume of oil ashore.

12.1 EMBA

Figure 12.1 shows the full geographic EMBA derived by overlaying the results from all 200 spill simulations at the low (≥1 g/m^2) exposure thresholds.

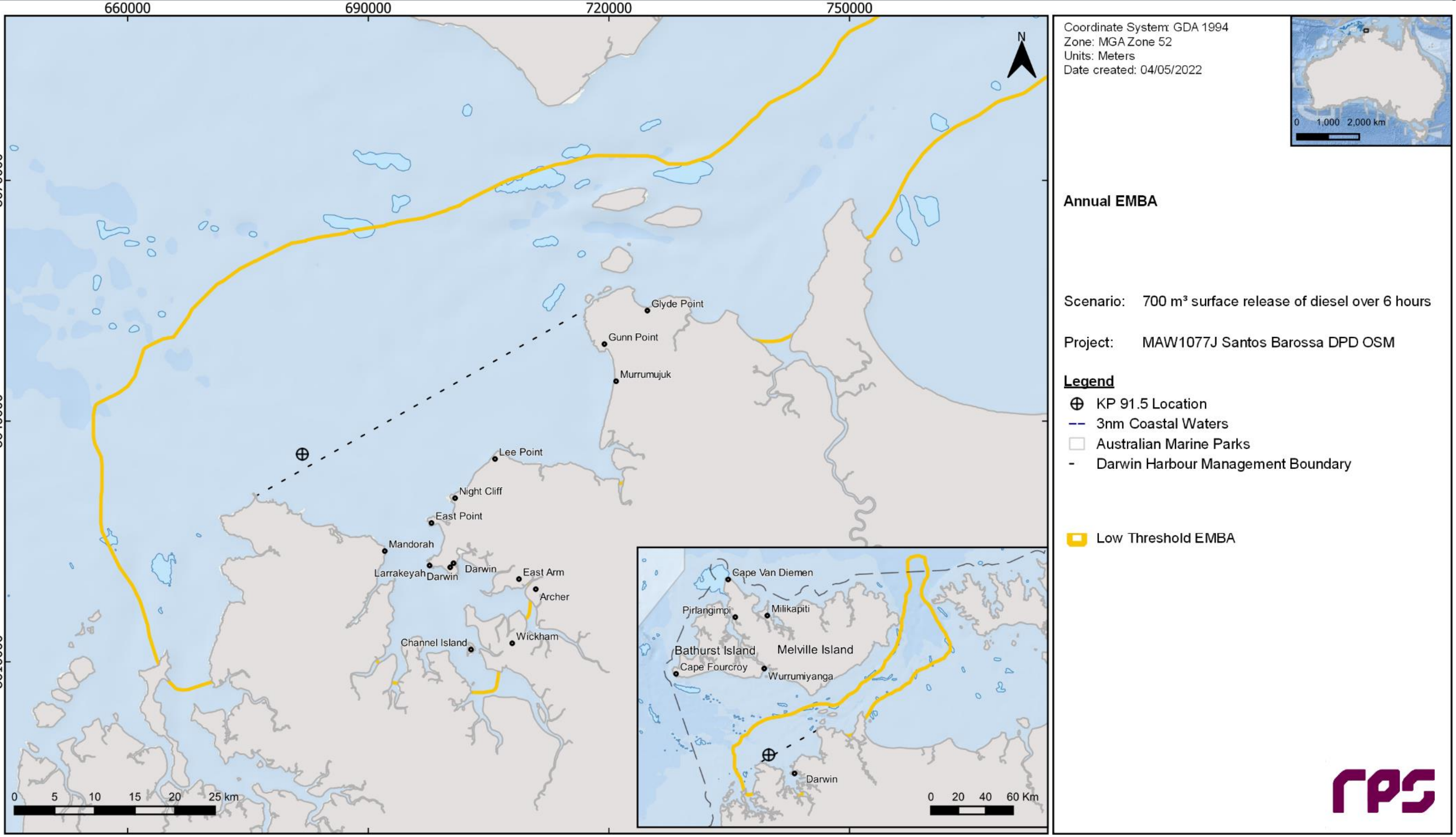


Figure 12.1 Predicted low threshold risk EMBA from an offshore pipelay vessel fuel tank rupture at KP91.5. The annualised results were calculated from 200 spill simulations.

12.2 Stochastic Analysis

12.2.1 Floating Oil Exposure

Table 12.1 summarises the maximum distances and directions travelled by the floating oil from the release location at each threshold for each season. The maximum distances to the low (≥1 g/m^2), moderate (≥10 g/m^2) and high (≥ 50 g/m^2) exposure zones were 26.4 km (southeast), 19.9 km (southeast) and 14 km (west northwest), occurring during dry season conditions. Table 12.2 summarises the potential floating oil exposure to individual receptors for each season and Figure 12.2 to Figure 12.3 illustrate the extent of floating oil exposure for each season.

Given that the release location was 1.11 km east of Charles Point Wide RFPA and 0.65 km north of the Outer Harbour WQ Zone, the probability of oil exposure was greatest for these receptors (100% at the low threshold for both seasons) and would take 1 hour for a spill to reach the boundaries of the receptors.

Otherwise, floating oil exposure at the low and moderate thresholds were predicted at Restricted Area 5 and Middle Harbour WQ Zone with all probabilities ≤10% (see Table 12.2).

Table 12.1 Maximum distances and directions travelled by floating oil from an offshore pipelay vessel fuel tank rupture at KP91.5 for each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential floating oil exposure		
		Low	Moderate	High
Dry	Maximum distance (km) from release location	26.4	19.9	14.0
	Maximum distance (km) from the release location (99th percentile)	23.5	17.5	13.8
	Direction	SE	SE	WNW
Wet	Maximum distance (km) from release location	24.9	19.3	12.4
	Maximum distance (km) from release location (99th percentile)	20.6	18.0	12.2
	Direction	SE	WNW	SE

Table 12.2 Summary of the potential exposure by floating oil to individual receptors from an offshore pipelay vessel fuel tank rupture at KP91.5 for each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry						Wet					
		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)			Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
RFPA	Charles Point Wide	100	90	38	0.04	0.04	0.13	97	82	27	0.04	0.04	0.08
Restricted Area	5	3	1	-	0.54	1.50	-	2	-	-	0.67	-	-
WQ Zones	East Arm	-	-	-	-	-	-	1	-	-	1.38	-	-
	Middle Harbour	6	2	-	0.29	0.29	-	10	1	-	0.17	0.29	-
	Outer Harbour	100	92	35	0.04	0.04	0.08	100	92	31	0.04	0.04	0.13

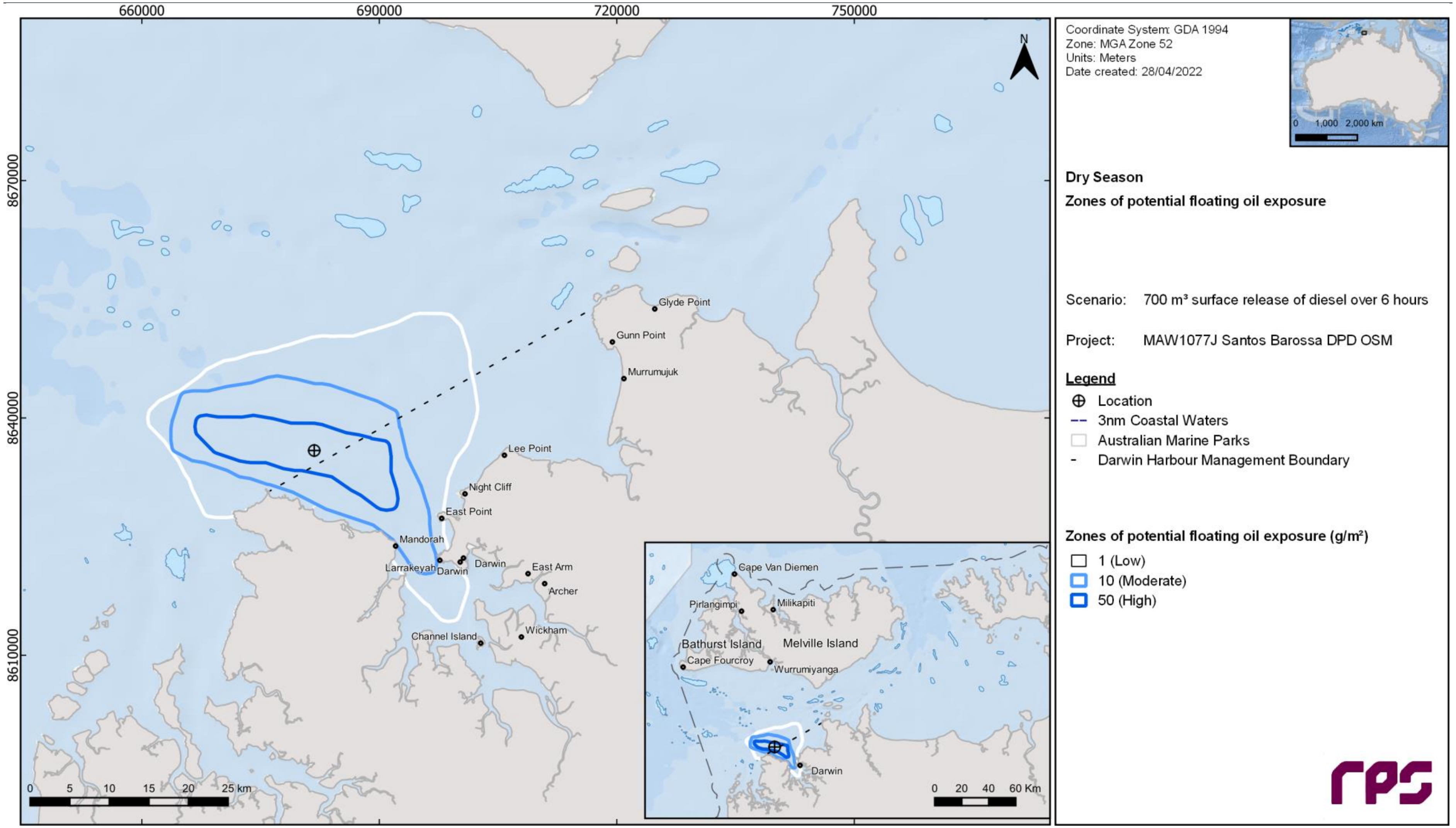


Figure 12.2 Zones of potential floating oil exposure from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations.

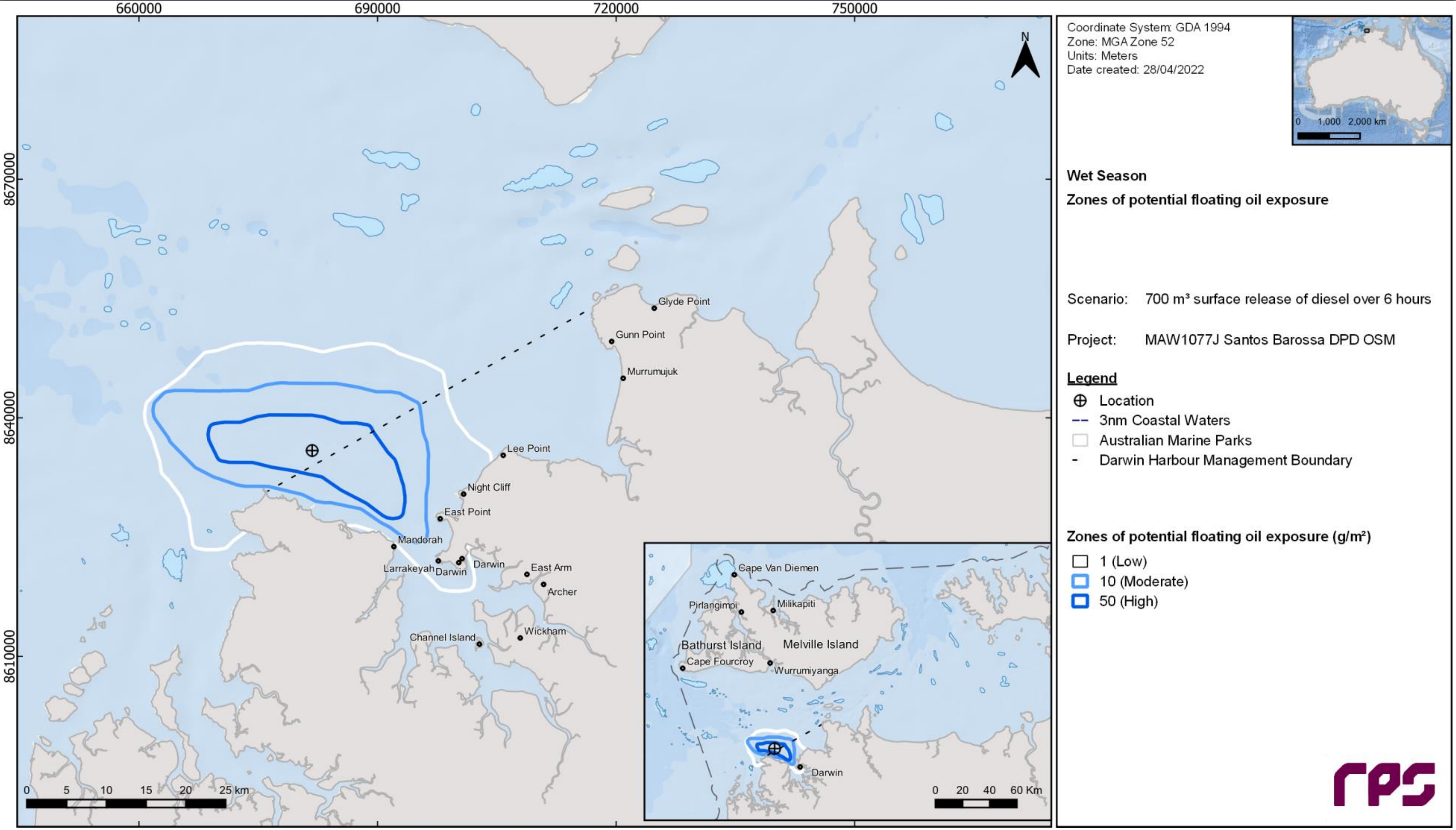


Figure 12.3 Zones of potential floating oil exposure from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations.

12.2.2 Shoreline Accumulation

Table 12.3 summarises the predicted oil accumulation on any shoreline during each season. The probability of oil accumulation at, or above, the low threshold (10 g/m^2) was 25% (dry season) and 50% (wet season). The minimum time before oil accumulation at, or above, the low threshold ranged between 1.5 days (dry season) and 0.96 days (wet season). The maximum volume ashore for a single spill ranged between 28.1 m^3 (dry season) and 59.7 m^3 (wet season) and the maximum length of shoreline contacted at the low threshold was 23.1 km (dry season) and 22.1 km wet season). The maximum lengths of oil accumulation on shorelines at, or above, the moderate (100 – 1,000 g/m^2) and high (≥1,000 g/m^2) thresholds was 12 km and 2 km, respectively, during the wet season.

Table 12.4 and Table 12.5 summarise the oil accumulation on individual shoreline receptors for each season. The maximum potential shoreline loading for the specified thresholds for each season are presented in Figure 12.4 and Figure 12.5.

The greatest probabilities of oil accumulation at, or above, the low threshold was predicted for the East Arm (16% dry and 33% wet conditions), Outer Harbour East (4% dry and 20% wet seasons) and Outer Harbour West (9% dry and 10% wet seasons). The greatest volume (peak) of oil accumulation during the dry and wet seasons was predicted occurred along Outer Harbour West (22.2 m^3) and Outer Harbour East shorelines (43.8 m^3), respectively. The minimum time before oil accumulation at the low threshold was 1.50 days (Outer Harbour West) during the dry season and 0.96 days (Cox-Finniss) during the wet season conditions.

Table 12.3 Summary of oil accumulation on any shoreline from an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season.

Shoreline Statistics	Dry			Wet		
	Low	Moderate	High	Low	Moderate	High
Probability of accumulation on any shoreline (%)	25	3	-	50	12	1
Absolute minimum time before oil ashore (days)	1.50	1.96	-	0.96	1.29	3.54
Maximum length of shoreline contacted (km)	23.1	7.0	-	22.1	12.0	2.0
Average length of shoreline contacted (km)	6.6	3.0	-	6.8	4.9	2.0
	Dry			Wet		
Maximum volume of hydrocarbons ashore (m^3)	28.1			59.7		
Average volume of hydrocarbons ashore (m^3)	1.3			3.2		

Table 12.4 Summary of oil accumulation on individual shoreline sectors from an offshore pipelay vessel fuel tank rupture at KP91.5 for the dry season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Cox-Finniss	4	1	-	1.92	2.50	-	1	194	0.1	6.3	6.0	2.0	-	8.0	2.0	-
East Arm	16	-	-	1.79	-	-	3	89	0.2	3	2.8	-	-	6.0	-	-
Middle Arm	2	-	-	4.50	-	-	<1	15	<0.1	0.3	1.0	-	-	1.0	-	-
Outer Harbour East	4	-	-	7.29	-	-	2	36	0.1	2.5	5.2	-	-	9.0	-	-
Outer Harbour West	9	2	-	1.50	1.96	-	5	680	0.3	22.2	3.2	3.0	-	10.0	5.0	-
Shoal Bay	2	-	-	13.13	-	-	<1	18	<0.1	1.8	3.0	-	-	5.0	-	-
Vernon Islands	8	-	-	7.71	-	-	1	27	<0.1	0.8	1.5	-	-	2.0	-	-
West Arm	6	1	-	2.58	3.58	-	1	113	0.2	7	4.2	1.0	-	12.0	1.0	-

Table 12.5 Summary of oil accumulation on individual shoreline sectors from an offshore pipelay vessel fuel tank rupture at KP91.5 for the wet season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Cox-Finniss	5	1	-	0.96	1.83	-	2	298	0.2	8.1	8.2	1.0	-	18.0	1.0	-
East Arm	33	9	1	1.25	1.46	3.63	8	1,050	0.9	16	3.3	2.1	1	8.0	5.0	1.0
Middle Arm	-	-	-	-	-	-	<1	6	<0.1	0.3	-	-	-	-	-	-
Outer Harbour East	20	6	1	1.71	2.25	3.54	10	1,116	1.3	43.8	5.4	4.5	1	12.0	8.0	1.0
Outer Harbour West	10	3	-	1	1.29	-	6	399	0.4	16.9	4.7	4.0	-	11.0	5.0	-
Shoal Bay	2	-	-	9.46	-	-	<1	22	<0.1	1.6	2.5	-	-	3.0	-	-
Vernon Islands	9	-	-	9.13	-	-	2	76	<0.1	1.8	1.8	-	-	3.0	-	-
West Arm	5	-	-	3.46	-	-	1	50	<0.1	1.8	2.6	-	-	7.0	-	-

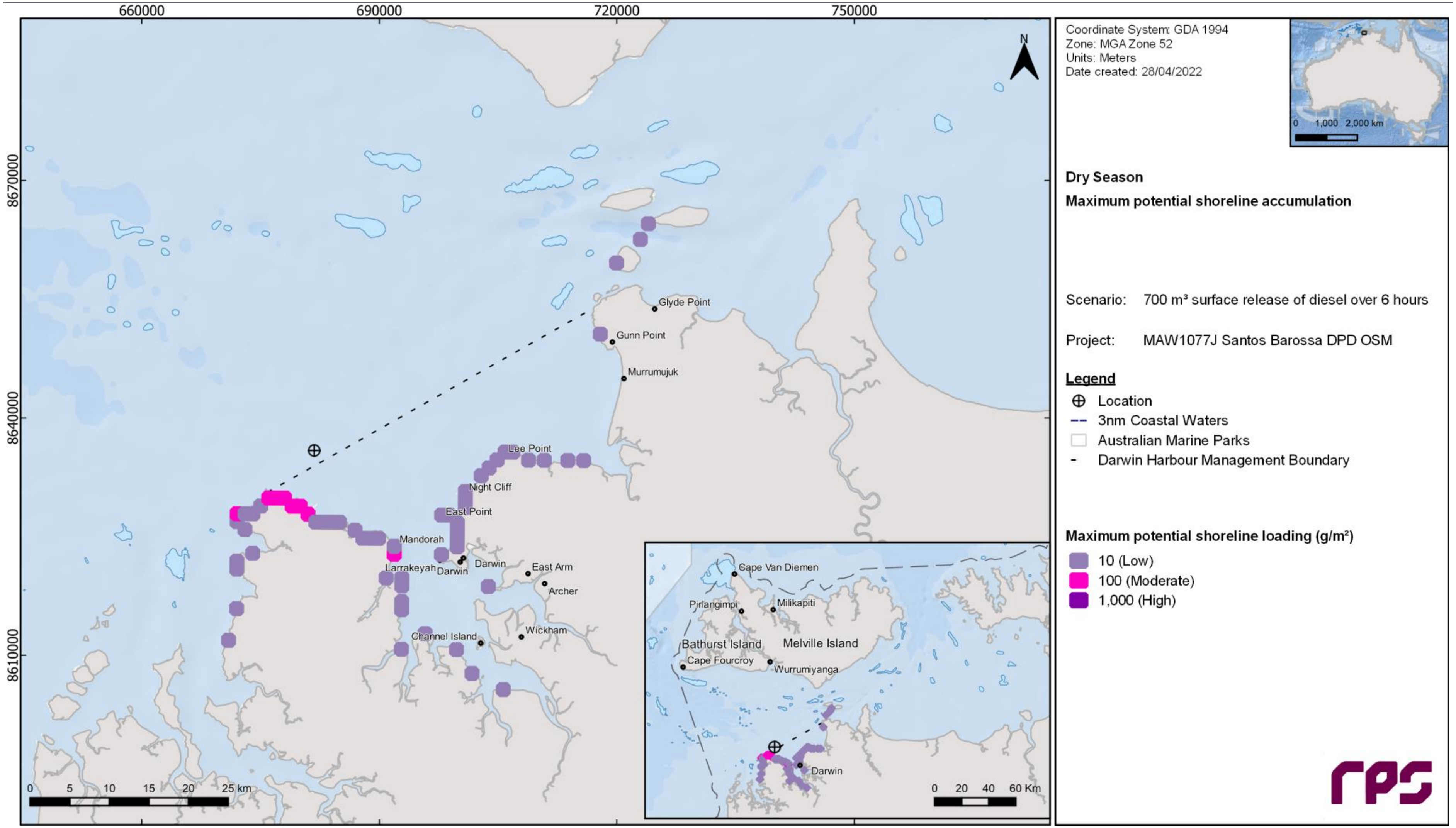


Figure 12.4 Maximum potential shoreline loading from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations.

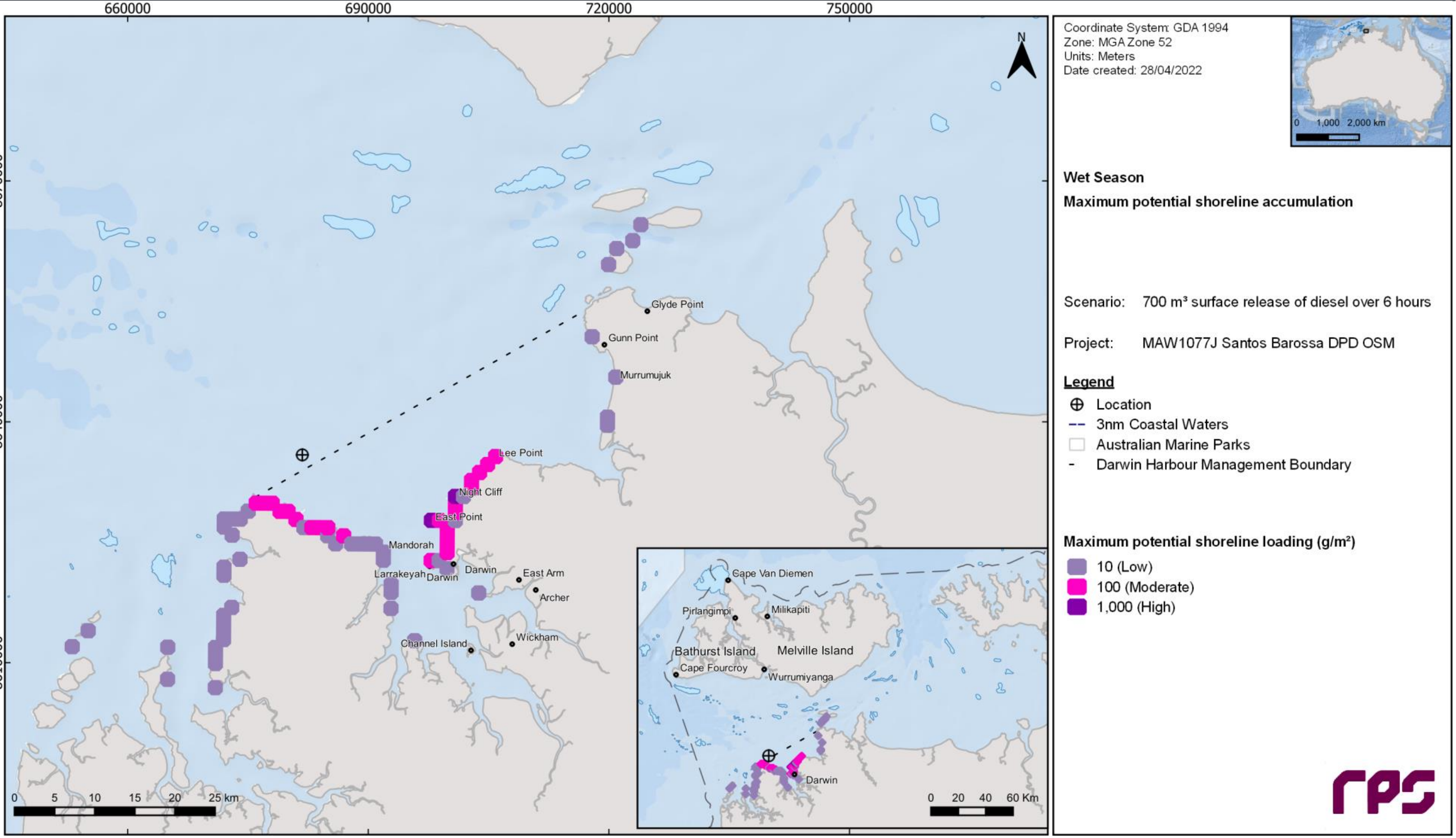


Figure 12.5 Maximum potential shoreline loading from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations.

12.2.3 In-water exposure

12.2.3.1 Dissolved Hydrocarbons

Table 12.6 summarises the maximum distances and directions travelled by dissolved hydrocarbons from the release location to each threshold in the 0 – 10 m depth layer. The maximum distances to the low (≥ 10 ppb) and moderate (≥ 50 ppb) exposure zones were 16.9 km (west) and 13.7 km (southeast), respectively. There was no exposure predicted for either season at the high threshold (≥ 400 ppb).

Table 12.7 and Table 12.8 summarise the potential exposure to receptors from dissolved hydrocarbons in the 0 – 10 m and 10 – 20 m depth layers, respectively, for each threshold and season. Figure 12.6 to Figure 12.9 illustrate the extents of dissolved hydrocarbon exposure for each season in the 0 – 10 m and 10 – 20 m depth layers.

Four receptors (Charles Point Wide RFPA, Booya shipwreck, Middle Harbour and Outer Harbour WQ Zones) were predicted to be exposed to dissolved hydrocarbons at the low threshold in the 0 – 10 m depth during the dry and wet seasons with probabilities ranging from 1% to 40%. The maximum instantaneous concentrations were 97 ppb predicted at Charles Point Wide RFPA during the dry season and 91 ppb within the Outer Harbour WQ Zone during the wet season.

In comparison, within the 10 – 20 m depth layer only two receptors were predicted to be exposed to dissolved hydrocarbons at the low threshold (Charles Point Wide RFPA (dry and wet seasons) and the Outer Harbour WQ Zone (wet season)) and probabilities of 1% (meaning 1 simulation out of 100 had triggered the exposure).

Table 12.6 Maximum distances and directions travelled by dissolved hydrocarbons (0 – 10 m depth layer) from an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential dissolved hydrocarbon exposure		
		Low 10 ppb	Moderate 50 ppb	High 400 ppb
Dry	Maximum distance (km) from the release location	16.9	10.0	-
	Maximum distance (km) from the release location (99th percentile)	16.5	9.6	-
	Direction	W	ESE	-
Wet	Maximum distance (km) from the release location	15.8	13.7	-
	Maximum distance (km) from the release location (99th percentile)	15.2	13.5	-
	Direction	W	SE	-

Table 12.7 Summary of dissolved hydrocarbon exposure for each receptor in the 0 – 10 m depth layer for an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry							Wet						
		Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure			Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure		
			Low	Moderate	High	Low	Moderate	High		Low	Moderate	High	Low	Moderate	High
RFPA	Charles Point Wide	97	33	4	-	0.08	0.13	-	75	33	2	-	0.04	0.13	-
Shipwrecks	Booya	10	1	-	-	0.38	-	-	38	7	-	-	0.29	-	-
WQ Zones	Middle Harbour	23	2	-	-	0.33	-	-	25	1	-	-	0.42	-	-
	Outer Harbour	94	28	6	-	0.04	0.13	-	91	40	4	-	0.04	0.13	-

Table 12.8 Summary of dissolved hydrocarbon exposure for each receptor in the 10 – 20 m depth layer for an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry							Wet						
		Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure			Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure		
			Low	Moderate	High	Low	Moderate	High		Low	Moderate	High	Low	Moderate	High
RFPA	Charles Point Wide	10	1	-	-	0.08	0.13	-	25	1	-	-	0.04	0.13	-
WQ Zones	Outer Harbour	7	-	-	-	0.04	0.13	-	38	1	-	-	0.04	0.13	-

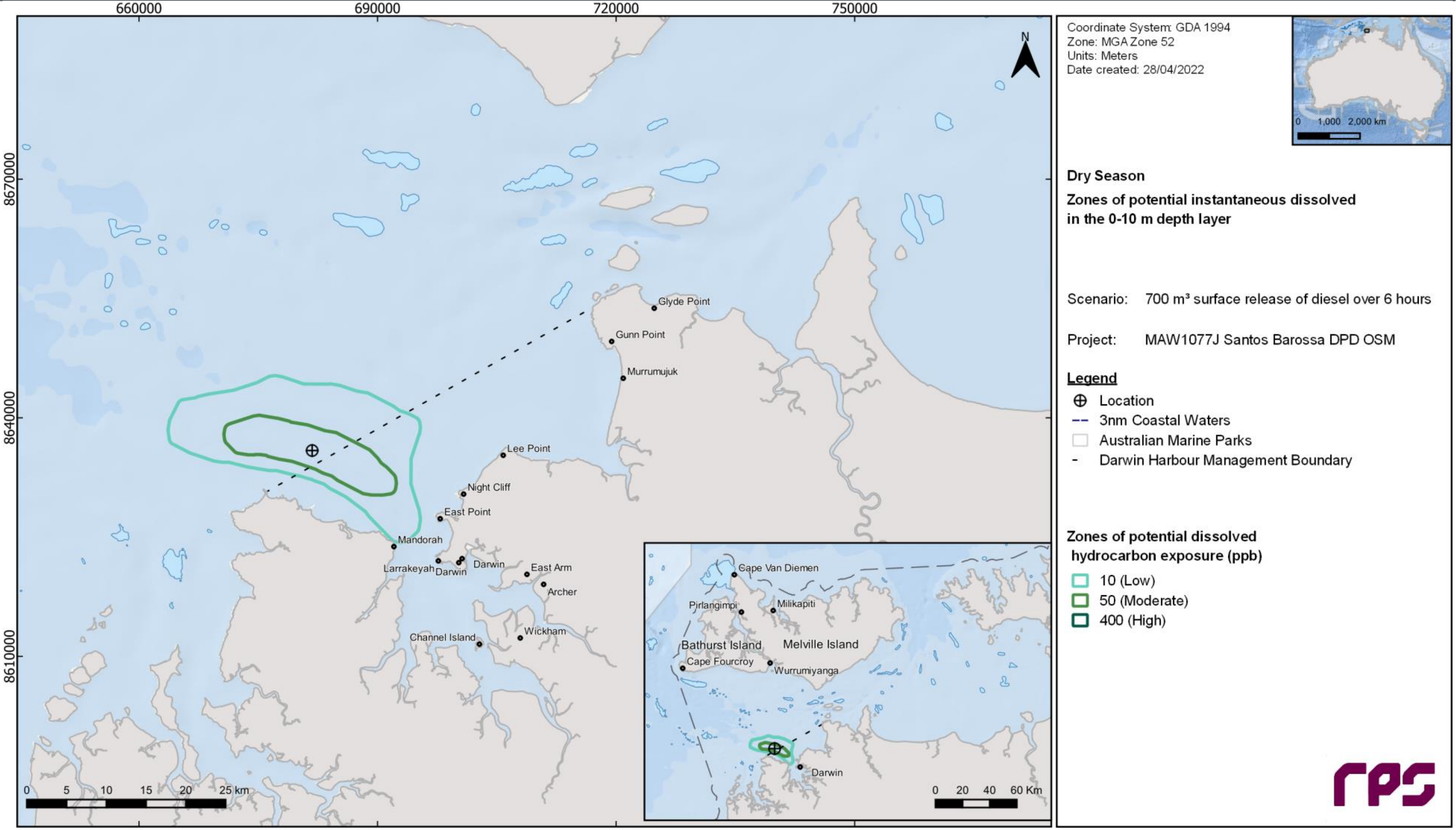


Figure 12.6 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations.

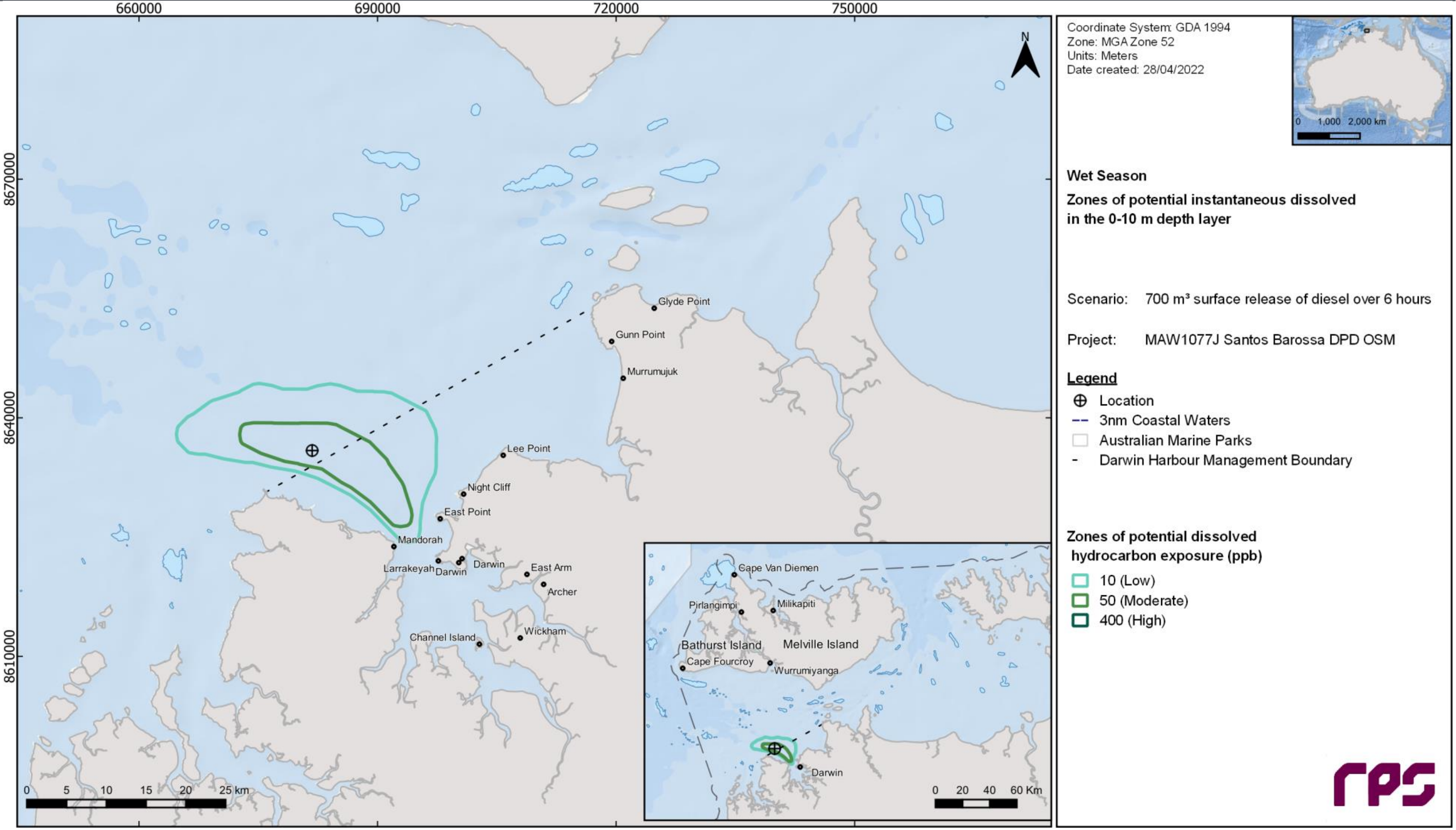


Figure 12.7 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations.

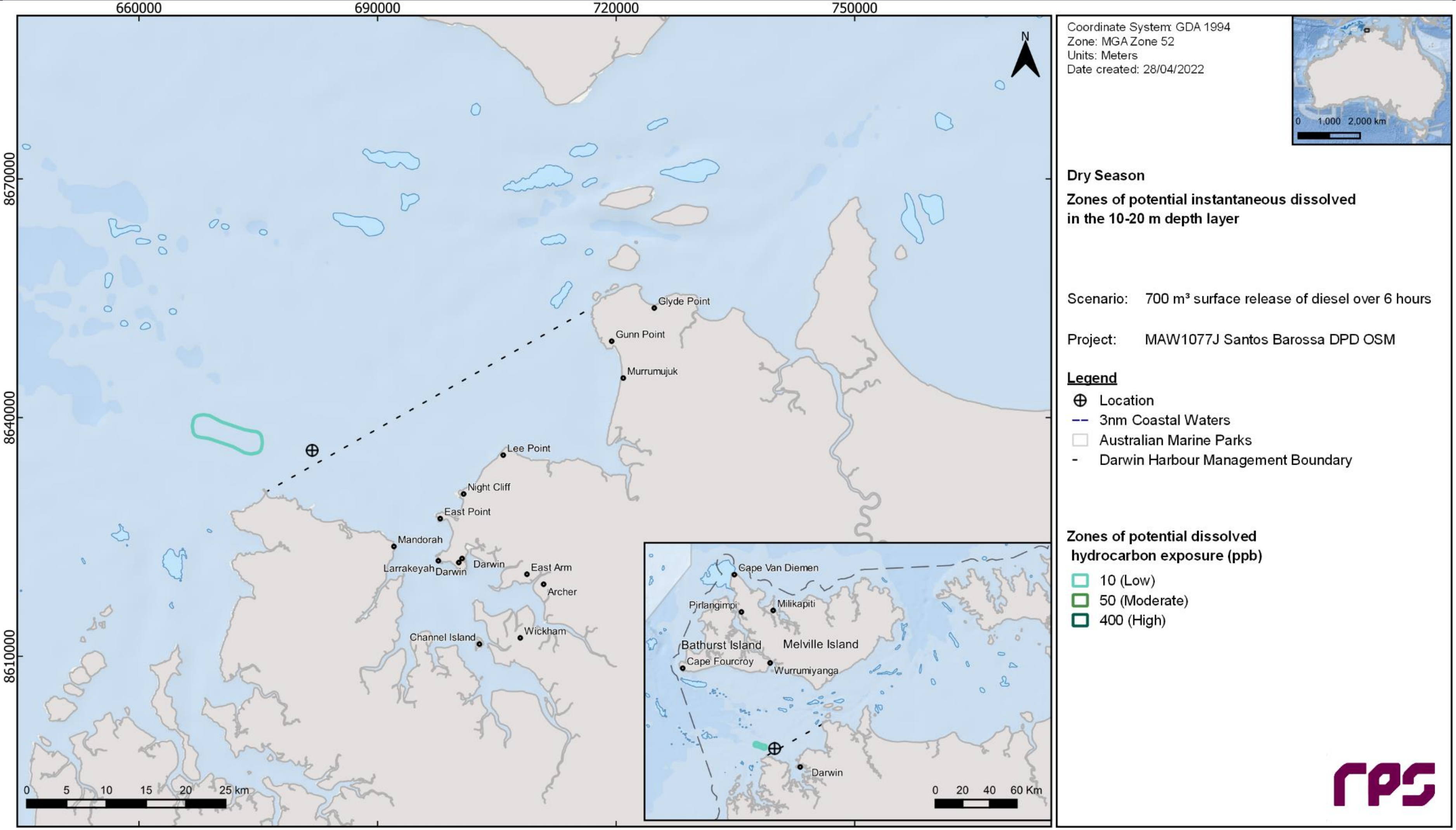


Figure 12.8 Zones of potential dissolved hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations.

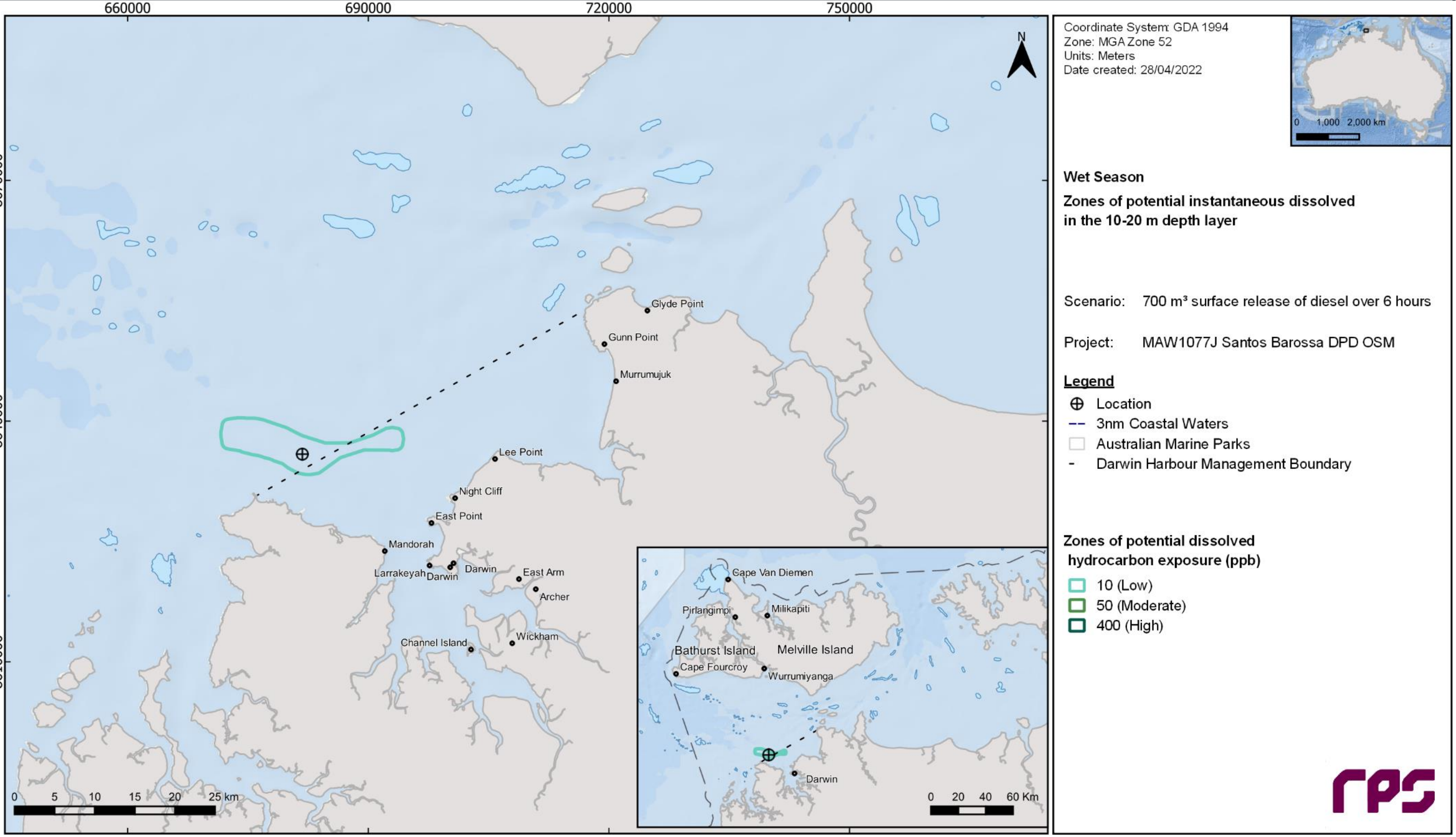


Figure 12.9 **Zones of potential dissolved hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations.**

12.2.3.2 Entrained Hydrocarbons

Table 12.9 summarises the maximum distances and directions travelled by entrained hydrocarbons within the 0 – 10 m depth layer at the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds, which ranged between 182.3 km northeast (wet conditions) and 51.3 km east northeast (wet conditions) from the release location, respectively.

Table 12.10 and Table 12.11 summarise the potential exposure to receptors from entrained hydrocarbons in the 0 – 10 m and 10 – 20 m depth layers, respectively, for each season. Figure 12.10 to Figure 12.13 illustrate extent of entrained hydrocarbon exposure for each season in the 0 – 10m and 10 – 20 m depth layers.

Given that the proximity of the release location to Charles Point Wide RFPA (1.11 km east) and Outer Harbour WQ Zone (0.65 km north), the probability of exposure was greatest for these receptors (100% at the low threshold for both seasons) and would take 1 hour for a spill to reach the boundaries of the receptors.

During the dry and wet seasons 5 and 10 RSBs, respectively, were predicted to be exposed to entrained hydrocarbons at the low threshold with probabilities ranging from 1 – 28% during the two seasons. During both seasons the Foelsche Bank was predicted to have the greatest probability of low exposure threshold (28% dry season wet season). It was also the only RSB to be exposed at the moderate threshold, with a 1% probability and took up to 6.46 days before exposure.

In addition, low entrained hydrocarbon exposure was predicted at 9 and 11 shipwreck receptors during the dry and wet season, respectively, with probabilities ranging from 23% (Marchart 3) and 100% (Booya) during the dry season, and 2% (Marchart 3) and 98% (Booya) during the wet season.

Furthermore, 6 and 7 WQ Zones for the dry and wet season conditions were predicted to be exposed to entrained hydrocarbons at the low threshold. The probabilities ranged from 42% (Buffalo Creek) and 100% (Middle Harbour) during the dry season and 25% (Middle Arm) and 98% (Middle Harbour) during the wet season. The maximum entrained hydrocarbon concentrations were also predicted at Outer Harbour during both the dry (8,733 ppb) and wet (8,974 ppb) seasons.

In comparison, in the 10 – 20 m depth layer only Charles Point Wide RFPA and the Outer Harbour WQ Zone were predicted to be exposed to hydrocarbons at the low threshold during the two seasons. Exposure at the high threshold was predicted within Charles Point Wide RFPA and the probability was 6%.

Table 12.9 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential entrained hydrocarbon exposure	
		Low 10 ppb	Moderate 100 ppb
Dry	Maximum distance (km) from release location	147.7	36.9
	Maximum distance (km) from release location (99th percentile)	142.1	34.5
	Direction	NE	ENE
Wet	Maximum distance (km) from release location	182.3	51.3
	Maximum distance (km) from release location (99th percentile)	174.7	48.7
	Direction	NE	ENE

Table 12.10 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer for an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry					Wet				
		Maximum concentration (ppb)	Probability (%) of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure		Maximum concentration (ppb)	Probability (%) of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure	
			Low	Mod	Low	Mod		Low	Mod	Low	Mod
RSB	Abbott Shoal	6	-	-	-	-	15	4	-	12.08	-
	Foelsche Bank	109	28	1	4.79	6.46	214	28	1	4.71	7.42
	Giles Shoal	3	-	-	-	-	15	1	-	19.25	-
	Hancox Shoal	12	1	-	10.50	-	9	-	-	-	-
	Knight Reef	11	1	-	11.71	-	11	1	-	9.96	-
	Marsh Shoal	36	8	-	5.88	-	94	7	-	4.75	-
	Mataram Shoal	4	-	-	-	-	12	1	-	23.50	-
	Middle Reef	5	-	-	-	-	19	1	-	3.67	-
	Oliver Reef	17	1	-	9.96	-	19	4	-	9.04	-
	Taiyun Shoal	8	-	-	-	-	15	3	-	11.67	-
	Taylor Patches	4	-	-	-	-	11	2	-	12.04	-
NP	Djukbinj	12	1	-	14.71	-	28	6	-	9.46	-
RFPA	Charles Point Wide	7,051	100	100	0.04	0.04	6,886	100	93	0.04	0.04
	Melville Island	6	-	-	-	-	10	1	0	22.13	-
Restricted Area	5	212	100	33	0.21	0.79	308	97	59	0.29	0.88
Shipwrecks	Bell Bird	93	97	-	1.42	-	227	94	27	1.29	2.42
	Booya	1,156	100	59	0.21	0.21	2,468	98	72	0.17	0.17
	British Motorist	97	97	-	1.42	-	230	94	26	1.29	2.42
	Cape Hotham Wreck	6	-	-	-	-	20	2	-	10.46	-
	Diemen	193	99	31	0.29	1.29	293	97	55	0.21	2.33
	East Vernon Island Wreck	9	-	-	-	-	26	4	-	9.46	-
	Landing Barge	80	97	-	2.33	-	182	94	12	1.29	2.46
	Marchart 3	45	23	-	2.96	-	78	2	-	2.33	-

	Mauna Loa USAT	94	96	-	1.38	-	213	94	20	1.29	2.83
	Vietnamese Refugee Boat Pk76	108	97	2	1.42	3.42	256	95	38	1.25	2.38
	Yu Han 22	55	89	-	2.50	-	131	93	5	2.38	3.50
Near shore waters	Tiwi Islands	7	-	-	-	-	12	1	-	15.83	-
CR	Vernon Islands	69	16	-	4.88	-	162	19	1	4.79	7.92
WQ Zones	East Arm	80	97	-	2.33	-	182	94	13	1.29	2.46
	Middle Arm	8	-	-	-	-	19	25	-	6.63	-
	West Arm	88	97	-	1.38	-	134	95	16	1.79	3.92
	Middle Harbour	2,643	100	48	0.25	0.29	2,465	98	71	0.17	0.17
	Outer Harbour	8,733	100	100	0.04	0.04	8,974	100	95	0.04	0.04
	Shoal Bay	375	100	34	2.17	2.71	467	94	24	2.17	2.67
	Buffalo Creek	34	42	-	6.83	-	49	35	-	4.21	-

Table 12.11 Probability of entrained hydrocarbons exposure to receptors in the 10 – 10 m depth layer for an offshore pipelay vessel fuel tank rupture at KP91.5 during each season. Results were calculated from 100 spill simulations 2er season.

Receptor		Dry					Wet				
		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure	
			Low	High				Low	High		
RFPA	Charles Point Wide	16	12	-	0.04	0.04	15	15	6	0.04	0.04
WQ Zones	Outer Harbour	17	9	-	0.04	0.04	17	10	-	0.04	0.04

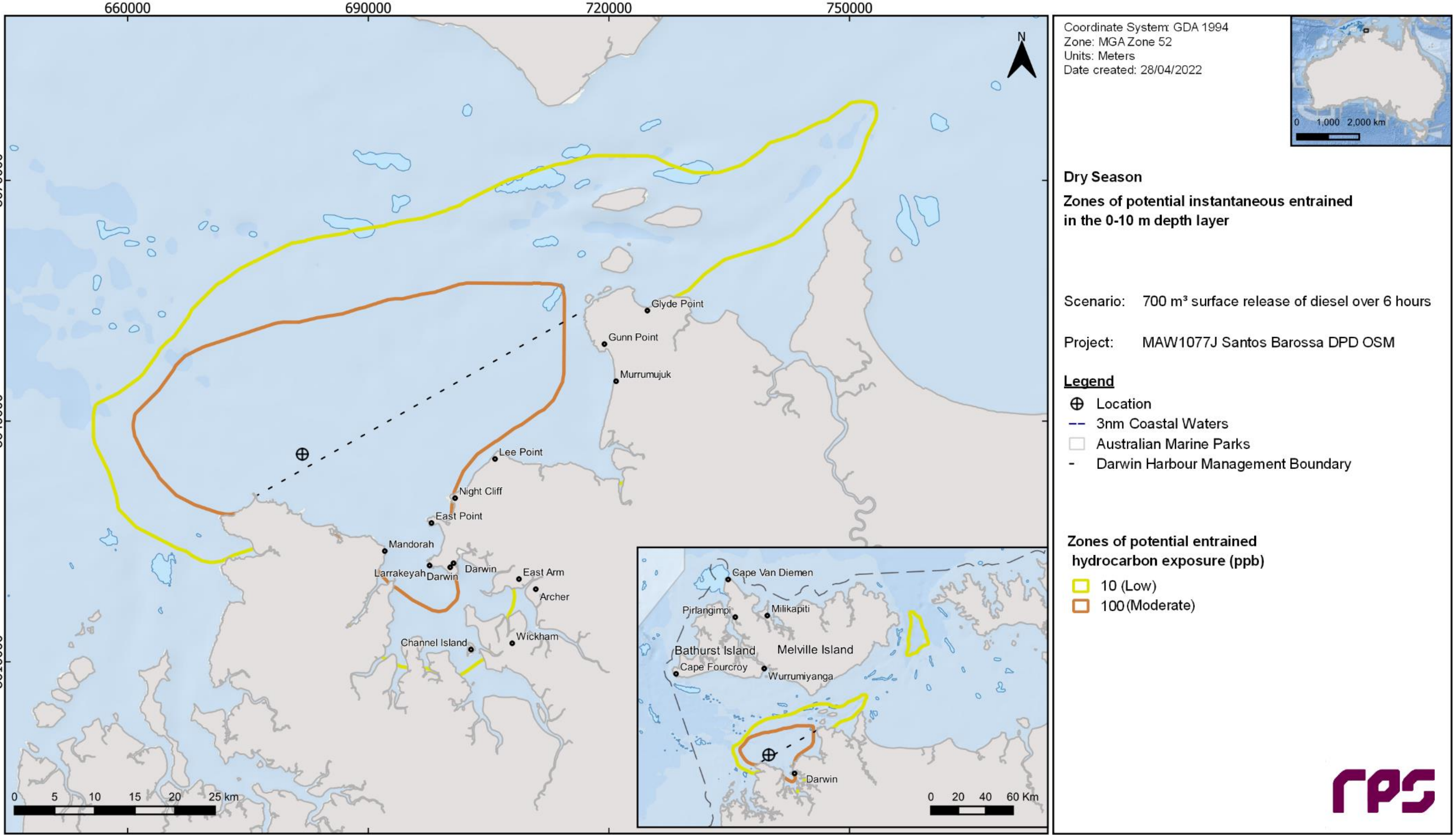


Figure 12.10 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations.

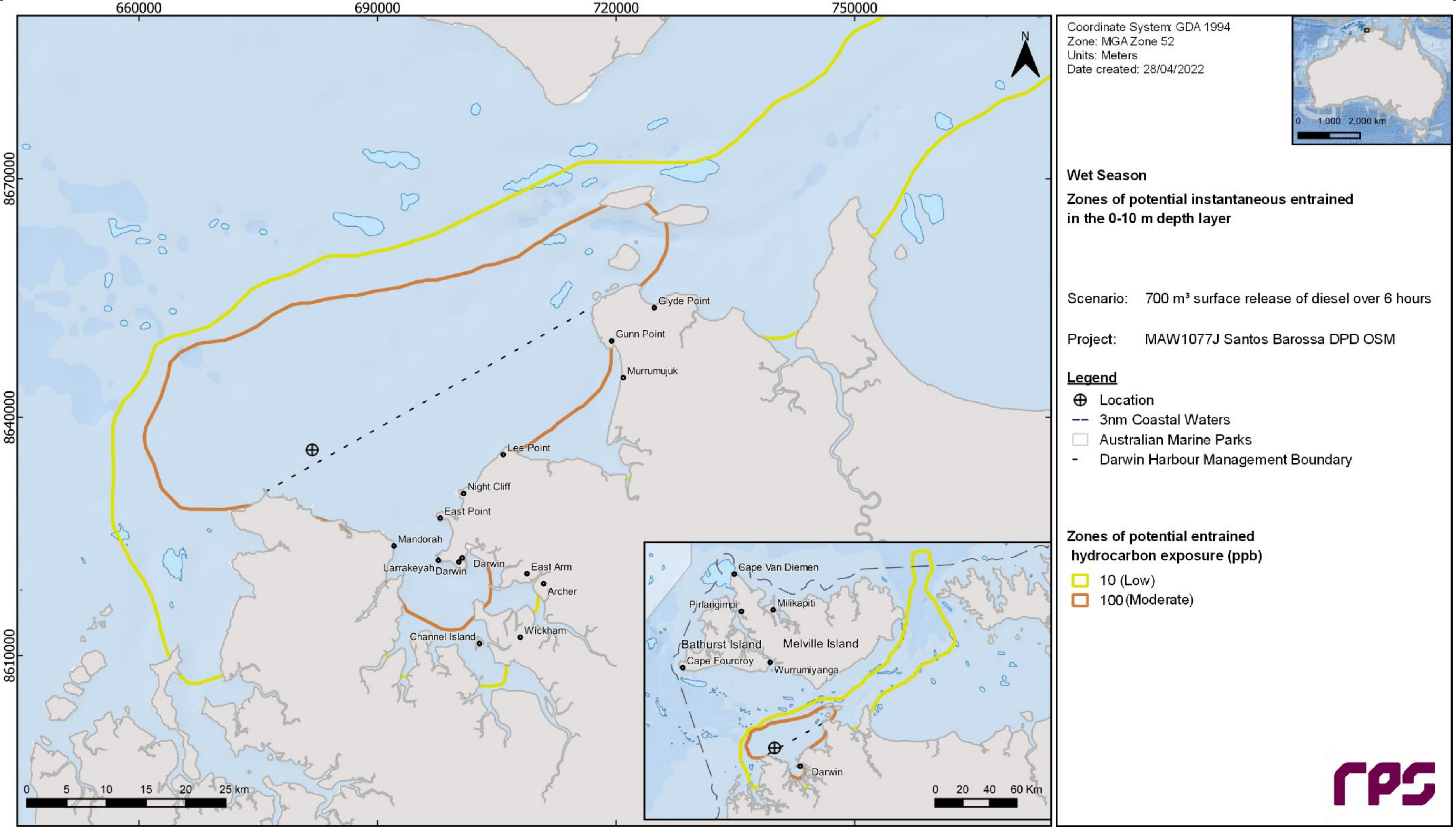


Figure 12.11 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations.

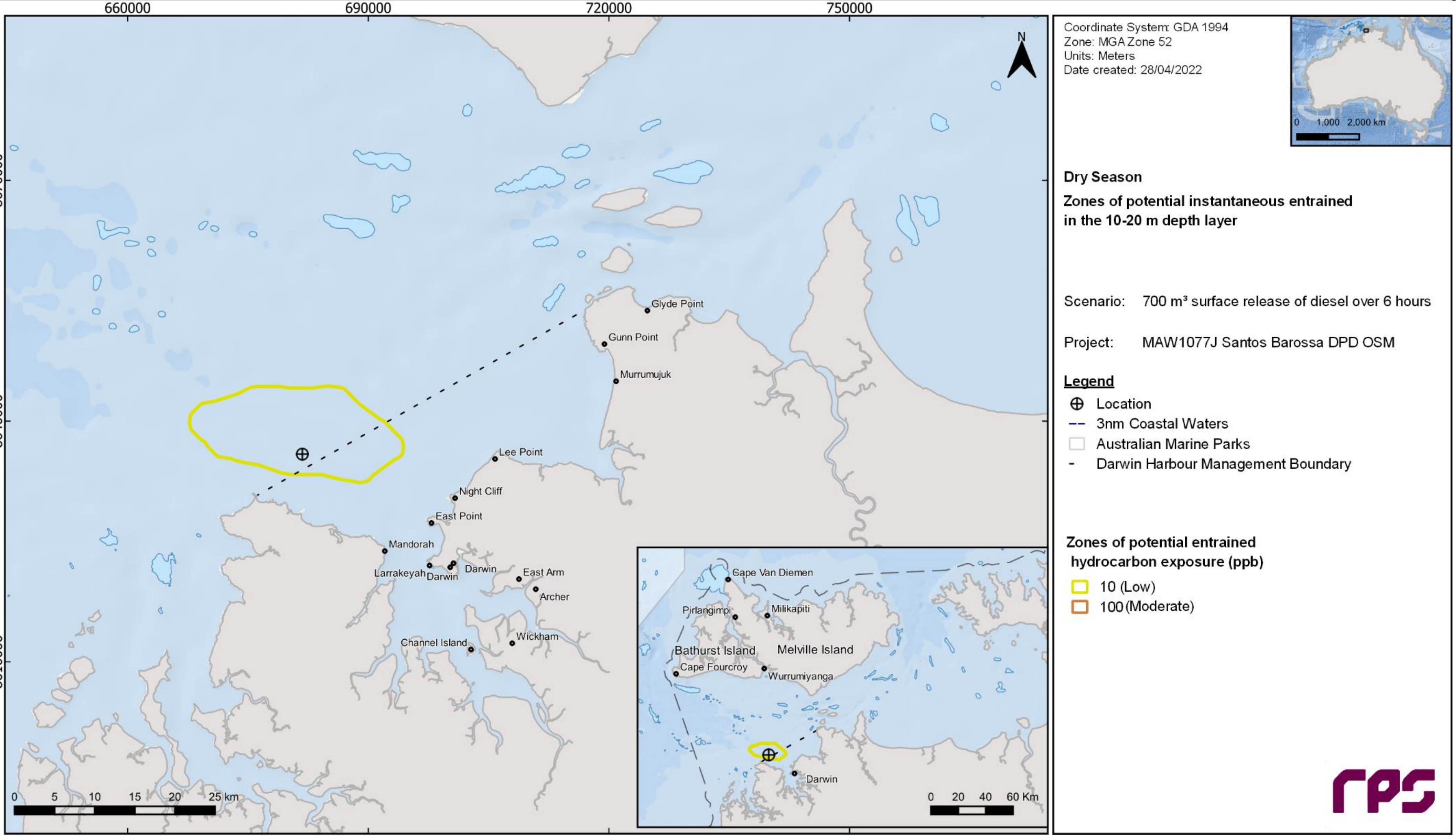


Figure 12.12 Zones of potential entrained hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during dry season conditions. The results were calculated from 100 spill simulations.

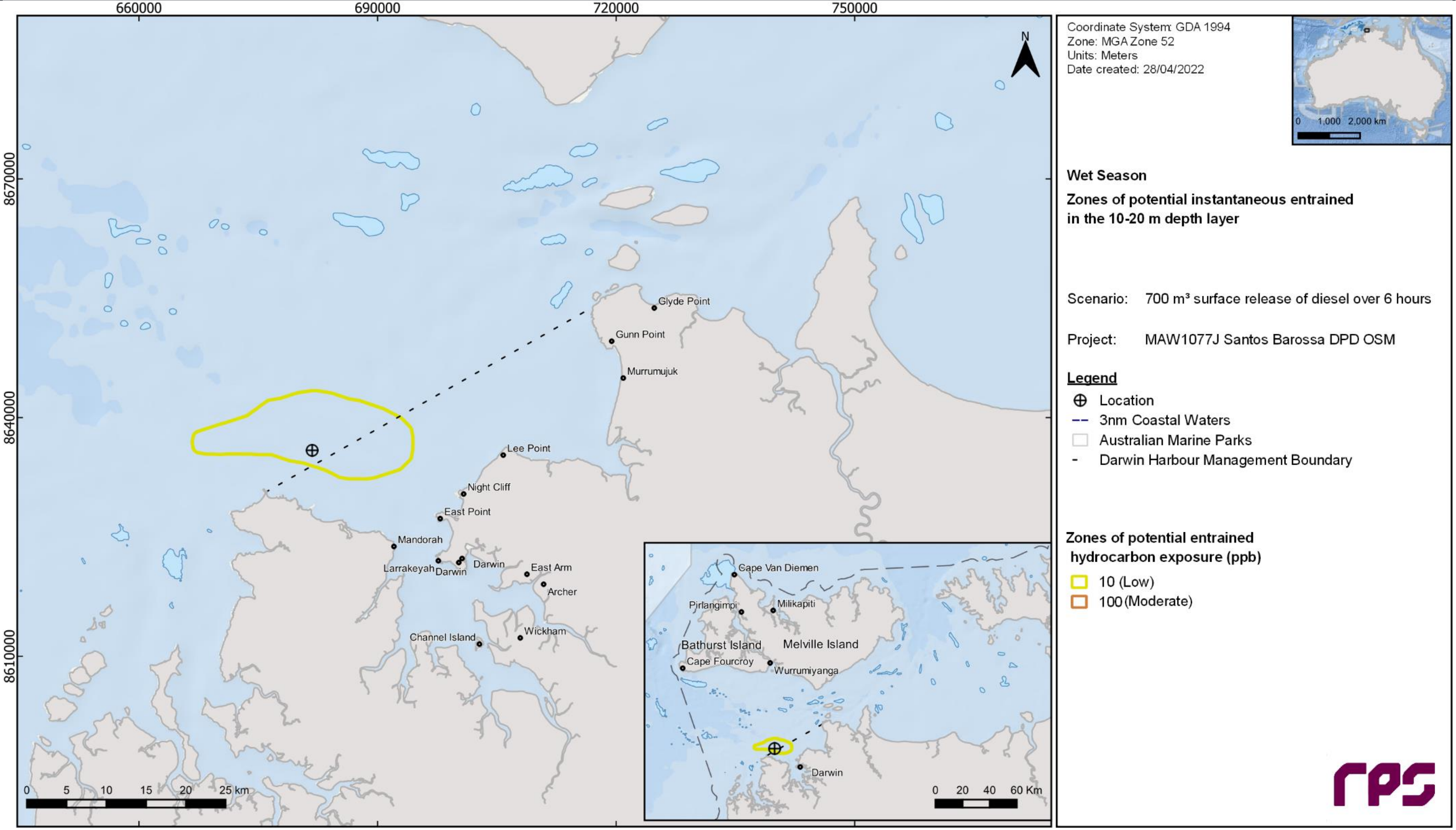


Figure 12.13 Zones of potential entrained hydrocarbon exposure at 10 – 20 m below the sea surface from an offshore pipelay vessel fuel tank rupture at KP91.5 during wet season conditions. The results were calculated from 100 spill simulations.

12.3 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic simulation resulting in the largest volume ashore (59.7 m^3) was identified as run 97, which commenced at 4 pm 14 March 2019, during the wet season.

Zones of floating oil exposure on the sea surface (swept area) and shoreline accumulation over the entire 50-day simulation are presented in Figure 12.14. The spill drifted predominantly east-southeast from the release location and the oil was predicted to initially accumulate on the shoreline between Lee Point and Larrakeyah.

Zones of entrained hydrocarbon exposure within the 0 – 10 m depth layer (surface layer) are presented in Figure 12.15.

No zones of dissolved hydrocarbon exposure above the minimum reporting threshold were predicted for the simulation.

Figure 12.16 and Figure 12.17 displays timeseries of the area of floating oil exposure and volume of oil ashore for each threshold during the 50-day simulation.

Figure 12.18 presents the fates and weathering for the corresponding single spill trajectory. At the conclusion of the simulation, approximately 590 m^3 (85%) of the spilled oil had evaporated and 33 m^3 (5%) remained on the shoreline. In addition, 54 m^3 (8%) was predicted to have decayed by the end of the simulation, while there was no oil predicted to remain on the surface.

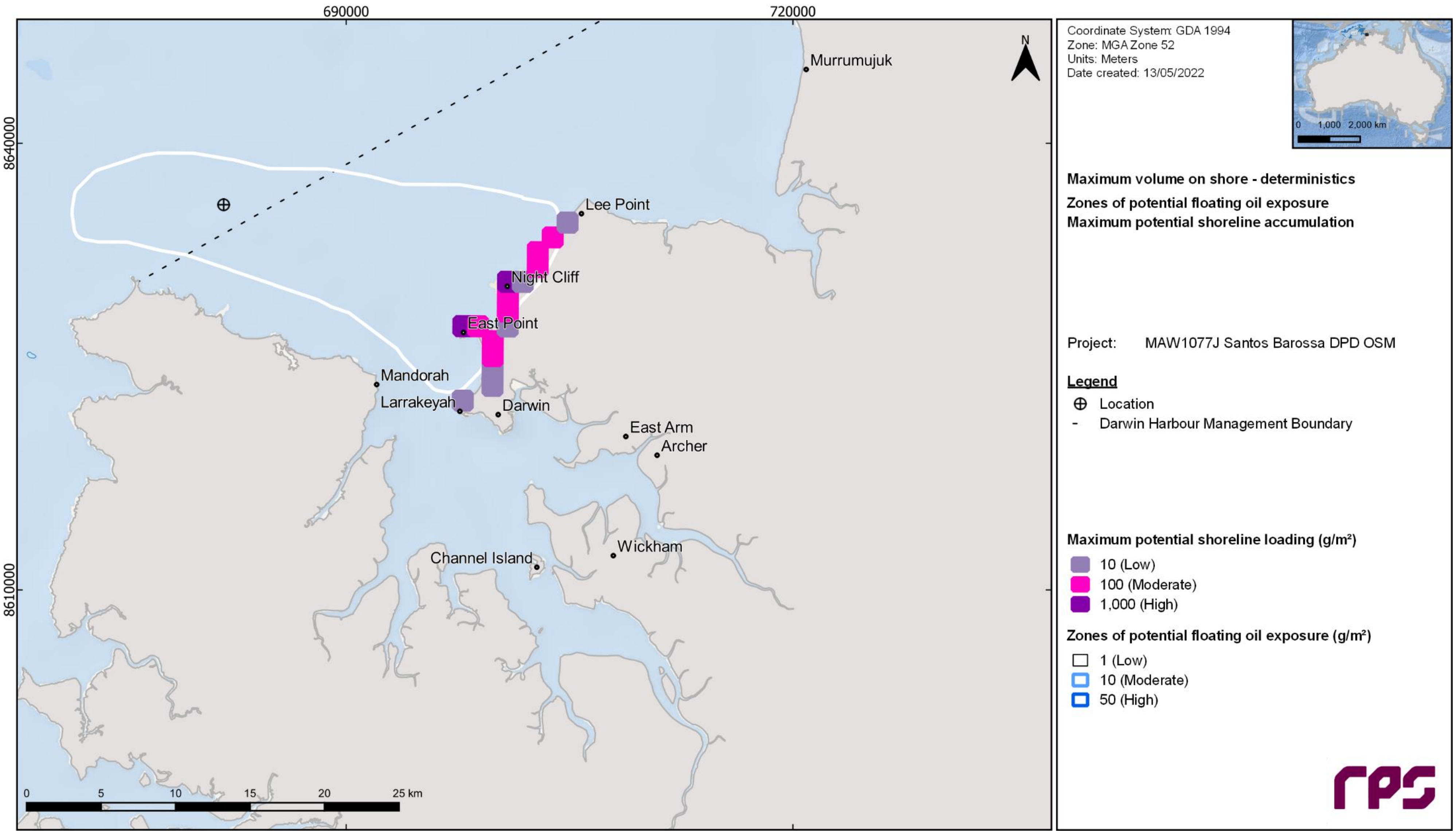


Figure 12.14 Zones of potential exposure on the sea surface and shoreline accumulation (over the 50 days) for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season.

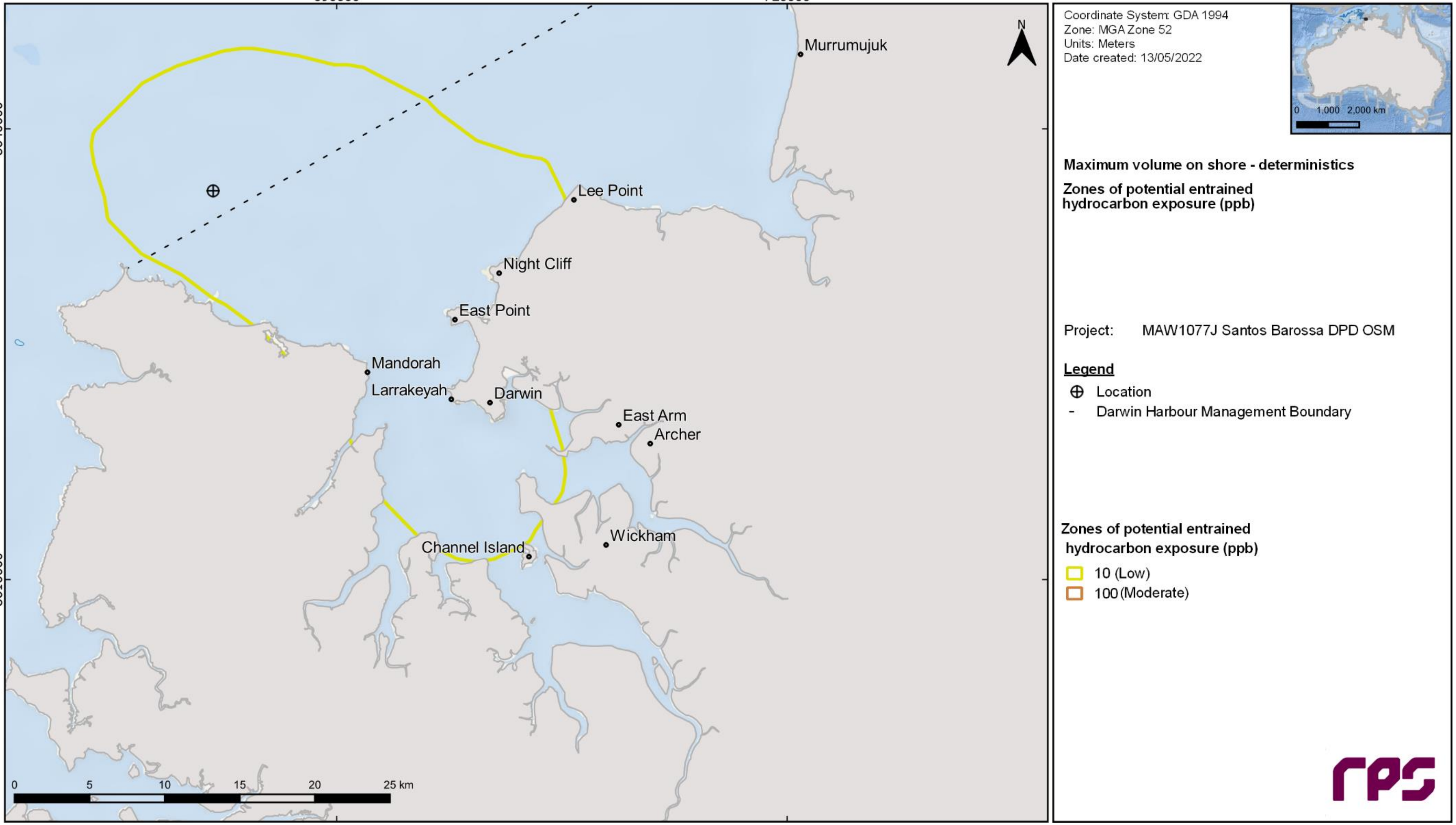


Figure 12.15 Zones of potential entrained hydrocarbon exposure 0 – 10 m below the sea (over the 50-days) for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season.

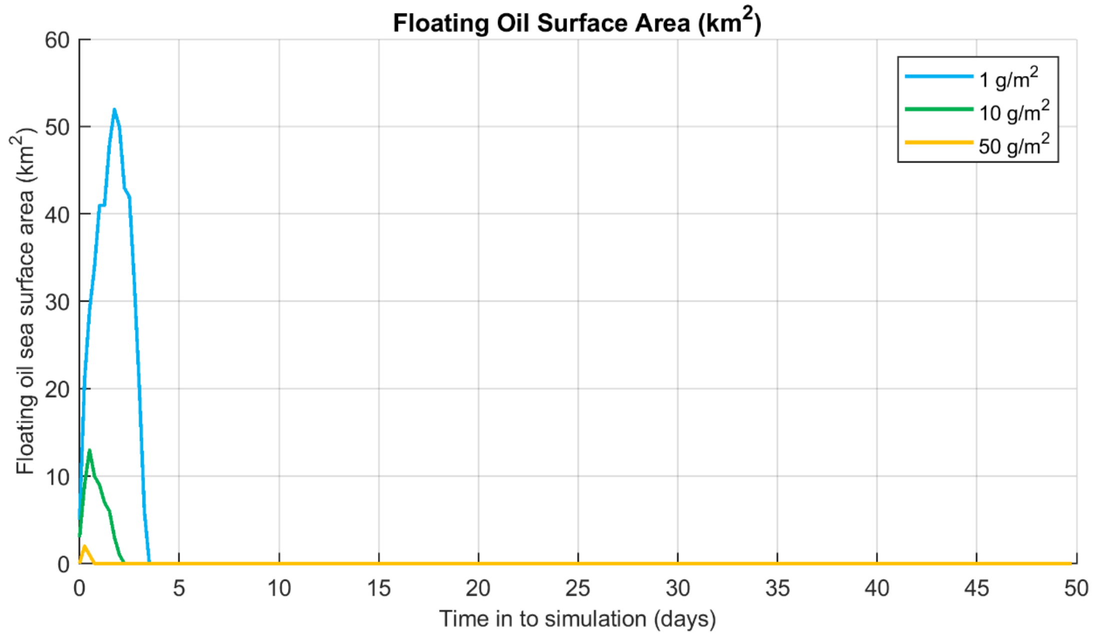


Figure 12.16 Time series of the area of floating oil exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season.

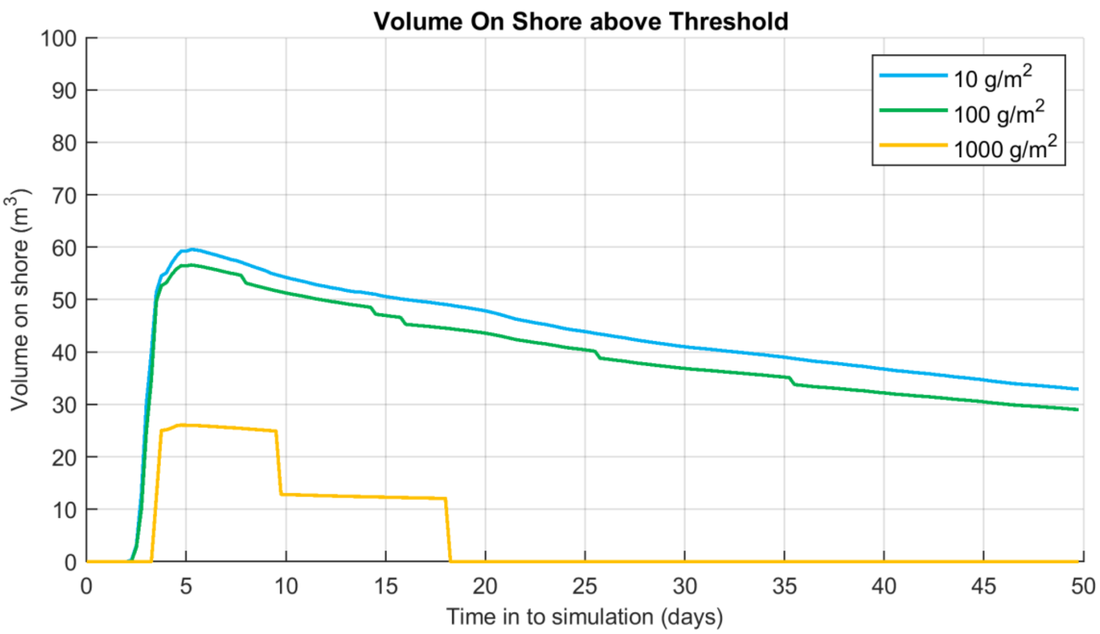


Figure 12.17 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season.

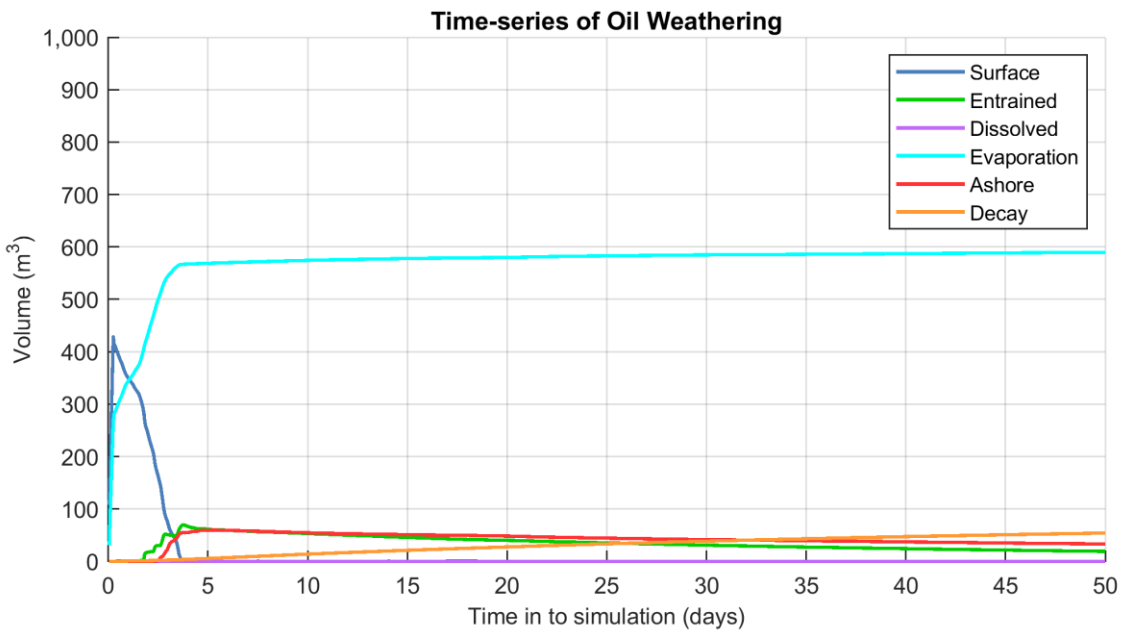


Figure 12.18 Predicted weathering and fates for the simulation resulting in the maximum volume of oil ashore starting at 4 pm 14 March 2019, during the wet season.

13 SCENARIO 2 RESULTS – VESSEL FUEL TANK RUPTURE AT KP114

This scenario examined the potential exposure following an 87.5 m^3 surface release of MDO over 6 hours in the event of a vessel fuel tank rupture at KP114. A total of 200 spill trajectories were simulated (i.e., 100 spills per season) and tracked for 20 days.

Section 13.1 presents the low threshold environment that may be affected (EMBA), resulting from the 200 spill simulations. Section 13.2 shows the seasonal (or stochastic) analysis, while Section 13.3 presents in more detail the results for the simulation resulting in the largest volume of oil ashore.

13.1 EMBA

Figure 13.1 shows the full geographic EMBA derived by overlaying the results from all 200 spill simulations at the low (≥1 g/m^2) exposure thresholds.

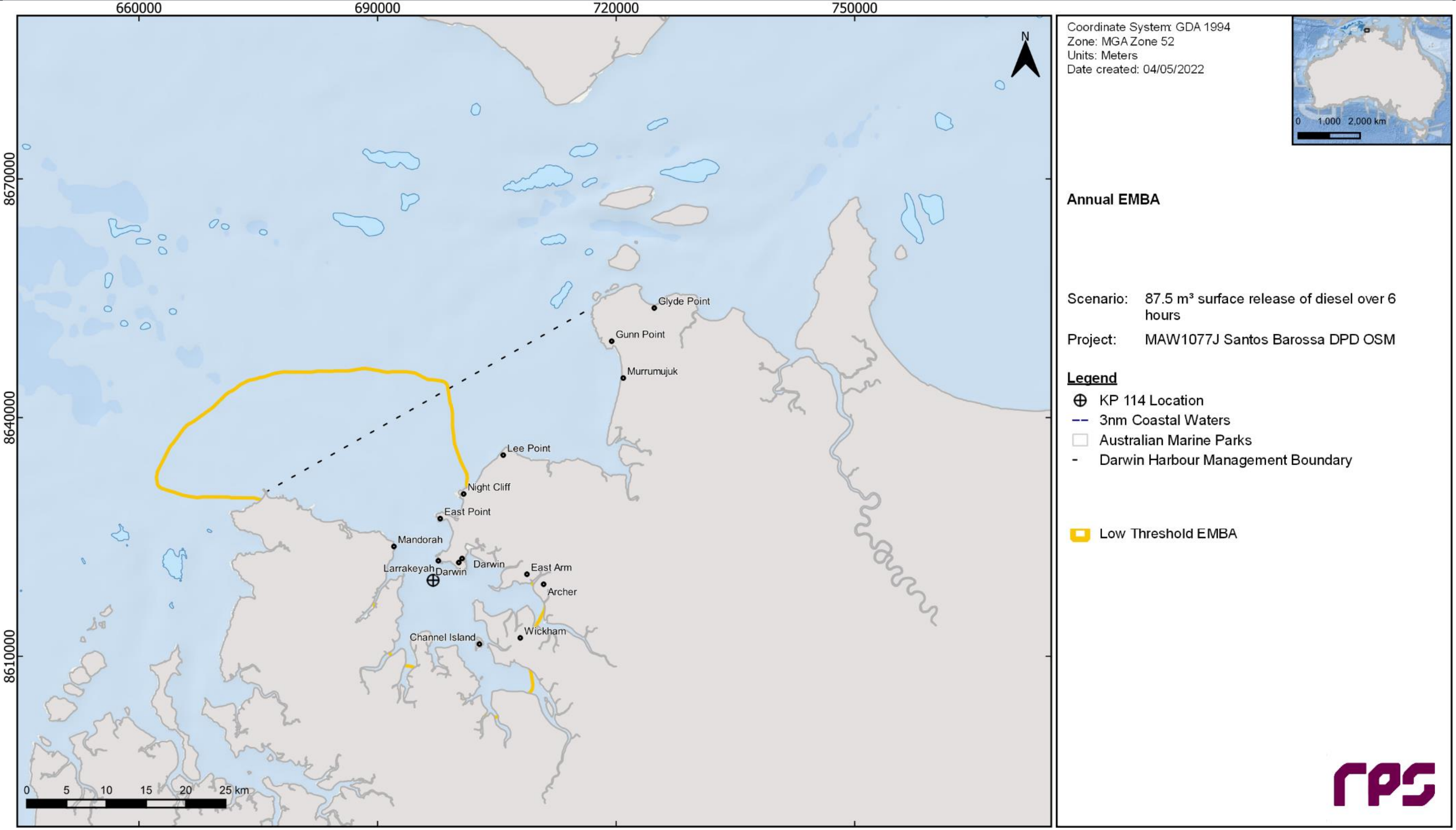


Figure 13.1 Predicted low threshold risk EMBA from a vessel fuel tank rupture at KP114. The annualised results were calculated from 200 spill simulations.

13.2 Stochastic Analysis

13.2.1 Floating Oil Exposure

Table 13.1 summarises the maximum distances and directions travelled by the floating oil from the release location at each threshold for each season. The maximum distances to the low (≥1 g/m^2), moderate (≥10 g/m^2) and high (≥ 50 g/m^2) exposure zones were 29.3 km (west northwest), 14.9 km (southeast) and 0.1 km (west northwest), respectively, during dry season conditions and 29.3 km (west northwest), 11.0 km (southeast) and 0.1 km (west northwest), respectively during wet season conditions. Table 13.2 summarises the potential floating oil exposure to individual receptors for each season and Figure 13.2 and Figure 13.3 illustrate the extent of floating oil exposure for each season.

During both the dry and wet seasons, floating oil exposure at the low threshold was predicted at Restricted Areas 4, 5 and 6 with probabilities ranging between 11 – 35% and 2 – 27%, respectively. No moderate or high exposure was predicted for any Restricted Area.

Only the one simulation during wet season conditions (1% probability) had triggered the low threshold exposure within Charles Point Wide RFPA and it took 0.67 days.

Additionally, four WQ Zones had recorded floating oil exposure at the low threshold with probabilities ranging between 7 – 60% and 11 – 35% during the dry and wet seasons, respectively, (see Table 13.2). Due to the influence of the tides forcing the oil out of the harbour during the ebb tide, the Outer Harbour WQ Zone had also recorded exposure at the moderate threshold during dry (8%) and wet (3%) season conditions, which took as a minimum 0.21 days.

Table 13.1 Maximum distances and directions travelled by floating oil from vessel fuel tank rupture at KP114 at each threshold for each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential floating oil exposure		
		Low	Moderate	High
Dry	Maximum distance (km) from release location	20.3	14.9	0.1
	Maximum distance (km) from the release location (99th percentile)	19.6	12.8	0.1
	Direction	NW	NW	SE
Wet	Maximum distance (km) from release location	29.3	11.0	0.1
	Maximum distance (km) from release location (99th percentile)	24.0	9.6	0.1
	Direction	WNW	NW	SE

Table 13.2 Summary of the potential exposure by floating oil to individual receptors from a vessel fuel tank rupture at KP114 for each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry						Wet					
		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)			Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
RFPA	Charles Point Wide	-	-	-	-	-	-	1	-	-	0.67	0.67	-
Restricted Areas	4	35	-	-	0.29	-	-	27	-	-	0.33	-	-
	5	11	-	-	0.21	-	-	2	-	-	0.29	-	-
	6	31	-	-	0.33	-	-	20	-	-	0.33	-	-
WQ Zones	East Arm	9	-	-	0.29	-		21	-	-	0.29	-	
	Middle Arm	7	-	-	0.21	-		11	-	-	0.21	-	
	West Arm	38	-	-	0.25	-		30	-	-	0.25	-	
	Outer Harbour	60	8	-	0.08	0.21		35	3	-	0.08	0.21	

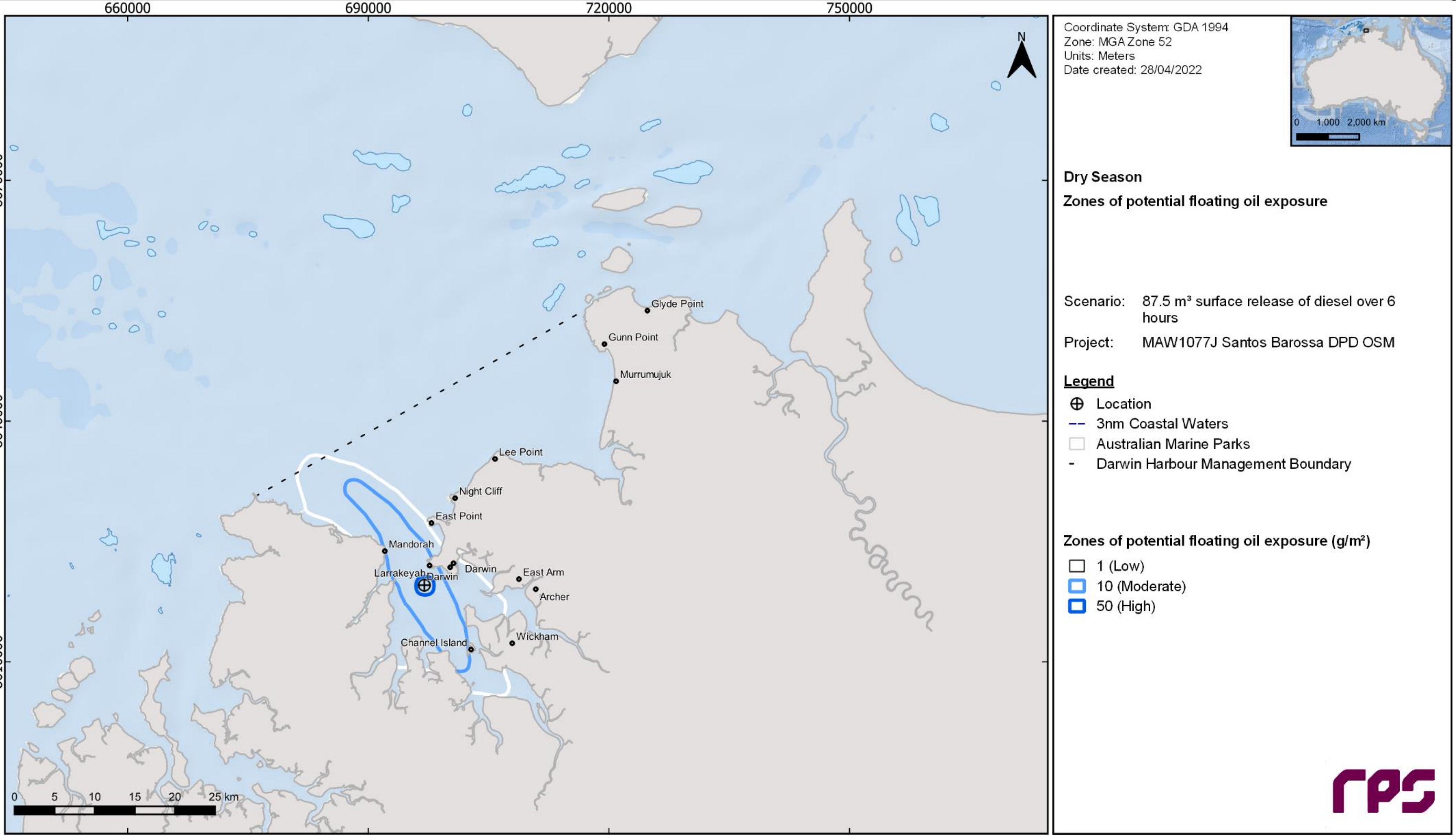


Figure 13.2 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

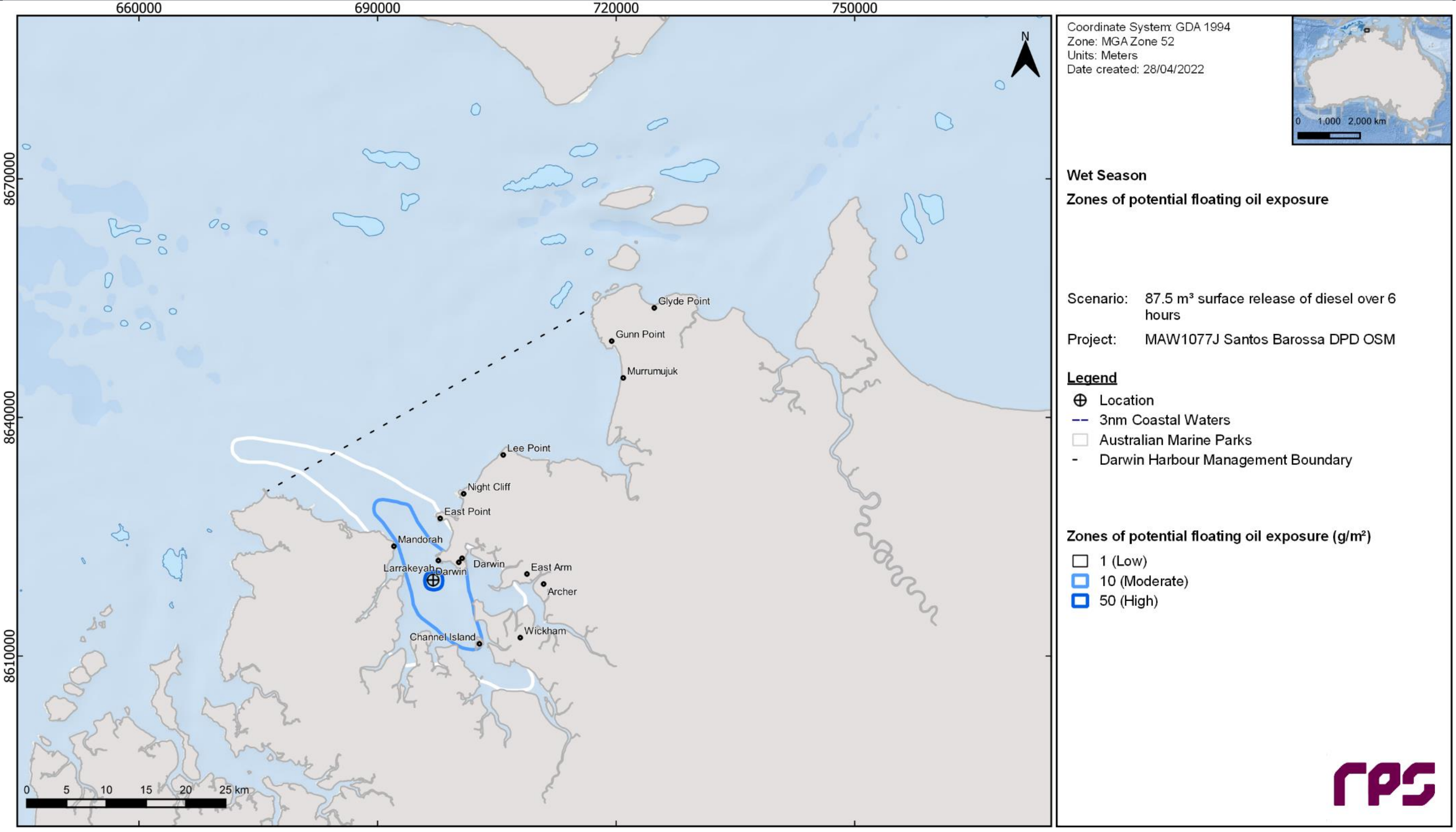


Figure 13.3 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

13.2.2 Shoreline Accumulation

Table 13.3 summarises the predicted oil accumulation on any shoreline during each season. The probability of oil accumulation at, or above, the low threshold (10 g/m^2) was 94% (dry season) and 83% (wet season). The minimum time before oil accumulation at, or above, the low threshold ranged between 0.21 days (dry season) and 0.17 days (wet season). The maximum volume ashore for a single spill ranged between 24.8 m^3 (dry season) and 24.7 m^3 (wet season) and the maximum length of shoreline contacted at the low threshold was 29.6 km (dry season) and 28.1 km (wet season). The maximum lengths of oil accumulation on shorelines at, or above, the moderate (100 – 1,000 g/m^2) and high (≥1,000 g/m^2) thresholds was 5.5 km (dry season) and 6.5 km (wet season), and 0.5 km (dry season), respectively there was no shoreline contact at the high (≥1,000 g/m^2) threshold during wet season conditions.

Table 13.4 and Table 13.5and summarise the oil accumulation on individual shoreline receptors for each season. The maximum potential shoreline loading for the specified thresholds for each season are presented in Figure 13.4 and Figure 13.5.

The highest probability of oil accumulation at the low threshold was predicted along the West Arm (78% dry and 47% wet seasons) and East Arm (32% dry and 48% wet conditions) shorelines. The greatest volume (peak) of oil accumulation during the dry and wet seasons occurred along the West Arm shoreline (24.2 m^3 (dry season) and 24.6 m^3 (wet season)). The minimum time before oil accumulation at the low threshold was 0.21 days (East Arm) for the dry season and 0.17 days (East Arm) during the wet season conditions.

Table 13.3 Summary of oil accumulation on any shoreline from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Shoreline Statistics	Dry			Wet		
	Low	Moderate	High	Low	Moderate	High
Probability of accumulation on any shoreline (%)	94	45	1	83	52	-
Absolute minimum time before oil ashore (days)	0.21	0.38	1.25	0.17	0.21	-
Maximum length of shoreline contacted	29.6	5.5	0.5	28.1	6.5	-
Average length of shoreline contacted (km)	7.3	1.8	0.5	9.8	2.2	-
	Dry			Wet		
Maximum volume of hydrocarbons ashore (m^3)	24.8			24.7		
Average volume of hydrocarbons ashore (m^3)	4.5			5.8		

Table 13.4 Summary of oil accumulation on individual shoreline sectors from a vessel fuel tank rupture at KP114 for the dry season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Cox-Finniss	2	-	-	1.42	-	-	<1	21	<0.1	0.2	0.5	-	-	0.5	-	-
East Arm	32	8	-	0.21	0.42	-	6	642	0.5	8.4	2.4	1.0	-	13.0	2.0	-
Middle Arm	9	2	-	0.33	0.63	-	2	197	0.2	4.5	3.0	1.7	-	6.5	2.0	-
Outer Harbour East	-	-	-	-	-	-	<1	4	<0.1	<0.1	-	-	-	-	-	-
Outer Harbour West	4	-	-	0.79	-	-	<1	41	<0.1	1.3	2.7	-	-	4.5	-	-
West Arm	78	38	1	0.29	0.38	1.25	10	1,189	3.6	24.2	6.6	1.8	0.5	23	4	0.5
Wickham Point	15	1	-	0.58	0.83	-	2	102	0.1	2.7	1.9	0.5	-	4.5	0.5	-

Table 13.5 Summary of oil accumulation on individual shoreline sectors from a vessel fuel tank rupture at KP114 for the wet season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Cox-Finniss	-	-	-	-	-	-	<1	5	<0.1	< 0.1	-	-	-	-	-	-
East Arm	48	16	-	0.17	0.21	-	5	776	1.1	14.6	3.2	1.2	-	15.0	3.0	-
Middle Arm	21	2	-	0.29	0.83	-	1	154	0.2	2.8	1.8	0.7	-	4.0	1.0	-
Outer Harbour East	2	-	-	1.25	-	-	<1	28	<0.1	0.2	0.5	-	-	0.5	-	-
Outer Harbour West	3	-	-	1.08	-	-	<1	35	<0.1	1.4	2	-	-	3.5	-	-
West Arm	47	31	-	0.21	0.46	-	10	852	3.5	24.6	9.2	2.5	-	25.0	6.5	-
Wickham Point	45	7	-	0.21	0.58	-	6	364	0.8	7.6	3	1.1	-	6.5	2.0	-

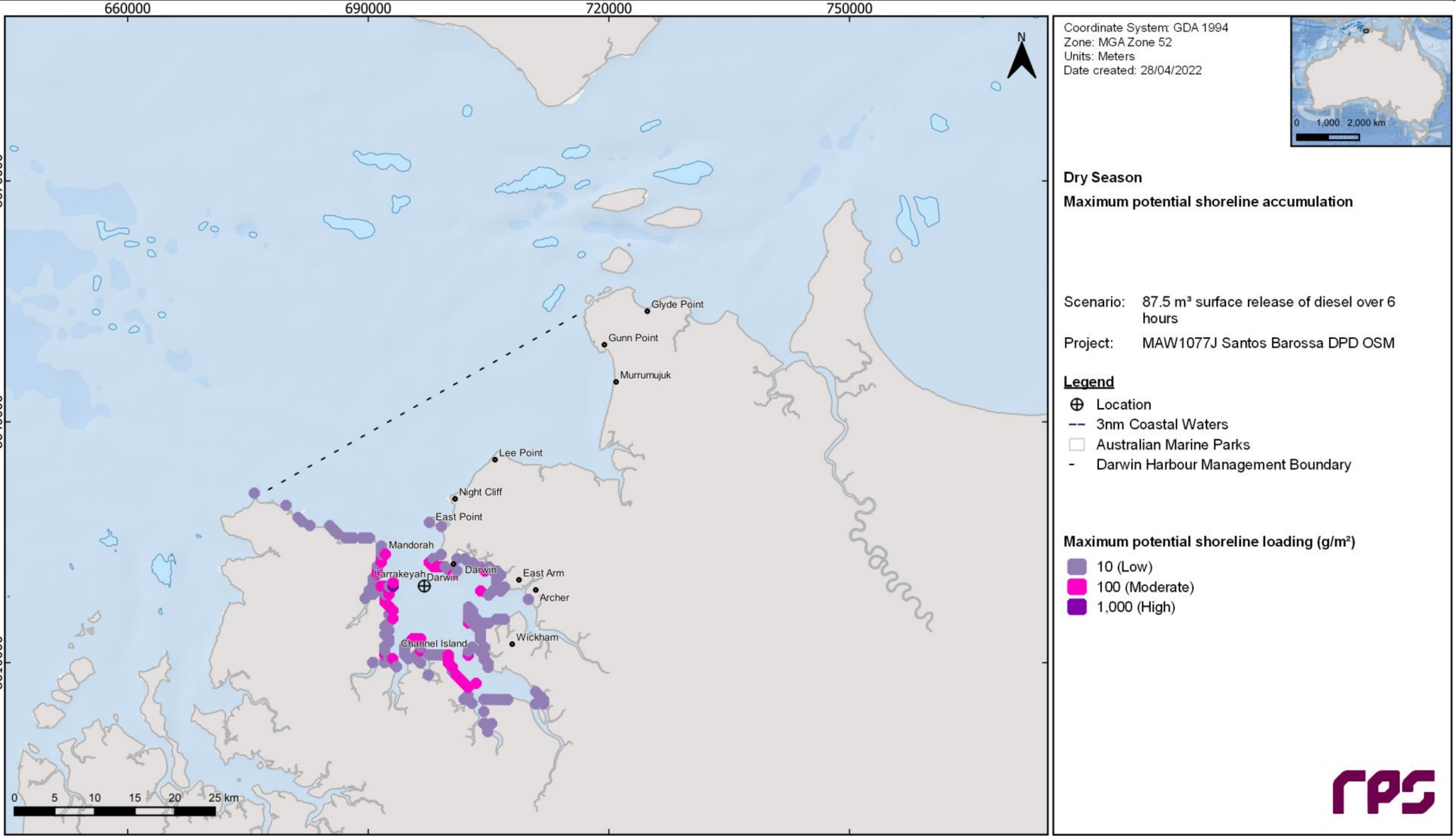


Figure 13.4 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

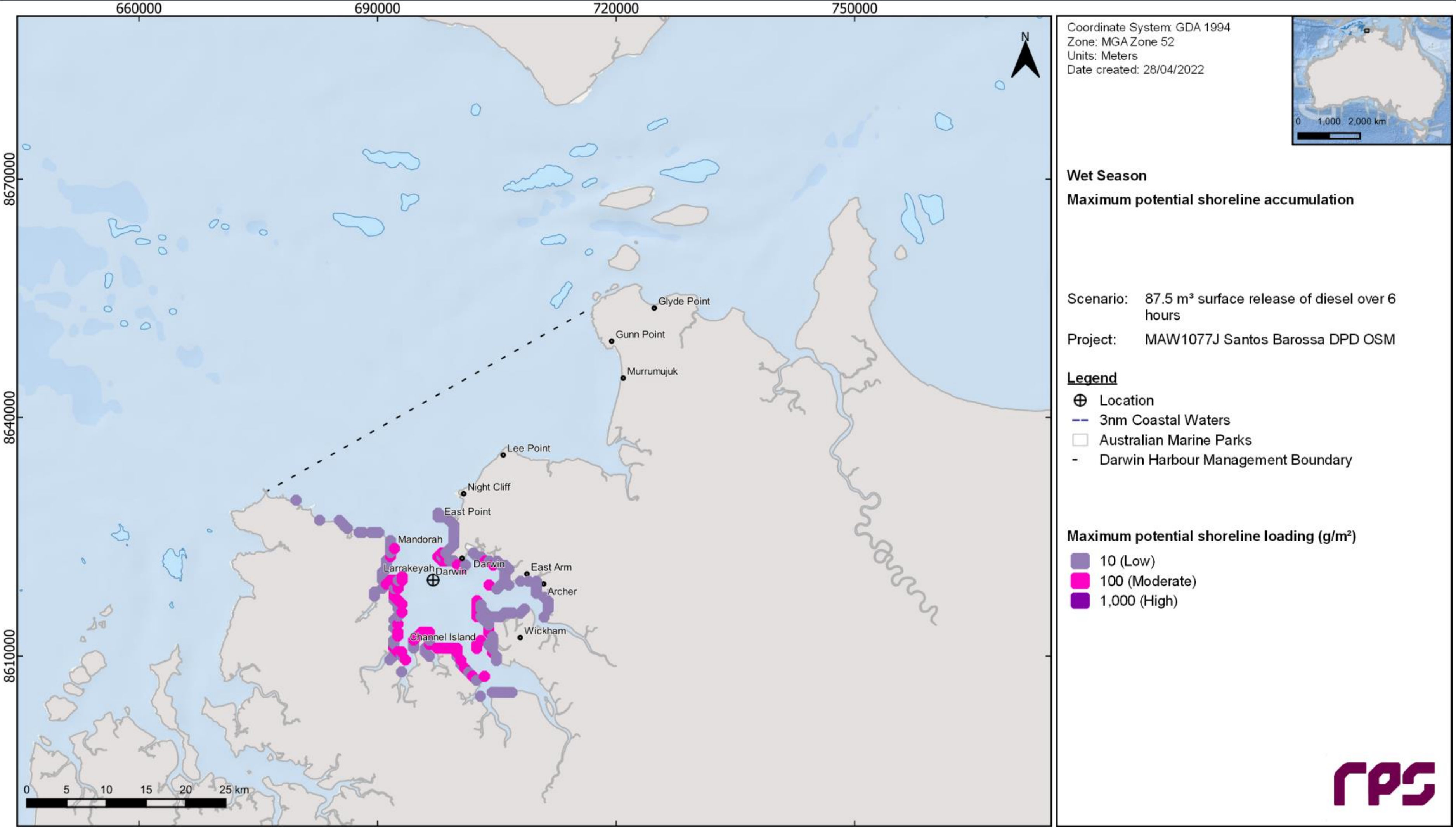


Figure 13.5 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

13.2.3 In-water exposure

13.2.3.1 Dissolved Hydrocarbons

Table 13.6 summarises the maximum distances and directions travelled by dissolved hydrocarbons from the release location to the low threshold (≥ 10 ppb), in the 0 – 10 m depth layer as there was no exposure predicted for the moderate and high thresholds. The maximum distances during the dry and wet seasons were 3.9 km and 12.2 km north northwest, respectively. Exposure was limited to the 0 – 10 m depth layer.

Table 13.7 summarises the potential exposure to receptors from dissolved hydrocarbons in the 0 – 10 m depth layer for each threshold and season. Figure 13.6 and Figure 13.7 illustrate the extent of dissolved hydrocarbon exposure for each season in the 0 – 10 m depth layers.

There was no exposure to any receptor during the dry season. Under wet season conditions, 3 receptors had recorded exposure at the low threshold (Ham Luong and Mauna Loa USAT shipwreck, and Outer Harbour WQ Zone) and the probabilities ranged between 1 and 6%. There was no exposure at the moderate threshold to any receptor. The maximum instantaneous dissolved concentrations were 9 ppb and 21 ppb predicted at the Mauna Loa USAT shipwreck during dry and wet seasons, respectively.

Table 13.6 Maximum distances and directions travelled by dissolved hydrocarbons (0 – 10 m depth layer) from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential dissolved hydrocarbon exposure		
		Low 10 ppb	Moderate 50 ppb	High 400 ppb
Dry	Maximum distance (km) from the release location	3.9	-	-
	Maximum distance (km) from the release location (99th percentile)	3.9	-	-
	Direction	NNW	-	-
Wet	Maximum distance (km) from the release location	12.2	-	-
	Maximum distance (km) from the release location (99th percentile)	12.2	-	-
	Direction	NNW	-	-

Table 13.7 Summary of dissolved hydrocarbon exposure for each receptor in the 0 – 10 m depth layer from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry							Wet						
		Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure			Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure		
			Low	Moderate	High	Low	Moderate	High		Low	Moderate	High	Low	Moderate	High
Shipwrecks	Ham Luong	6	-	-	-	-	-	-	21	6	-	-	0.13	-	-
	Mauna Loa USAT	9	-	-	-	-	-	-	21	4	-	-	0.17	-	-
	Outer Harbour	3	-	-	-	-	-	-	10	1	-	-	0.33	-	-

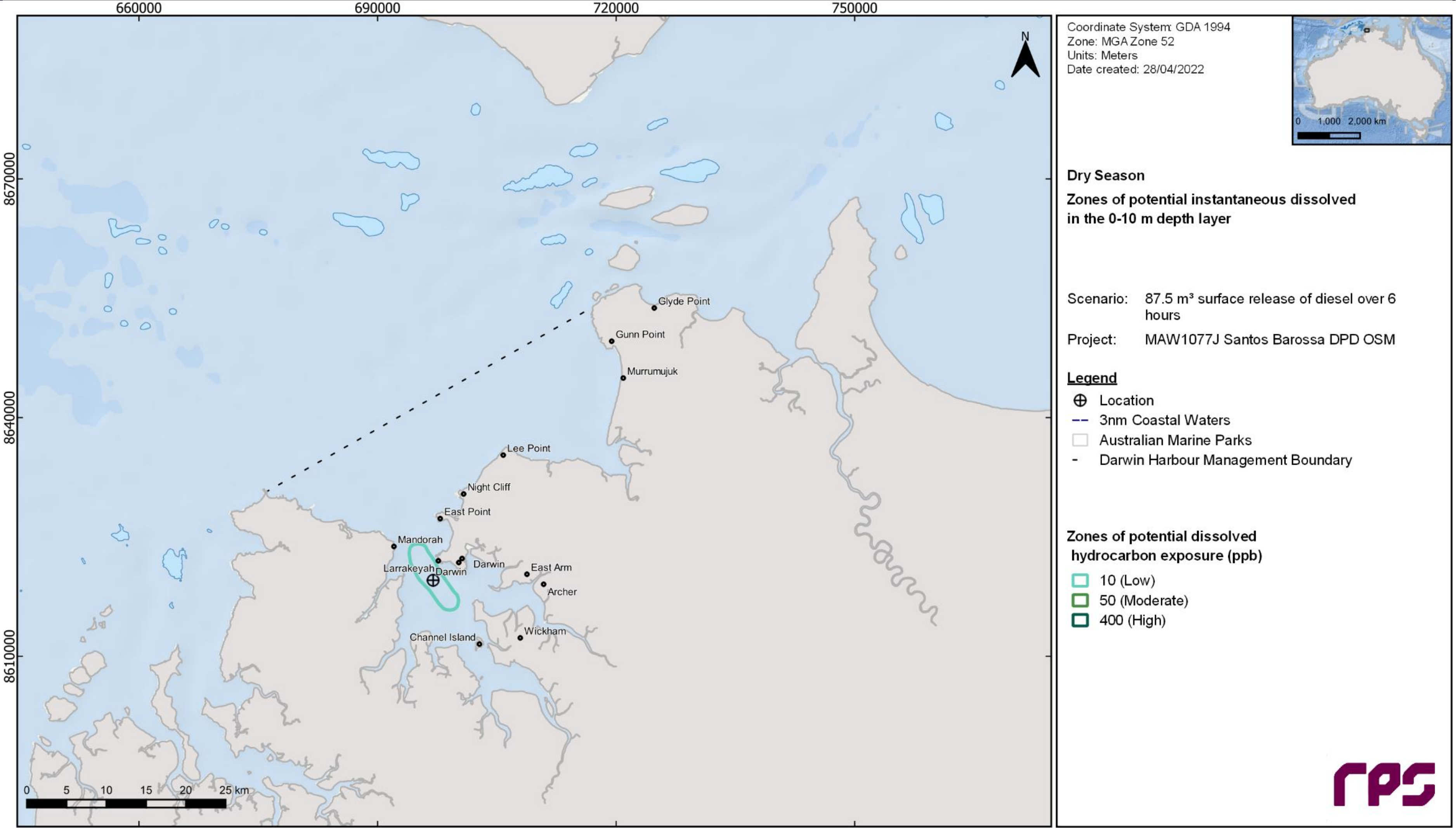


Figure 13.6 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

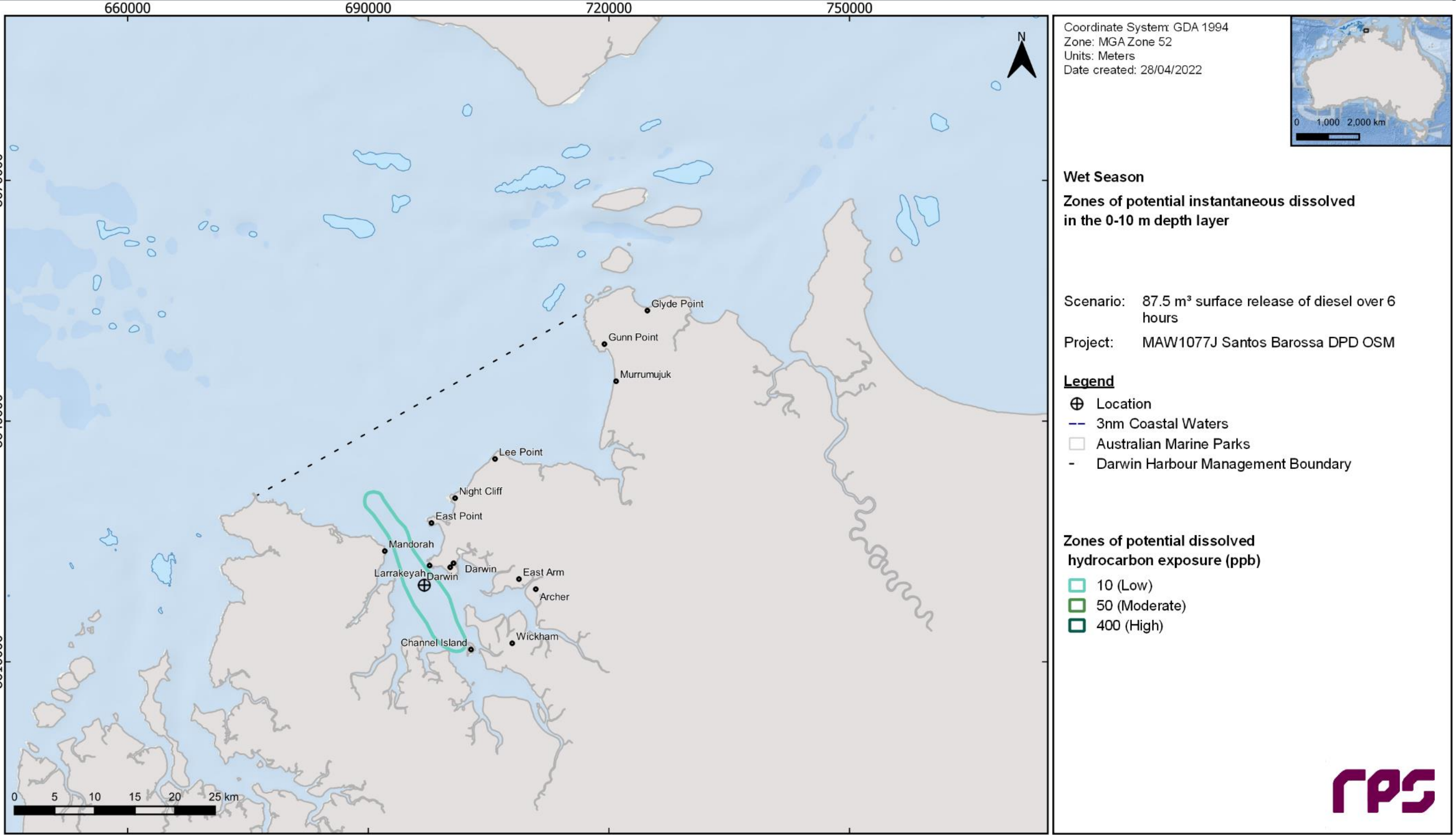


Figure 13.7 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

13.2.3.2 Entrained Hydrocarbons

Table 13.8 summarises the maximum distances and directions travelled by entrained hydrocarbons within the 0 – 10 m depth layers at the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds, which ranged between 36.1 km and 20.3 km west northwest from the release location, during the dry season conditions and 33.8 km and 23.9 km northwest from the release location, during the wet season conditions.

Table 13.9 summarises the potential exposure to receptors from entrained hydrocarbons in the 0 – 10 m depth layer for each season. Figure 13.8 and Figure 13.9 illustrate the extent of entrained hydrocarbon exposure for each season in the 0 – 10 m depth layer.

During both seasons the Charles Point Wide RFPA and four Restricted Areas (1, 4, 5 and 6) were predicted to be exposed to entrained hydrocarbons at the low threshold with probabilities ranging from 45 – 97% and 5 – 69% during the dry and wet seasons, respectively. During both seasons Restricted Area 6 was predicted to have the greatest probability of low threshold exposure (97% and 69%).

Exposure at the low threshold was predicted at 15 and 16 shipwreck receptors during the dry and wet season, respectively with probabilities ranging from 28% (Ellengowan) and 97% (Mauna Loa USAT) during the dry season and 2% (East Arm Vietnamese Refugee Boat 1) and 78% (Mauna Loa USAT) during the wet season.

Furthermore, 4 WQ Zones were predicted to be exposed at the low threshold with probabilities ranging from 31% (Middle Arm) and 93% (Outer Harbour) during the dry season. While under wet season conditions there were 5 receptors and probabilities ranging from 2% (Elizabeth River) and 70% (Outer Harbour) during the wet season. The maximum instantaneous concentrations were predicted at Outer Harbour during both the dry (436 ppb) and wet (677 ppb) seasons.

Table 13.8 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from the release location vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential entrained hydrocarbon exposure	
		Low 10 ppb	Moderate 100 ppb
Dry	Maximum distance (km) from release location	36.1	20.3
	Maximum distance (km) from release location (99th percentile)	34.8	19.4
	Direction	WNW	NW
Wet	Maximum distance (km) from release location	33.8	23.9
	Maximum distance (km) from release location (99th percentile)	32.8	23.0
	Direction	NW	NW

Table 13.9 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry					Wet				
		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure	
			Low	Mod	Low	Mod		Low	Mod	Low	Mod
RFPA	Charles Point Wide	71	45	-	0.71	-	117	36	1	0.71	0.96
Restricted Area	1	9	-	-	-	-	18	5	-	0.42	-
	4	130	94	7	0.21	0.58	253	67	1	0.17	0.38
	5	114	88	2	0.17	0.46	99	58	-	0.29	-
	6	181	97	22	0.17	0.42	350	69	2	0.13	0.33
Shipwrecks	Bell Bird	199	62	2	0.21	0.63	126	65	4	0.21	0.54
	Booya	122	83	3	0.17	0.33	282	60	2	0.13	0.21
	British Motorist	218	71	3	0.21	0.50	182	69	13	0.17	0.33
	Darwin Harbour Unidentified wreck 2	248	83	10	0.13	0.29	460	72	31	0.08	0.17
	Diemen	129	94	7	0.21	0.42	98	64	-	0.21	-
	East Arm Vietnamese Refugee Boat 1	6	-	-	-	-	14	2	-	0.88	-
	Ellengowan	75	28	-	0.46	-	84	41	-	0.17	-
	Ham Luong	1,073	96	45	0.04	0.04	1,588	78	50	0.04	0.04
	L. Ann	70	84	-	0.33	-	41	58	-	0.63	-
	Landing Barge	179	61	2	0.29	0.67	109	66	2	0.21	0.71
	Mandorah Unidentified wreck 1	70	84	-	0.33	-	41	58	-	0.63	-
	Mauna Loa USAT	1,197	97	46	0.04	0.04	1,992	78	49	0.04	0.04
	Middle Arm unidentified wreck	75	28	-	0.46	-	84	41	-	0.17	-
	Peary USS	262	82	12	0.17	0.25	310	72	30	0.13	0.21
	Vietnamese Refugee Boat Pk76	118	55	1	0.33	0.63	85	59	-	0.21	-

	Yu Han 22	500	95	27	0.08	0.13	521	75	20	0.08	0.17
WQ Zones	Elizabeth River	6	-	-	-	-	14	2	-	0.88	-
	East Arm	145	45	1	0.29	0.67	94	62	-	0.21	-
	Middle Arm	282	31	4	0.25	0.38	389	34	9	0.17	0.25
	West Arm	132	92	3	0.21	0.42	208	67	2	0.17	0.29
	Outer Harbour	436	93	22	0.13	0.13	677	70	21	0.08	0.13

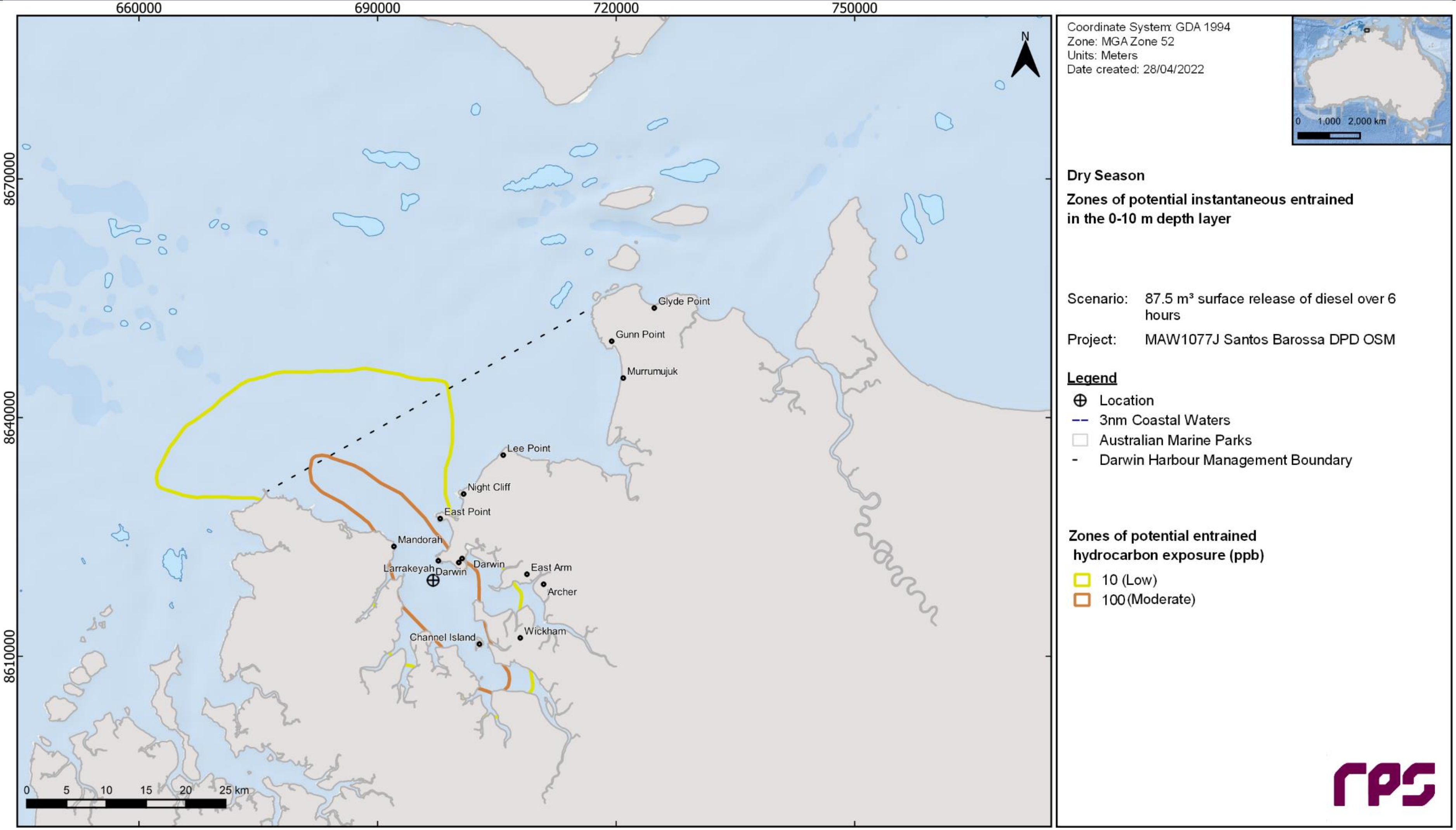


Figure 13.8 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

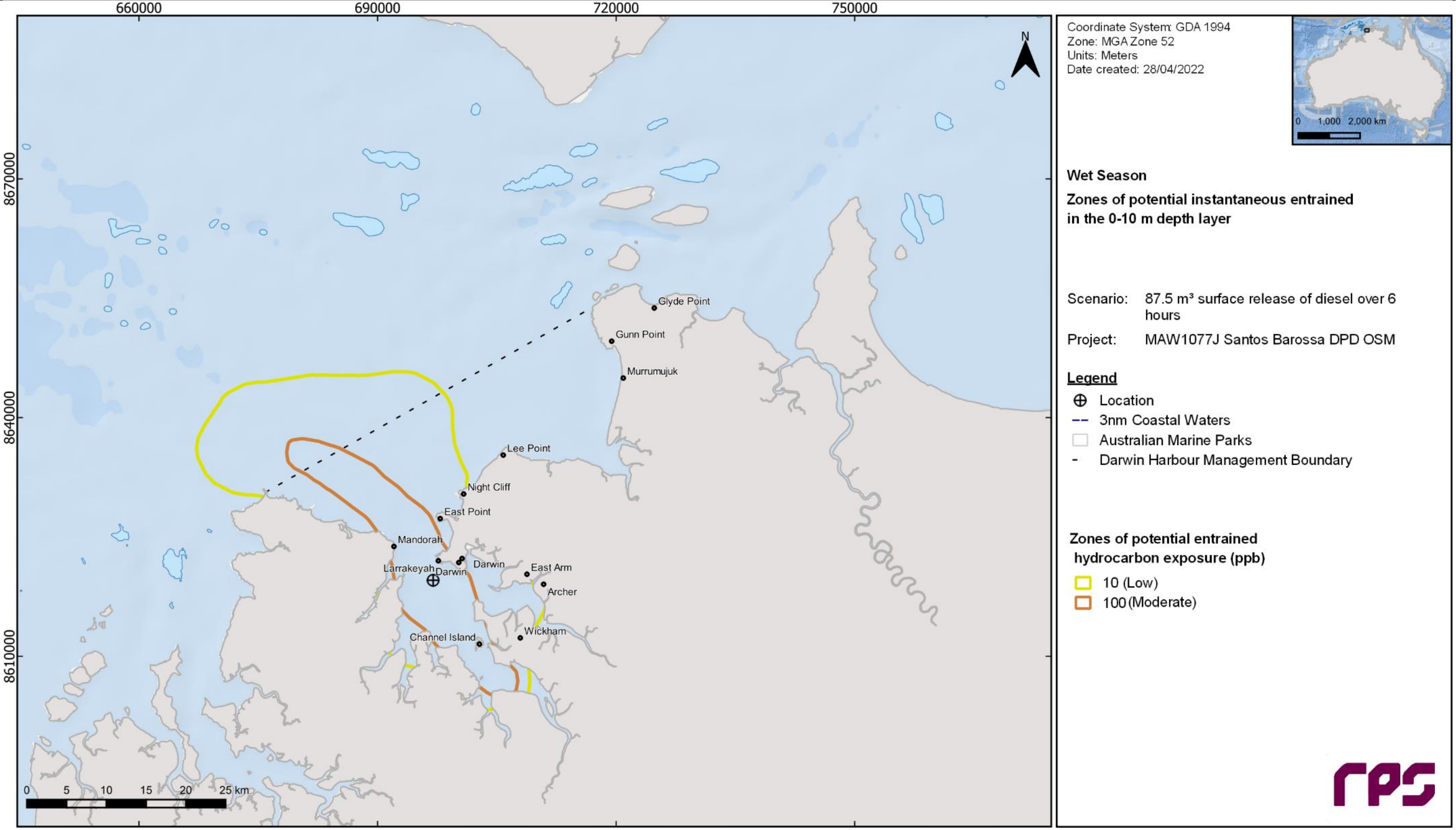


Figure 13.9 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

13.3 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic simulation resulting in the largest volume ashore (24.8 m^3) was identified as run 38, which commenced at 2 am 2 September 2019 during the dry season.

Zones of exposure on the sea surface (swept area) and shoreline accumulation over the entire 20-day simulation are presented in Figure 13.10. The spill had drifted predominately south and west from the release from the release location and the oil was predicted to accumulate on the western shoreline up to Mandorah.

Zones of entrained hydrocarbon exposure within the 0 – 10 m depth layer (surface layer) over the 20-day simulation are presented in Figure 13.11.

No zones of dissolved hydrocarbon exposure above the reporting threshold were predicted for the simulation.

Figure 13.12 and Figure 13.13 show time series of the area of floating oil and the volume of oil ashore exposure for each threshold during the 20-day simulation.

Figure 13.14 presents the fates and weathering for the corresponding single spill trajectory. At the conclusion of the simulation, approximately 74 m^3 (85%) of the spilled oil was lost to the atmosphere through evaporation and 10 m^3 (12%) remained on the shoreline. In addition, 2 m^3 (2%) was predicted to have decayed by the end of the simulation, while there was no oil predicted to remain on the surface.

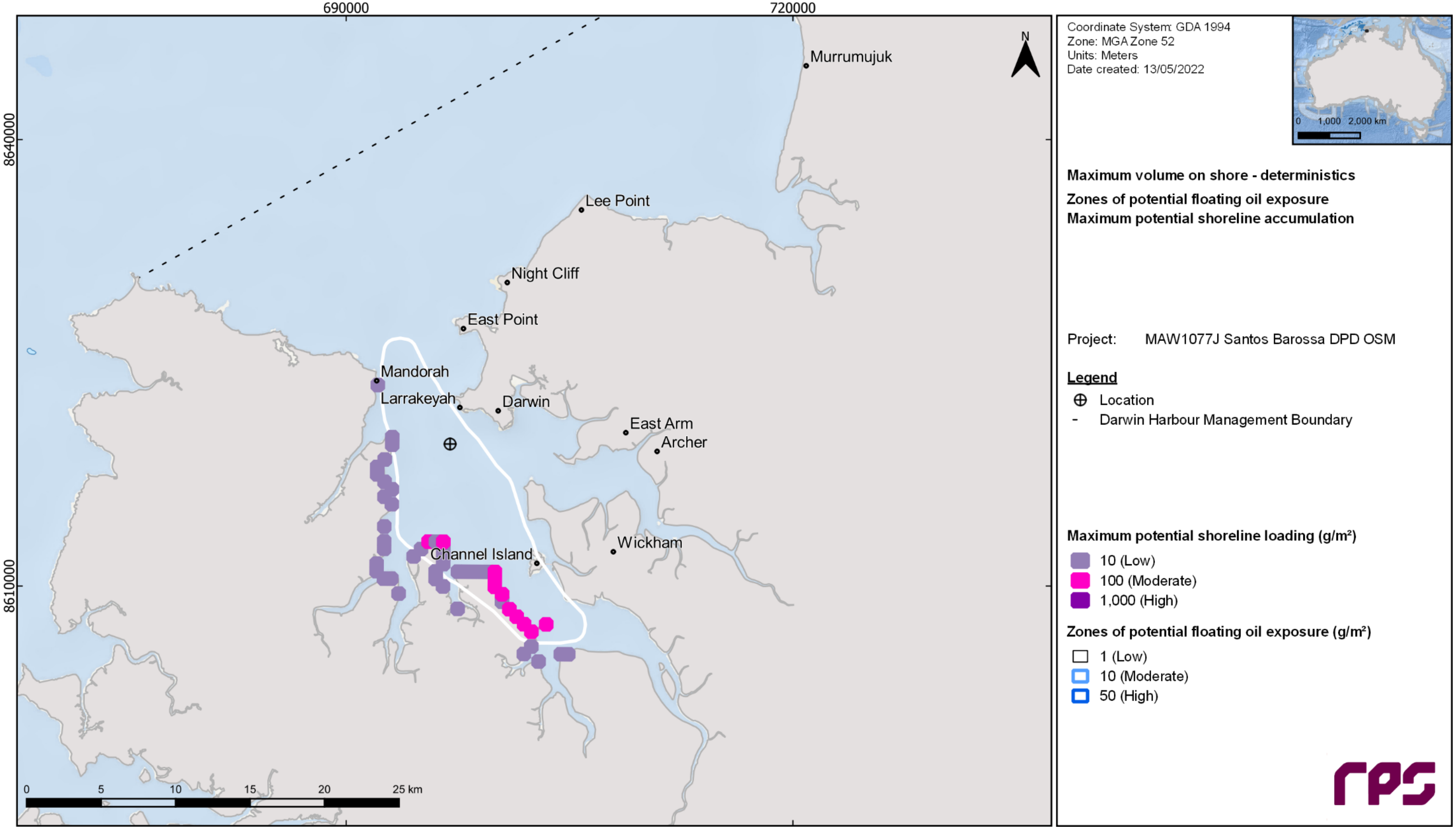


Figure 13.10 Zones of potential exposure on the sea surface and shoreline accumulation (over the 20-days) for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season.

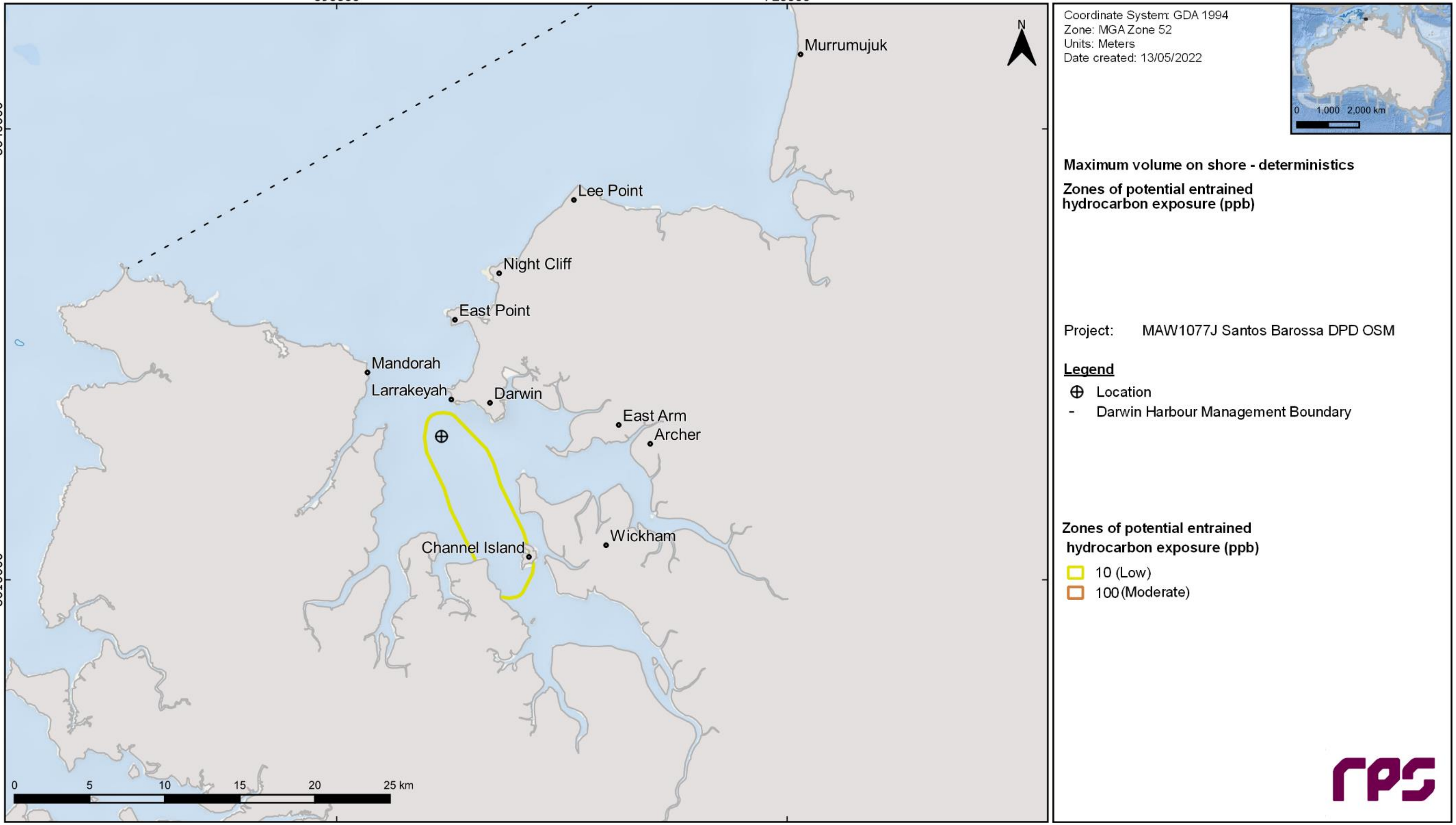


Figure 13.11 Zones of potential entrained hydrocarbon exposure 0 – 10 m below the sea (over the 20-days) for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season.

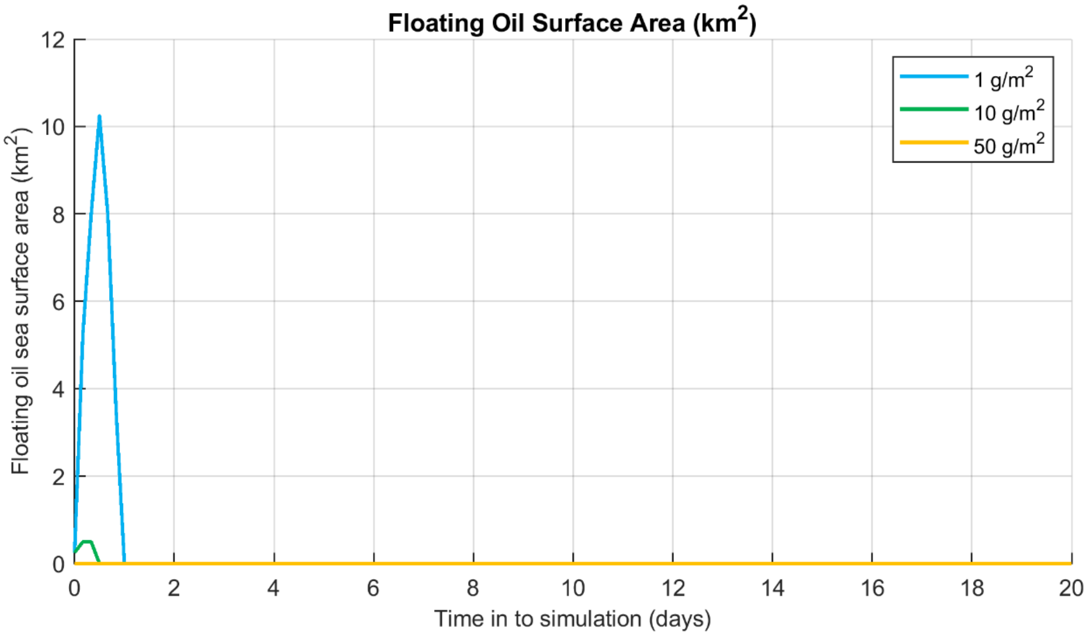


Figure 13.12 Time series of the floating oil surface area exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season.

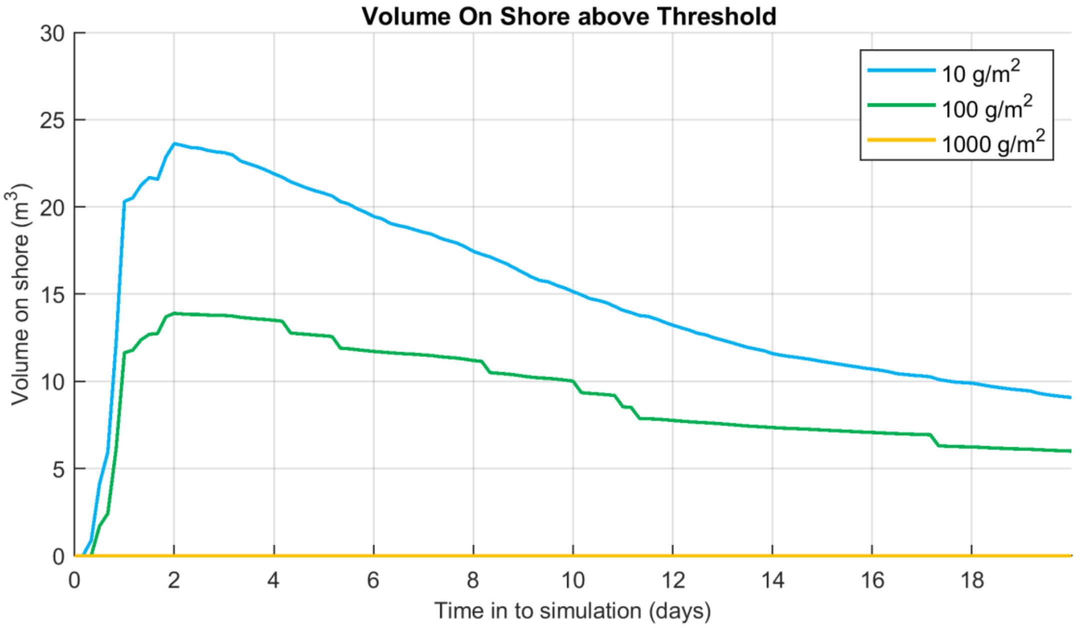


Figure 13.13 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season.

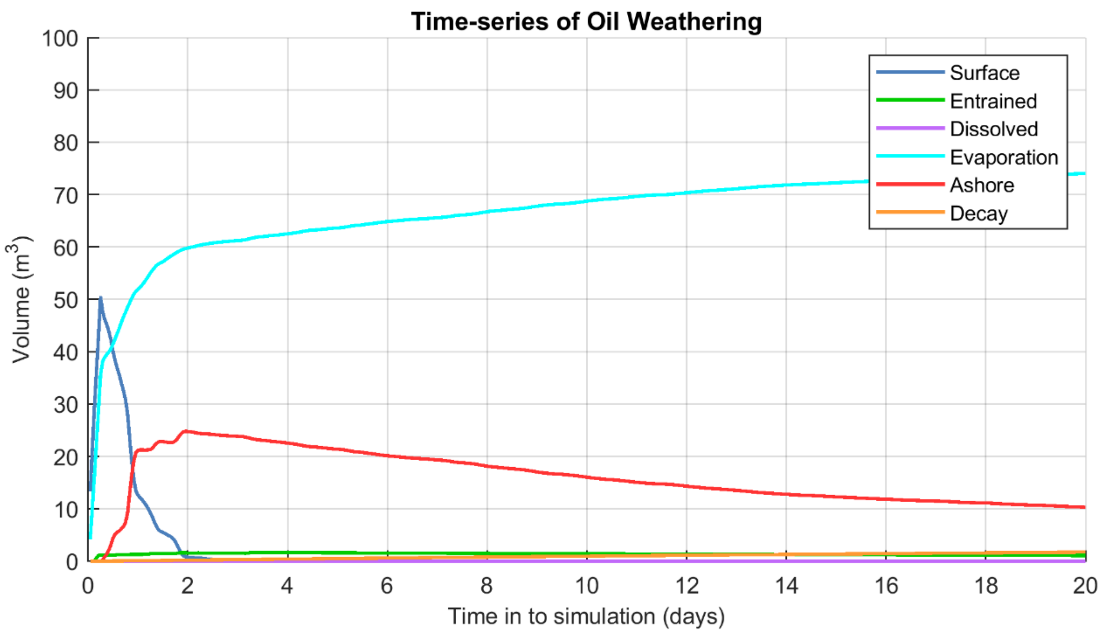


Figure 13.14 Predicted weathering and fates graph for the simulation resulting in the maximum volume of oil ashore starting at 2 am 2 September 2019 during the dry season.

14 SCENARIO 3 RESULTS – VESSEL TO VESSEL REFUELLING AT KP114

This scenario examined the potential exposure following an instantaneous 10 m^3 surface release of MDO vessel to vessel refuelling incident at KP114. A total of 200 spill trajectories were simulated (i.e., 100 spills per season) and tracked for 10 days.

Section 14.1 presents the low threshold environment that may be affected (EMBA) resulting from the 200 spill simulations. Section 14.2 shows the seasonal (or stochastic) analysis, while Section 14.3 presents in more detail the results for the simulation resulting in the largest volume of oil ashore.

14.1 EMBA

Figure 14.1 shows the full geographic EMBA derived by overlaying the results from all 200 spill simulations at the low (≥1 g/m^2) exposure thresholds.

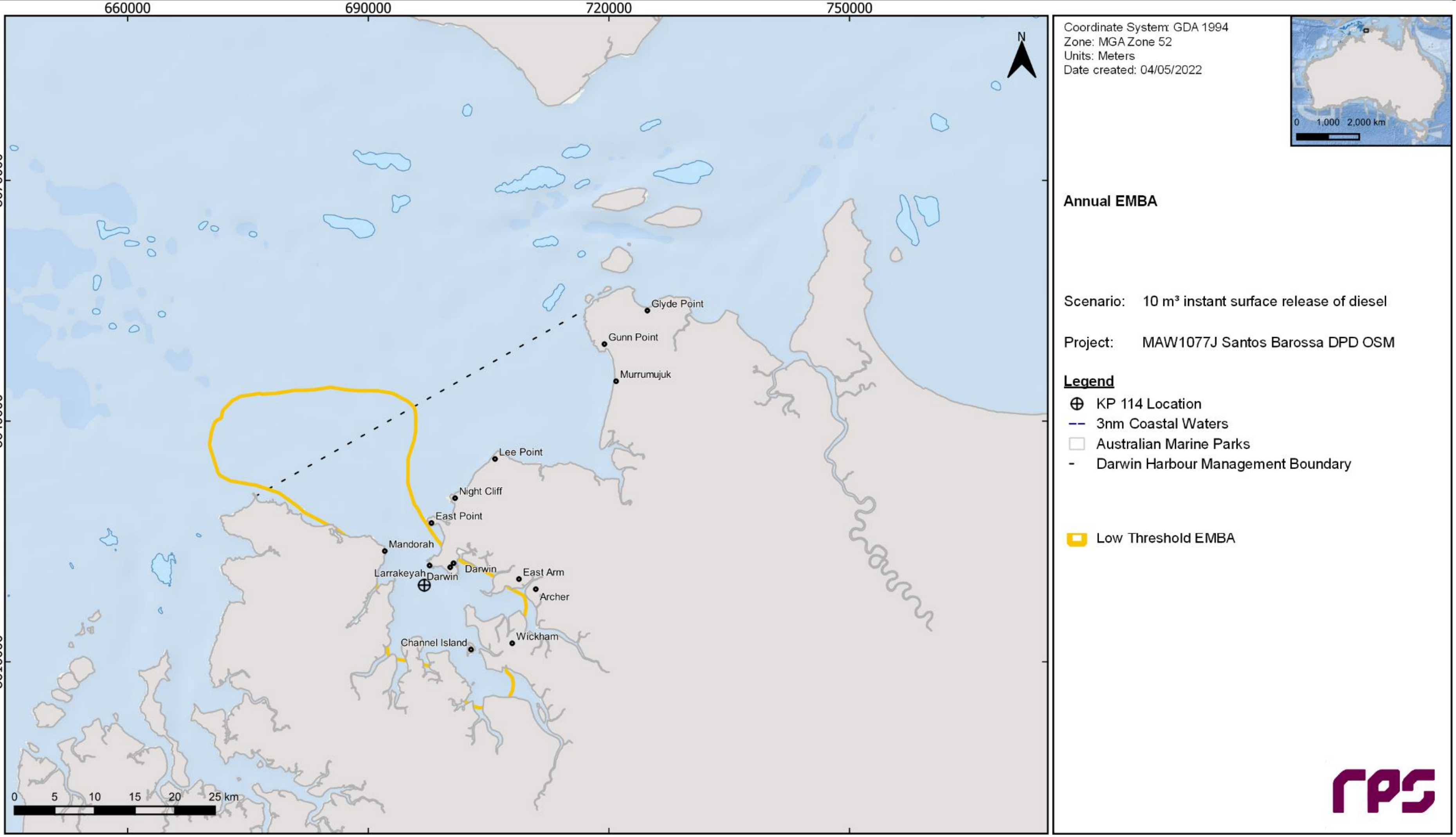


Figure 14.1 Predicted low threshold risk EMBA from a vessel to vessel refuelling incident at KP114. The annualised results were calculated from 200 spill simulations.

14.2 Stochastic Analysis

14.2.1 Floating Oil Exposure

Table 14.1 summarises the maximum distances and directions travelled by the floating oil from the release location at each threshold for each season. The maximum distances to the low (≥1 g/m^2) and moderate (≥10 g/m^2) exposure zones were 22.9 km (northwest) and 12.5 km (northwest), respectively during dry season conditions. There was no exposure predicted for the high threshold (≥ 50 g/m^2).

Table 14.2 summarises the potential floating oil exposure to individual receptors for each season. Figure 14.2 and Figure 14.3 illustrate the extent of floating oil exposure for each season.

During the dry season, exposure at the low threshold was predicted at Restricted Areas 4, 5 and 6 with probabilities ranging between 2 – 7%, while during the wet season exposure was predicted at Restricted Areas 4 (2%) and 5 (1%). No moderate or high threshold exposure was predicted for any Restricted Area.

Additionally, five WQ Zones were predicted to experience floating oil exposure at the low threshold with probabilities ranging between 2 – 21% and 2 – 19% during the dry and wet seasons, respectively (see Table 14.2).

Table 14.1 Maximum distances and directions travelled by floating oil from a vessel to vessel refuelling incident at KP114 at each threshold for each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential floating oil exposure		
		Low	Moderate	High
Dry	Maximum distance (km) from release location	22.9	12.5	-
	Maximum distance (km) from the release location (99th percentile)	21.5	12.5	-
	Direction	NW	NW	-
Wet	Maximum distance (km) from release location	19.6	5.5	-
	Maximum distance (km) from release location (99th percentile)	15.2	5.5	-
	Direction	NW	NNW	-

Table 14.2 Summary of the potential exposure by floating oil to individual receptors from a vessel to vessel refuelling incident at KP114 for each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry						Wet					
		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)			Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Restricted Areas	4	7	-	-	0.42	-	-	2	-	-	0.33	-	-
	5	2	-	-	0.21	-	-	1	-	-	0.29	-	-
	6	4	-	-	0.29	-	-	-	-	-	-	-	-
WQ Zones	East Arm	2	-	-	0.54	-	-	4	-	-	0.38	-	-
	Middle Arm	3	-	-	0.21	-	-	2	-	-	0.29	-	-
	West Arm	10	-	-	0.21	-	-	4	-	-	0.29	-	-
	Outer Harbour	21	2	-	0.08	0.13	-	19	-	-	0.08	-	-

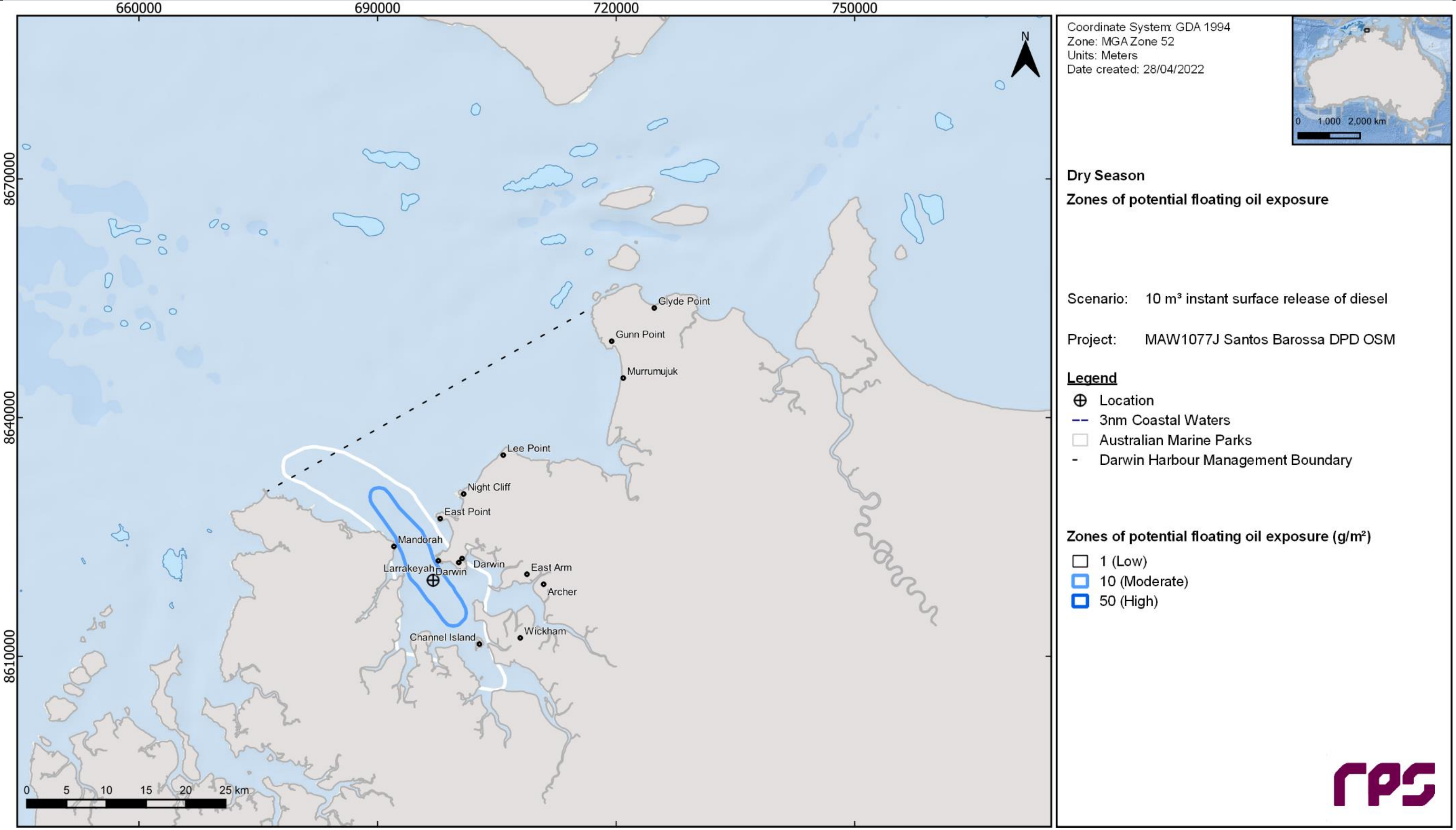


Figure 14.2 Zones of potential floating oil exposure from a vessel to vessel refuelling incident at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

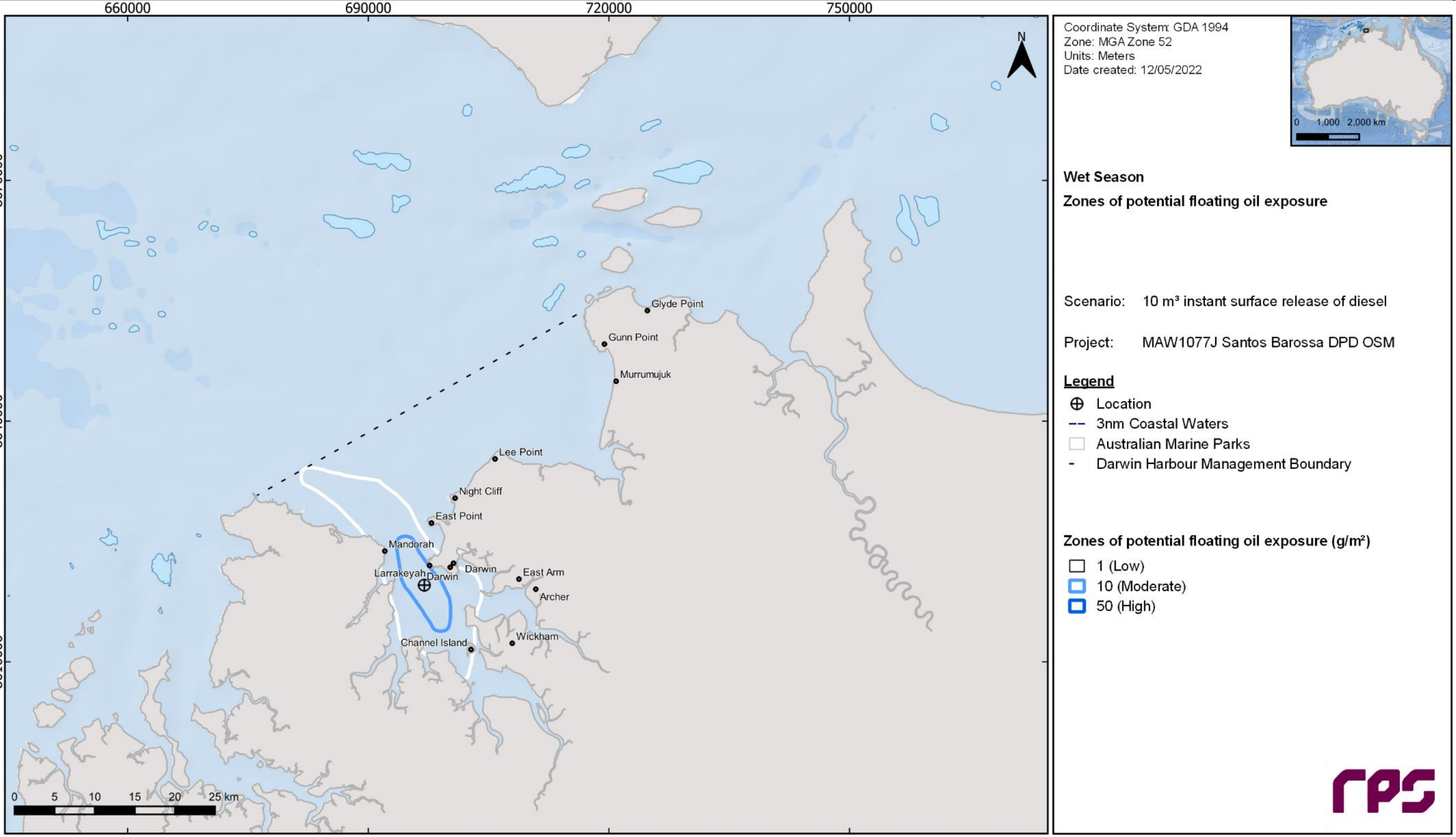


Figure 14.3 Zones of potential floating oil exposure from a vessel to vessel refuelling incident at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

14.2.2 Shoreline Accumulation

Table 14.3 summarises the predicted oil accumulation on any shoreline during each season. The probability of oil accumulation at, or above, the low threshold (10 g/m^2) was 58% during the dry and wet season. The minimum time before oil accumulation at, or above, the low threshold was 0.25 days and 0.29 days for the dry and wet seasons, respectively. The maximum volume ashore for a single spill ranged between 3.9 m^3 (dry season) and 4.3 m^3 (wet season). The maximum length of shoreline contacted at the low threshold was 9 km for the two seasons. The maximum lengths of oil accumulation on shorelines at, or above, the moderate (100 – 1,000 g/m^2) threshold was 2 km during wet season conditions. There was no oil accumulation predicted for the high threshold (≥1,000 g/m^2).

Table 14.4 and Table 14.5 summarise the oil accumulation on individual shoreline receptors for each season. The maximum potential shoreline loading for the specified thresholds for each season are presented in Figure 14.4 and Figure 14.5.

The greatest probabilities of oil accumulation at, or above, the low threshold was predicted for the West Arm (49% dry and 28% wet conditions) and East Arm (8% dry and 26% wet seasons) shorelines. The minimum time before the accumulation was 0.29 days (Middle Arm and West Arm) during the dry season and 0.25 days (East Arm and Wickham Point) during the wet season conditions.

The greatest volume (peak) of oil accumulation during the dry and wet seasons occurred along the West Arm (3.9 m^3) and Wickham Point (4.1 m^3) shorelines, respectively.

Table 14.3 Summary of oil accumulation on any shoreline from a vessel to vessel refuelling incident at KP114 during each season. Results were calculated from 100 spill simulations per season.

Shoreline Statistics	Dry			Wet		
	Low	Moderate	High	Low	Moderate	High
Probability of accumulation on any shoreline (%)	58	14	-	58	16	-
Absolute minimum time before oil ashore (days)	0.29	0.38	-	0.25	0.29	-
Maximum length of shoreline contacted	9	0.5	-	9	2	-
Average length of shoreline contacted (km)	2.6	0.4	-	3	0.7	-
		Dry			Wet	
Maximum volume of hydrocarbons ashore (m^3)		3.9			4.3	
Average volume of hydrocarbons ashore (m^3)		0.7			0.8	

Table 14.4 Summary of oil accumulation on individual shoreline sectors from a vessel to vessel refuelling incident at KP114 for the dry season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
East Arm	8	4	-	0.33	0.42	-	3	130	0.1	2.2	1.7	0.5	-	3.5	0.5	-
Middle Arm	4	-	-	0.29	-	-	<1	27	<0.1	0.3	1.4	-	-	1.5	-	-
Outer Harbour West	2	-	-	0.88	-	-	<1	61	<0.1	1.2	1.7	-	-	2	-	-
West Arm	49	6	-	0.29	0.38	-	3	137	0.5	3.9	2.4	0.5	-	8.5	0.5	-
Wickham Point	3	-	-	0.42	-	-	<1	27	<0.1	0.5	1.3	-	-	2	-	-

Table 14.5 Summary of oil accumulation on individual shoreline sectors from a vessel to vessel refuelling incident at KP114 for the wet season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m^2)		Volume on shoreline (m^3)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
East Arm	26	6	-	0.25	0.29	-	2	208	0.2	2.6	1.9	0.6	-	9	1	-
Middle Arm	1	-	-	0.33	-	-	55	55	0.4	0.4	1	-	-	1	-	-
Outer Harbour West	1	-	-	2.75	-	-	14	14	0.3	0.3	0.5	-	-	0.5	-	-
West Arm	28	8	-	0.29	0.29	-	5	199	0.4	3	2.8	0.6	-	8	1	-
Wickham Point	19	2	-	0.25	0.58	-	3	133	0.2	4.1	1.9	1.2	-	6	2	-

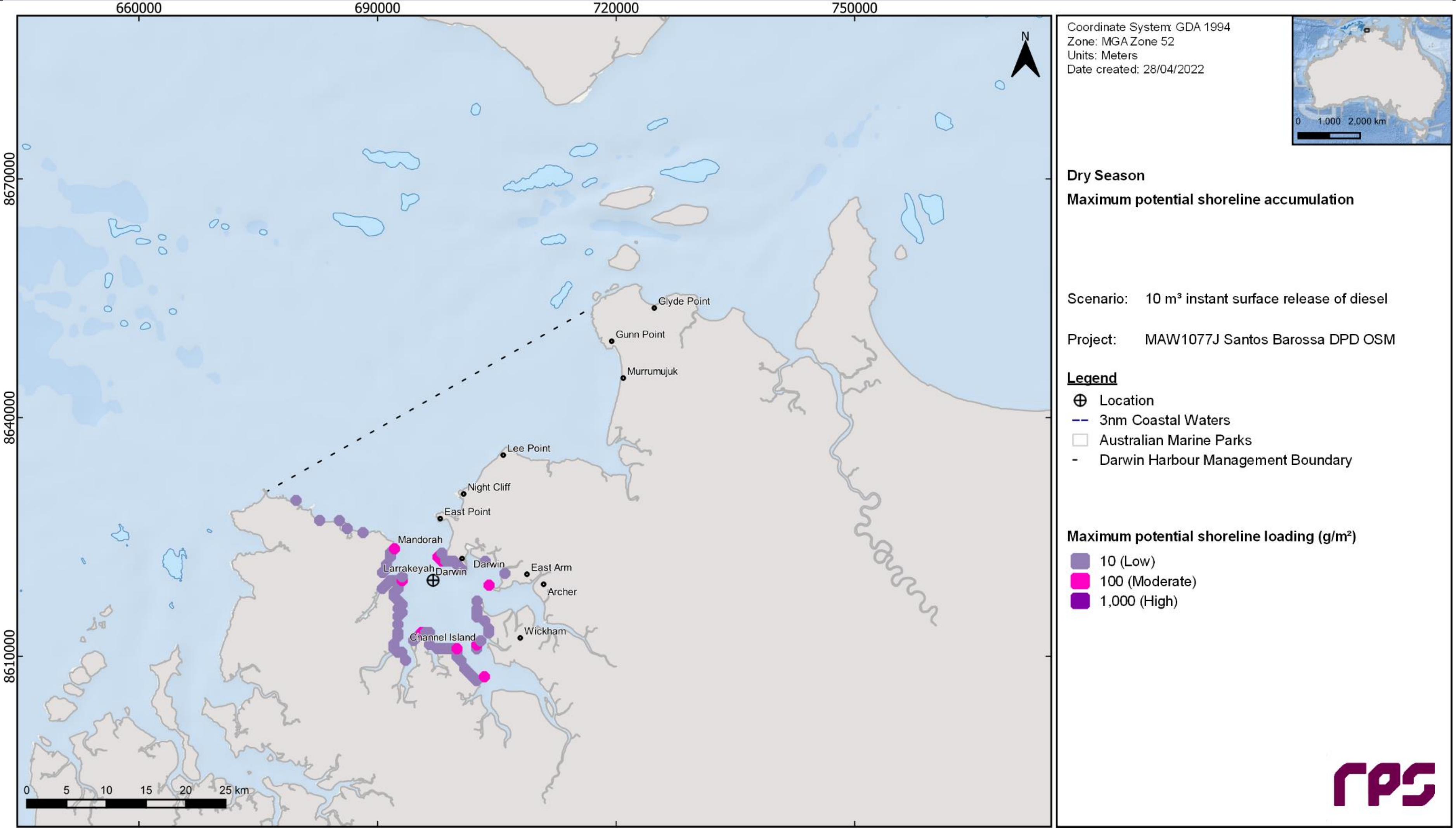


Figure 14.4 **Maximum potential shoreline loading from a vessel to vessel refuelling incident at KP114 during dry season conditions. The results were calculated from 100 spill simulations.**

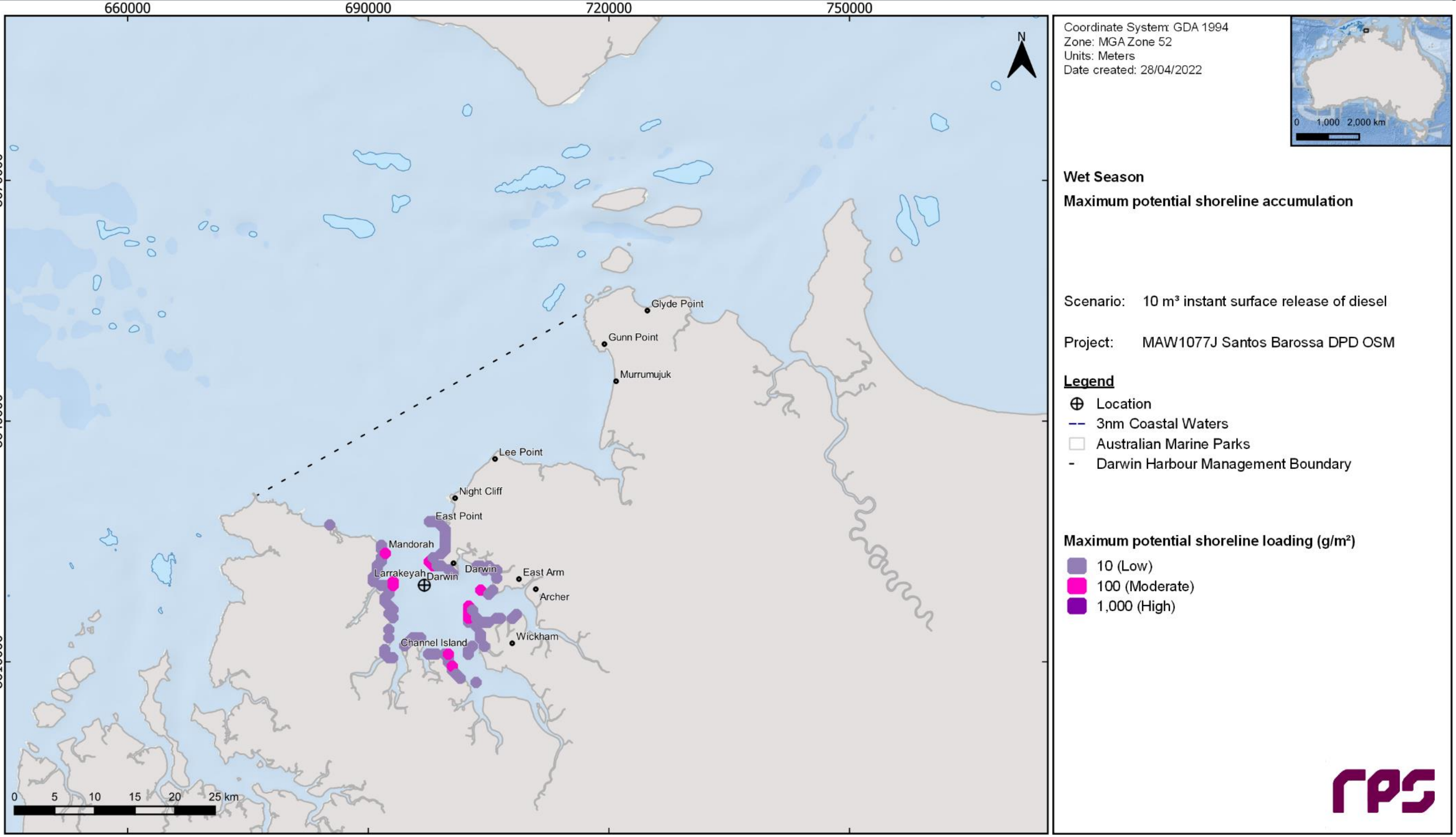


Figure 14.5 **Maximum potential shoreline loading from a vessel to vessel refuelling incident at KP114 during wet season conditions. The results were calculated from 100 spill simulations.**

14.2.3 In-water exposure

14.2.3.1 Dissolved Hydrocarbons

There was no dissolved hydrocarbon exposure predicted for any spills during this scenario at or above the low threshold ((≥ 10 ppb).

14.2.3.2 Entrained Hydrocarbons

Table 14.6 summarises the maximum distances and directions travelled by entrained hydrocarbons within the 0 – 10 m depth layers for the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds, which ranged between 32 km and 18.9 km northwest from the release location during dry season conditions and 31.9 km and 19.6 km northwest from the release location during wet season conditions.

Table 14.7 summarises the potential exposure to receptors from entrained hydrocarbons in the 0-10 m depth layer for each season. Figure 14.6 to Figure 14.7 illustrate extent of entrained hydrocarbon exposure for each season in the 0 – 10 m depth layer.

During both seasons the Charles Point Wide RFPA and three Restricted Areas (4, 5 and 6) were predicted to be exposed at the low threshold with probabilities ranging from 8 – 50% and 4 – 29% during the dry and wet seasons, respectively. During both seasons Restricted Area 6 was predicted to have the greatest probability of low threshold exposure (50% dry season and 29% wet season).

Exposure for the low threshold was predicted at 15 shipwreck receptors during both seasons, with probabilities ranging from 2% (Ellengowan and Middle Arm unidentified wreck) and 61% (Ham Luong) during the dry season and 2% (Ellengowan, Mandorah Unidentified wreck 1 and Middle Arm unidentified wreck) and 64% (Mauna Loa USAT) during the wet season. The maximum entrained concentrations were also predicted Ham Luong (745 ppb) and Mauna Loa USAT (639 ppb) shipwrecks for the two seasons.

Four WQ Zones were predicted to be exposed to entrained hydrocarbons at the low threshold during both seasons with probabilities ranging from 6% (East Arm) and 36% (Outer Harbour) during the dry season and 7% (Middle Arm) and 30% (Outer Harbour) during the wet season. The maximum entrained concentrations were predicted at Outer Harbour during both the dry (265 ppb) and wet (301 ppb) seasons.

Table 14.6 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from the release location for a vessel to vessel refuelling incident at KP114 during each season during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential entrained hydrocarbon exposure	
		Low 10 ppb	Moderate 100 ppb
Dry	Maximum distance (km) from release location	32.0	18.9
	Maximum distance (km) from release location (99th percentile)	30.9	18.7
	Direction	NW	NW
Wet	Maximum distance (km) from release location	31.9	19.6
	Maximum distance (km) from release location (99th percentile)	30.5	19.0
	Direction	NW	NW

Table 14.7 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer from a vessel to vessel refuelling incident at KP114 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry					Wet				
		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure	
			Low	Mod	Low	Mod		Low	Mod	Low	Mod
RFPA	Charles Point Wide	44	8	-	0.67	-	42	4	-	0.63	-
Restricted Area	4	34	36	-	0.21	-	36	14	-	0.29	-
	5	40	14	-	0.13	-	75	11	-	0.17	-
	6	44	50	-	0.17	-	66	29	-	0.29	-
Shipwrecks	Bell Bird	36	10	-	0.25	-	36	24	-	0.21	-
	Booya	48	12	-	0.13	-	54	15	-	0.13	-
	British Motorist	49	16	-	0.17	-	50	39	-	0.13	-
	Darwin Harbour Unidentified wreck 2	102	34	1	0.08	0.21	82	51	-	0.08	-
	Diemen	43	30	-	0.17	-	60	16	-	0.29	-
	Ellengowan	14	2	-	0.46	-	33	2	-	0.17	-
	Ham Luong	745	61	13	0.04	0.04	297	62	13	0.04	0.04
	L. Ann	15	6	-	0.42	-	15	2	-	0.54	-
	Landing Barge	25	10	-	0.29	-	36	29	-	0.25	-
	Mandorah Unidentified wreck 1	15	6	-	0.42	-	15	2	-	0.54	-
	Mauna Loa USAT	687	56	13	0.04	0.04	639	64	13	0.04	0.04
	Middle Arm unidentified wreck	14	2	-	0.46	-	33	2	-	0.17	-
	Peary USS	84	33	-	0.13	-	82	46	-	0.08	-
	Vietnamese Refugee Boat Pk76	24	4	-	0.33	-	20	7	-	0.29	-
	Yu Han 22	218	40	2	0.08	0.13	209	44	2	0.08	0.13
WQ Zones	East Arm	21	6	-	0.29	-	35	18	-	0.25	-

	Middle Arm	134	8	2	0.17	0.21	94	7	0	0.21	-
	West Arm	35	26	-	0.17	-	36	11	-	0.17	-
	Outer Harbour	265	36	5	0.08	0.13	301	30	6	0.08	0.08

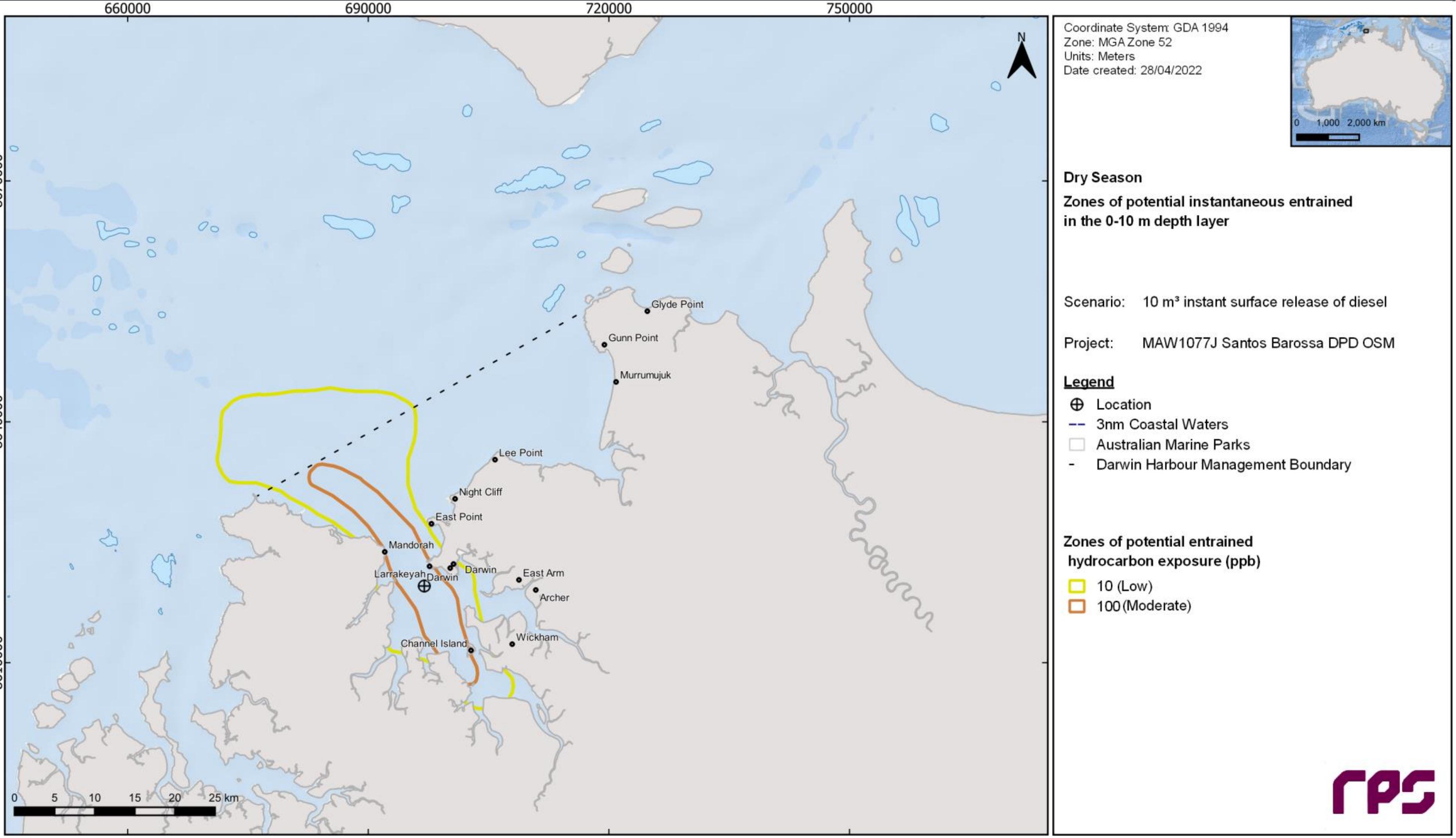


Figure 14.6 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel to vessel refuelling incident at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

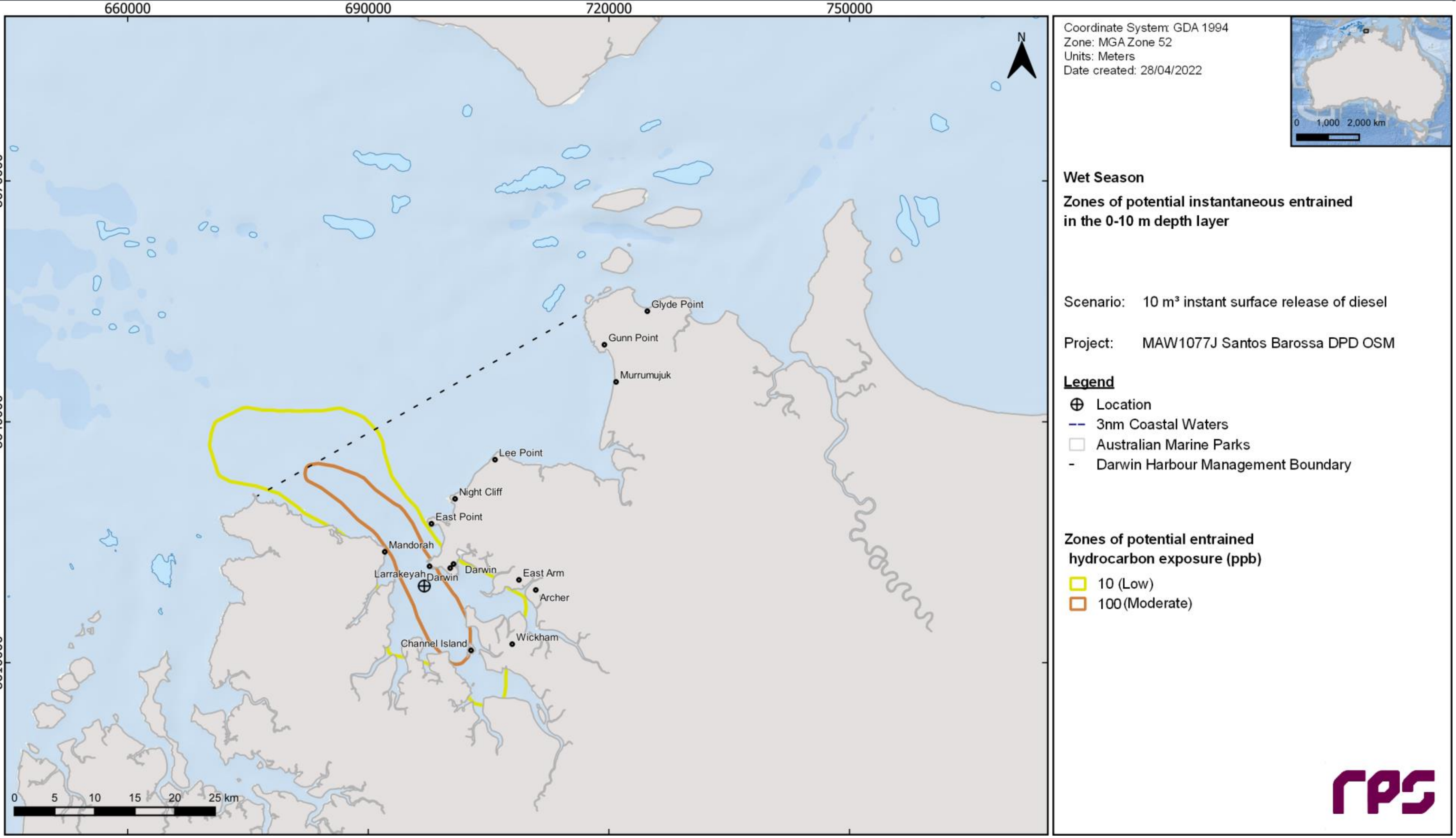


Figure 14.7 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel to vessel refuelling incident at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

14.3 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic simulation resulting in the largest volume ashore (4.3 m^3) was identified as run 69, which commenced at 6 pm 25 November 2019 during the wet season.

Zones of exposure on the sea surface (swept area) and shoreline accumulation over the entire 10-day simulation are presented in Figure 14.8. The spill had drifted south-southeast from the release from the release location and the oil was predicted to accumulate on the shoreline at Wickham.

No zones of entrained and dissolved hydrocarbon exposure were predicted above the minimum reporting thresholds or the simulation.

Figure 14.9 and Figure 14.10 show time series of the area of floating oil exposure and the volume of oil ashore for each threshold during the 10-day simulation.

Figure 14.11 presents the fates and weathering for the corresponding single spill trajectory. At the conclusion of the simulation, approximately 8 m^3 (80%) of oil had evaporated and 2 m^3 (20%) had accumulated on the shoreline.

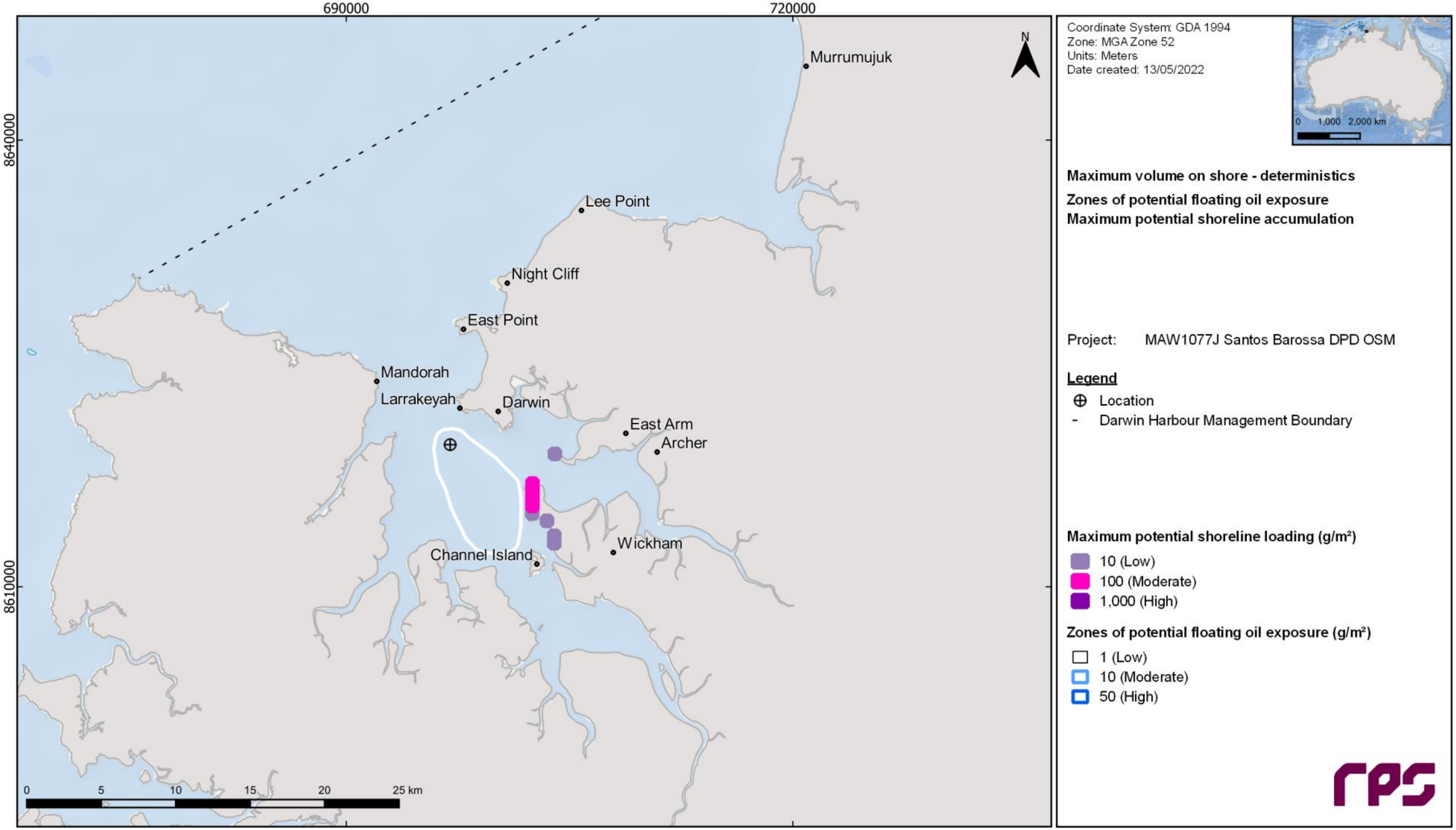


Figure 14.8 Zones of potential exposure on the sea surface and shoreline accumulation (over the 10 days) for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season.

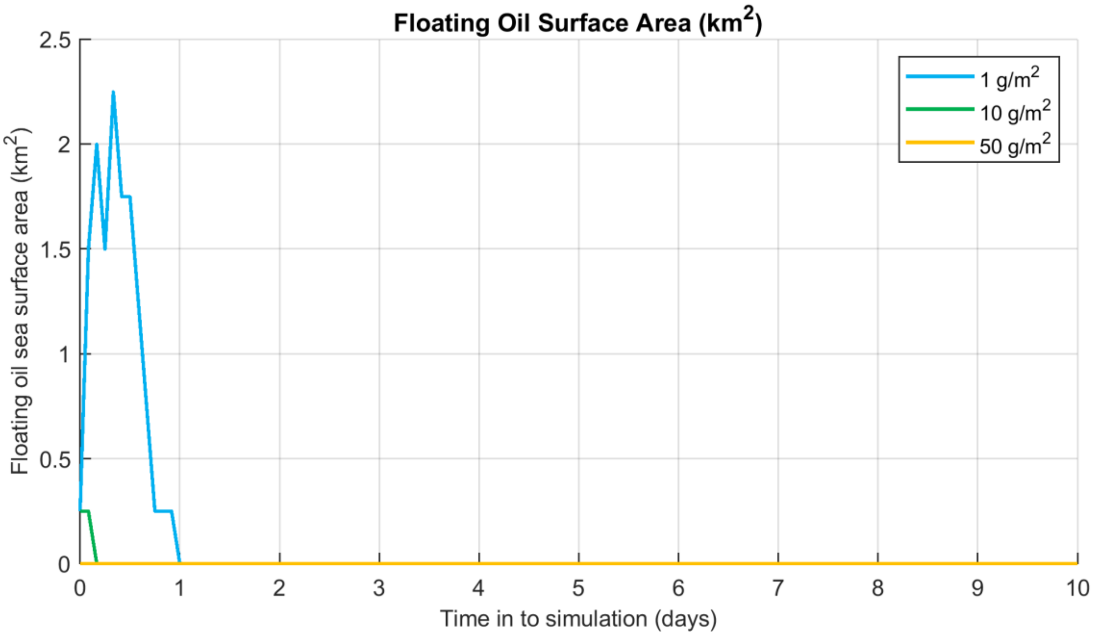


Figure 14.9 Time series of the area of floating oil exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season.

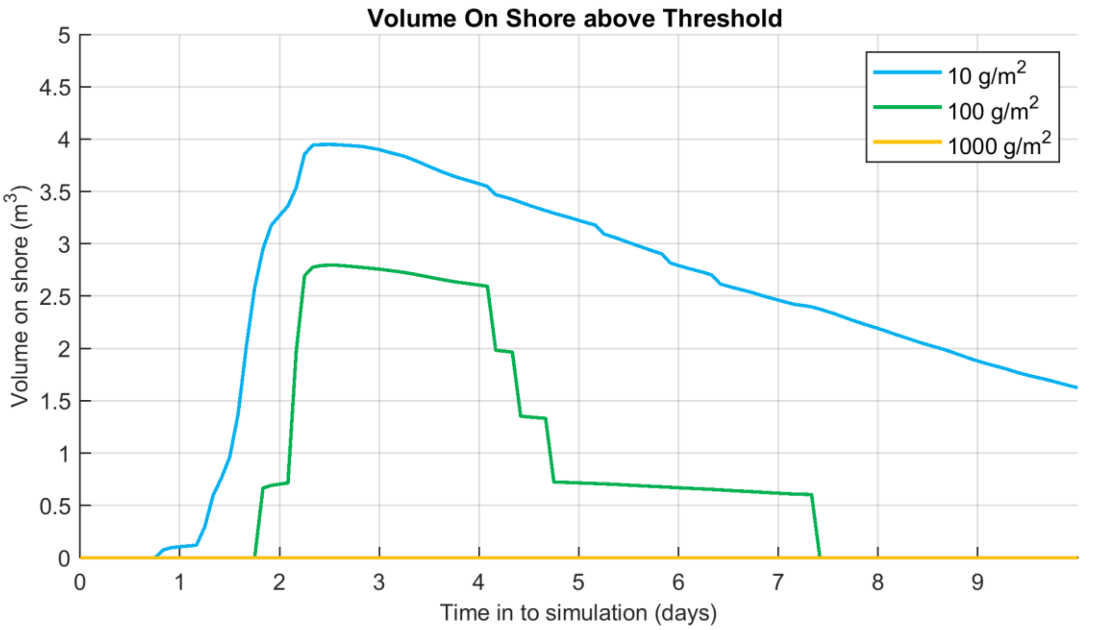


Figure 14.10 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season.

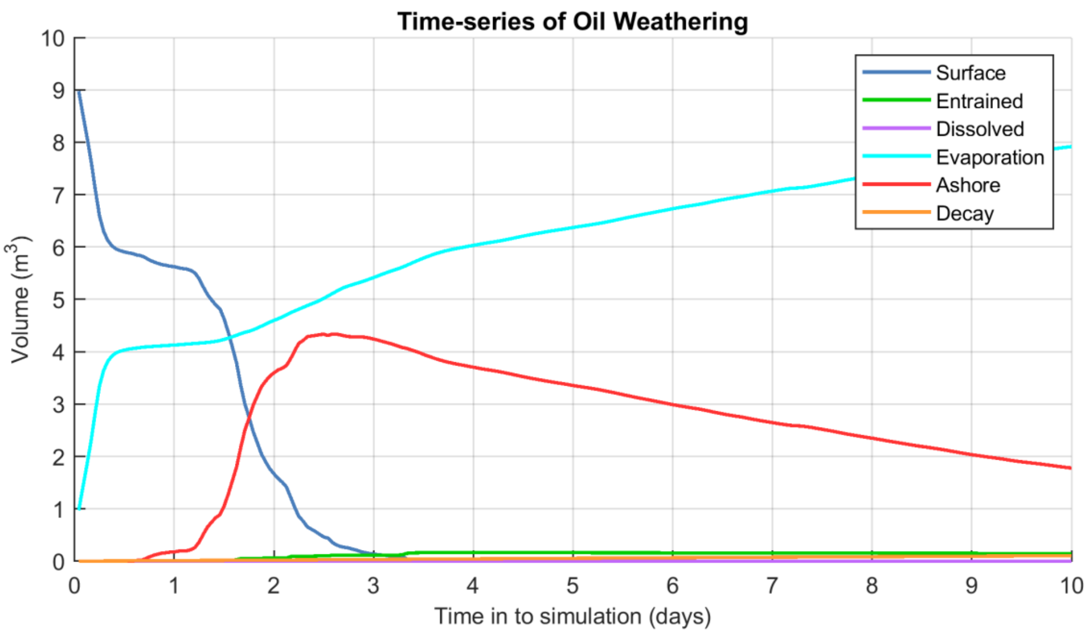


Figure 14.11 Predicted weathering and fates graph for the simulation resulting in the maximum volume of oil ashore starting at 6 pm 25 November 2019 during the wet season.

15 SCENARIO 4 RESULTS – VESSEL FUEL TANK RUPTURE AT KP114

This scenario examined the potential exposure following a 300 m^3 surface release of MDO over 6 hours in the event of a vessel fuel tank rupture at KP114. A total of 200 spill trajectories were simulated (i.e., 100 spills per season) and tracked for 30 days.

Section 15.1 presents the low threshold environment that may be affected (EMBA), resulting from the 200 spill simulations. Section 15.2 shows the seasonal (or stochastic) analysis, while Section 15.3 presents in more detail the results for the simulation resulting in the largest volume of oil ashore.

15.1 EMBA

Figure 15.1 shows the full geographic EMBA derived by overlaying the results from all 200 spill simulations at the low (≥1 g/m^2) exposure thresholds.

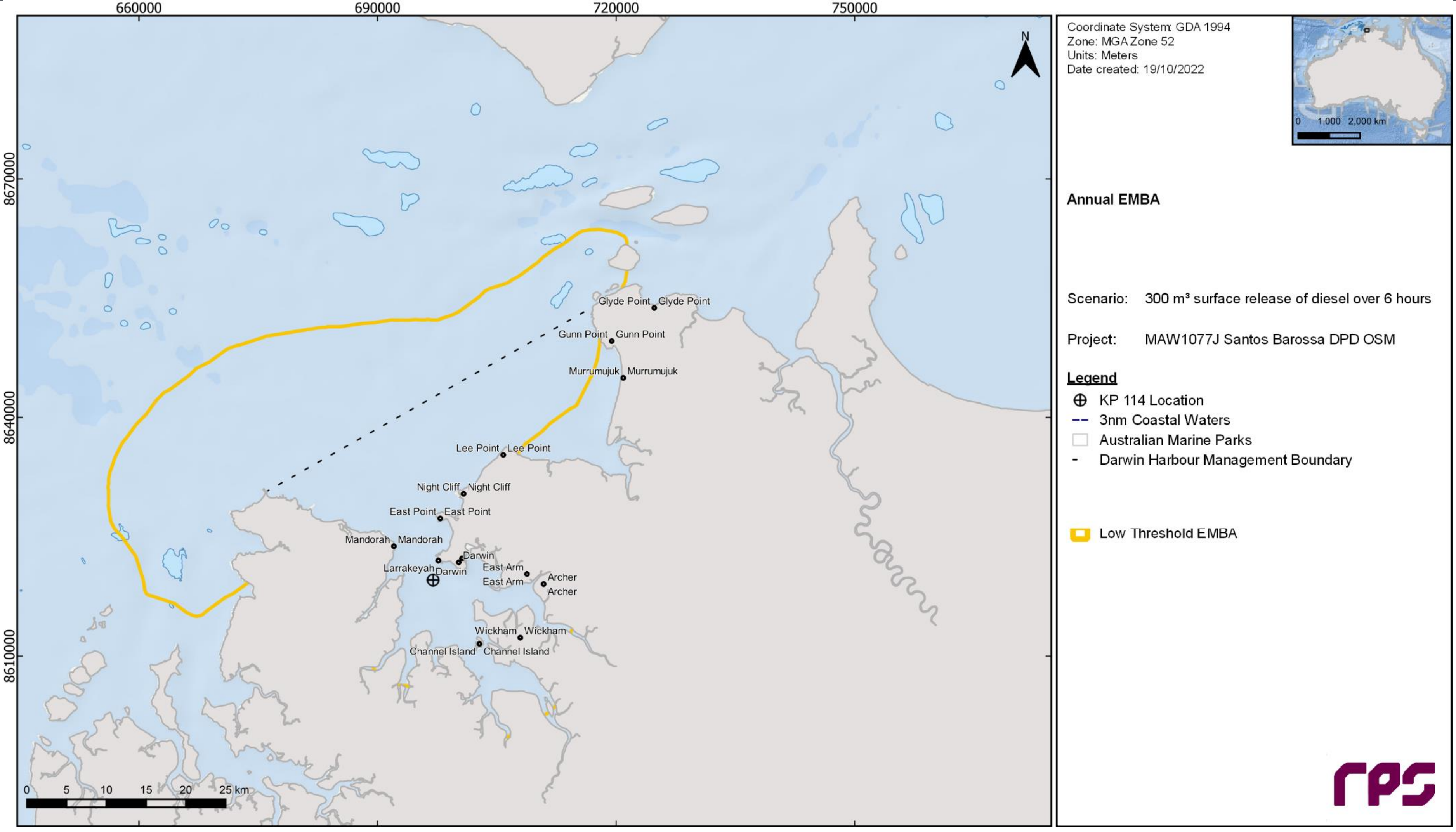


Figure 15.1 Predicted low threshold risk EMBA from a vessel fuel tank rupture at KP114. The annualised results were calculated from 200 spill simulations.

15.2 Stochastic Analysis

15.2.1 Floating Oil Exposure

Table 15.1 summarises the maximum distances and directions travelled by the floating oil from the release location at each threshold for each season. The maximum distances to the low (≥1 g/m^2), moderate (≥10 g/m^2) and high (≥ 50 g/m^2) exposure zones were 24.2 km (northwest), 19.6 km (northwest) and 10.2 km (north-northwest), respectively, during dry season conditions and 33.4 km (northwest), 18.9 km (northwest) and 8.4 km (north-northwest), respectively during wet season conditions. Table 15.2 summarises the potential floating oil exposure to individual receptors for each season and Figure 15.2 and Figure 15.3 illustrate the extent of floating oil exposure for each season.

During both the dry and wet seasons, floating oil exposure at the low threshold was predicted at Restricted Areas 1, 4, 5 and 6 with probabilities ranging between 1 – 60% and 1 – 30%, during the dry and wet season, respectively. Additionally, floating oil exposure at the moderate threshold was predicted at Restricted Areas 4 and 6 with probabilities of 10% and 4%, respectively during the dry season and 8% and 5%, respectively during the wet season. No high exposure was predicted for any Restricted Area.

Only the two simulation during wet season conditions (2% probability) triggered the low threshold exposure within Charles Point Wide RFPA, with a minimum time of exposure of 0.96 days.

During the dry season five WQ Zones recorded floating oil exposure at the low threshold with probabilities ranging between 13% (Middle Arm) and 100% (Middle Harbour). In comparison, during the wet season six WQ Zones recorded floating oil exposure at the low threshold with probabilities ranging between 1% (Elizabeth River) and 100% (Middle Harbour, see Table 15.2).

Table 15.1 Maximum distances and directions travelled by floating oil from vessel fuel tank rupture at KP114 at each threshold for each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential floating oil exposure		
		Low	Moderate	High
Dry	Maximum distance (km) from release location	24.2	19.6	10.2
	Maximum distance (km) from the release location (99th percentile)	21.2	18.7	9.9
	Direction	NW	NW	NNW
Wet	Maximum distance (km) from release location	33.4	18.9	8.4
	Maximum distance (km) from release location (99th percentile)	31.7	17.5	8.3
	Direction	NW	NW	NNW

Table 15.2 Summary of the potential exposure by floating oil to individual receptors from a vessel fuel tank rupture at KP114 for each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry						Wet					
		Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)			Probability of floating oil exposure (%)			Minimum time before floating oil exposure (days)		
		Low	Moderate	High	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
IMCRA	Beagle Gulf-Darwin Coast	100	100	99	0.04	0.04	0.04	100	100	97	0.04	0.04	0.04
IMCRA	Anson Beagle	100	100	99	0.04	0.04	0.04	100	100	97	0.04	0.04	0.04
RFPA	Charles Point Wide	-	-	-	-	-	-	2	-	-	0.96	-	-
Restricted Areas	1	1	-	-	1	-	-	1	-	-	1.92	-	-
Restricted Areas	4	60	10	-	0.17	0.42	-	30	8	-	0.29	0.5	-
Restricted Areas	5	25	2	-	0.21	0.33	-	17	-	-	0.17	-	-
Restricted Areas	6	55	4	-	0.21	0.46	-	30	5	-	0.25	0.46	-
WQ Zones	Elizabeth River	-	-	-	-	-	-	1	-	-	1.29	-	-
WQ Zones	East Arm	29	5	-	0.29	0.33	-	43	5	-	0.21	0.58	-
WQ Zones	Middle Arm	13	5	-	0.21	0.25	-	19	5	-	0.17	0.17	-
WQ Zones	West Arm	60	10	-	0.21	0.33	-	35	10	-	0.21	0.5	-
WQ Zones	Middle Harbour	100	100	99	0.04	0.04	0.04	100	100	97	0.04	0.04	0.04
WQ Zones	Outer Harbour	82	49	2	0.08	0.08	0.21	67	30	3	0.08	0.08	0.17

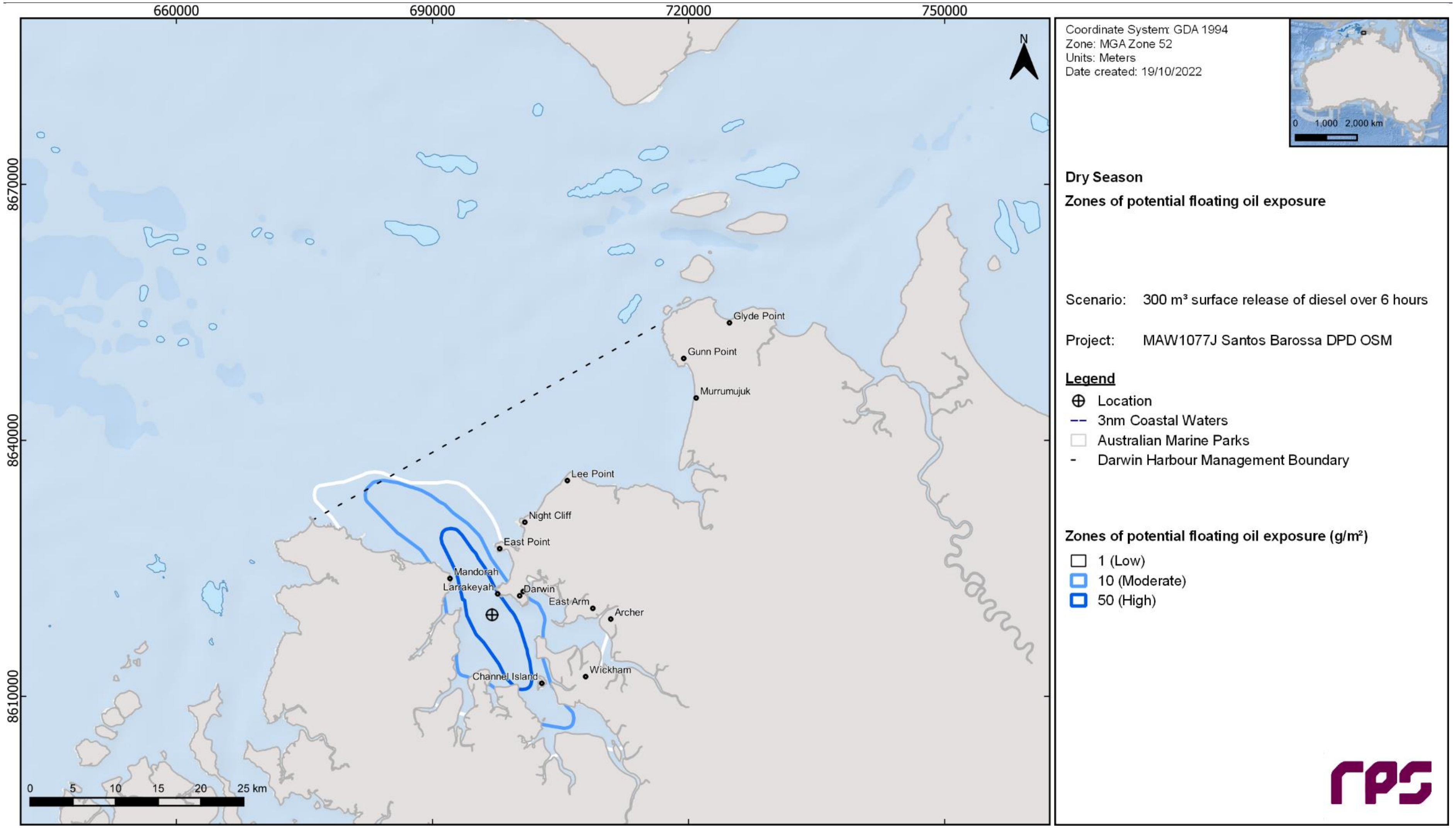


Figure 15.2 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

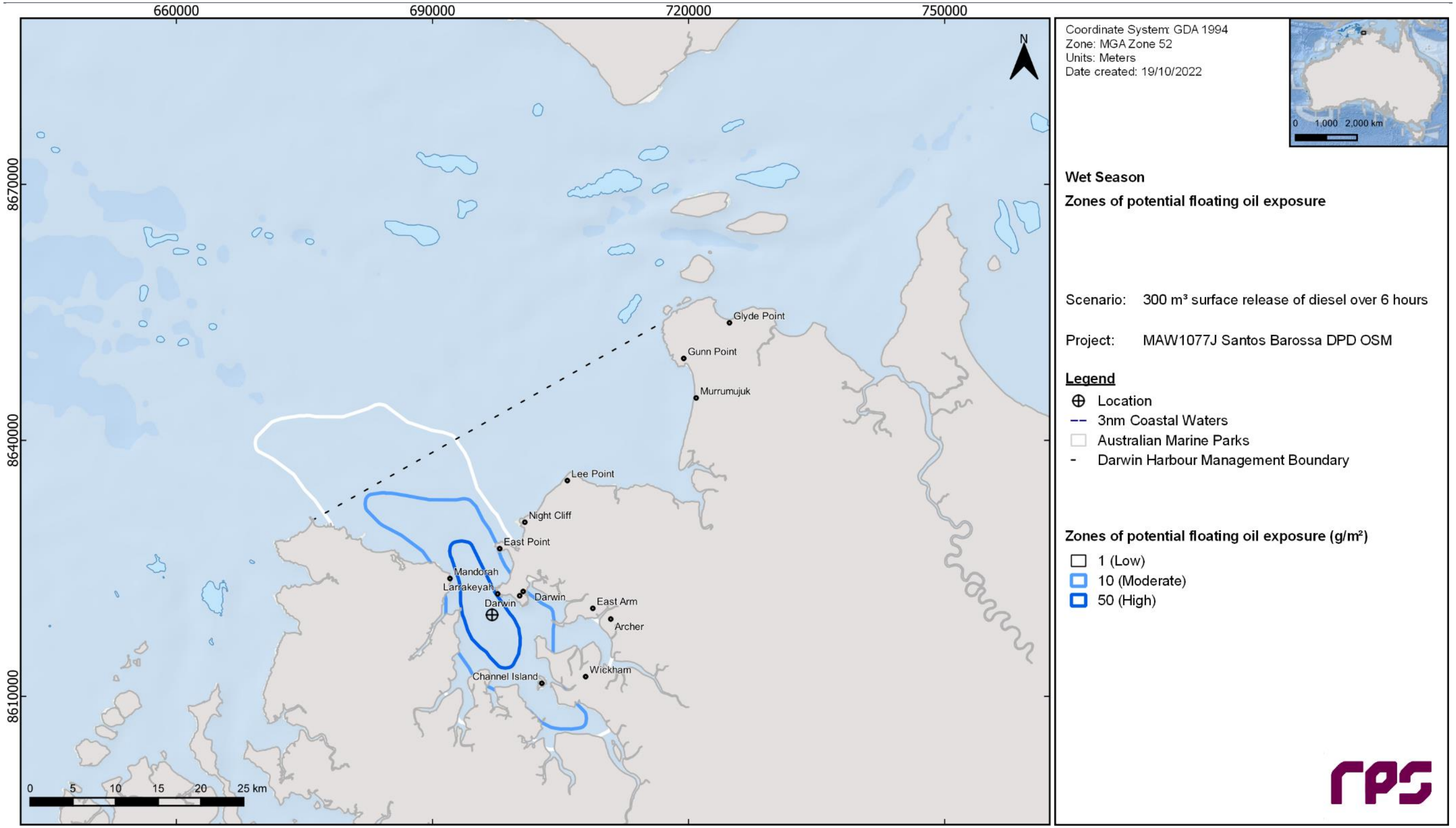


Figure 15.3 Zones of potential floating oil exposure from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

15.2.2 Shoreline Accumulation

Table 15.3 summarises the predicted oil accumulation on any shoreline during each season. The probability of shoreline accumulation at, or above, the low threshold (10 g/m^2) was 100% (dry season) and 91% (wet season). The minimum time before oil accumulation at, or above, the low threshold was 0.21 days during the dry and wet seasons. The maximum volume ashore for a single spill during the dry and wet season was 114.8 m^3 and 115.5 m^3, respectively, and the maximum length of shoreline contacted at the low threshold was 57.7 km (dry season) and 54.2 km (wet season). The maximum lengths of oil accumulation on shorelines at, or above, the moderate (100 – 1,000 g/m^2) and high (≥1,000 g/m^2) thresholds was 21.1 km (dry season) and 19.1 km (wet season), and 2.0 km (dry season) and 2.5 km (wet season), respectively.

Table 15.4 and Table 15.5 summarise the oil accumulation on individual shoreline receptors for each season. The maximum potential shoreline loading for the specified thresholds for each season are presented in Figure 15.4 and Figure 15.5.

The highest probability of oil accumulation at the low threshold was predicted along the West Arm (88% dry and 49% wet seasons) and East Arm (44% dry and 60% wet conditions) shorelines. The highest volume of oil accumulation during the dry and wet seasons occurred along the West Arm shoreline (103.5 m^3 (dry season) and 111.7 m^3 (wet season)). The minimum time before oil accumulation at the low threshold was 0.21 days (East Arm) for the dry season and 0.21 days (Wickham Point) during the wet season conditions.

Table 15.3 Summary of oil accumulation on any shoreline from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Shoreline Statistics	Dry			Wet		
	Low	Moderate	High	Low	Moderate	High
Probability of accumulation on any shoreline (%)	100	85	23	91	75	29
Absolute minimum time before oil ashore (days)	0.21	0.29	0.46	0.21	0.21	0.29
Maximum length of shoreline contacted	57.7	21.1	2.0	54.2	19.1	2.5
Average length of shoreline contacted (km)	15.5	4.4	0.9	16.1	5.2	1.0
	Dry			Wet		
Maximum volume of hydrocarbons ashore (m^3)	114.8			115.5		
Average volume of hydrocarbons ashore (m^3)	20.2			21.0		

Table 15.4 Summary of oil accumulation on individual shoreline sectors from a vessel fuel tank rupture at KP114 for the dry season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)	Minimum time before shoreline accumulation (days)	Load on shoreline (g/m²)	Volume on shoreline (m³)	Mean length of shoreline contacted (km)		Maximum length of shoreline contacted (km)
	High	High	Mean	Low	Moderate	High	High
Cox-Finniss	-	-	< 0.1	0.7	-	-	-
Vernon Islands	-	-	< 0.1	-	-	-	-
East Arm	3	0.63	2.2	3.5	1.9	0.5	0.5
Outer Harbour East	-	-	< 0.1	-	-	-	-
Wickham Point	-	-	0.6	3.7	1	-	-
Outer Harbour West	-	-	0.2	2.5	0.8	-	-
West Arm	20	0.46	16	12.4	4.1	0.8	2

Middle Arm	-	-	0.9	3.1	2.6	-	-

Table 15.5 Summary of oil accumulation on individual shoreline sectors from a vessel fuel tank rupture at KP114 for the wet season. Results were calculated from 100 spill simulations per season.

Shoreline sector	Maximum probability of shoreline loading (%)			Minimum time before shoreline accumulation (days)			Load on shoreline (g/m²)		Volume on shoreline (m³)		Mean length of shoreline contacted (km)			Maximum length of shoreline contacted (km)		
	Low	Moderate	High	Low	Moderate	High	Mean	Peak	Mean	Peak	Low	Moderate	High	Low	Moderate	High
Cox-Finniss	5	-	-	2	-	-	21	41	< 0.1	0.4	0.7	-	-	1	-	-
Vernon Islands	1	-	-	13.17	-	-	20	23	< 0.1	0.5	1	-	-	1	-	-
East Arm	60	38	6	0.25	0.33	0.5	74	1,899	3.9	54.8	5.3	1.6	0.7	18	8.5	1.5
Outer Harbour East	4	1	-	0.71	0.79	-	66	132	< 0.1	0.9	0.5	0.5	-	0.5	0.5	-
Wickham Point	50	31	2	0.21	0.29	1.67	78	1,103	3.1	31.7	5.3	2.4	0.5	12	7.5	0.5
Outer Harbour West	7	4	-	1.13	1.38	-	41	305	0.3	9.8	6.3	1.9	-	11	3.5	-
West Arm	49	36	16	0.25	0.33	0.5	112	4,870	11.5	111.7	12.8	5.4	1.2	37.5	16	2.5
Middle Arm	42	8	-	0.25	0.29	-	37	746	0.9	17.6	3	1.5	-	20	3	-

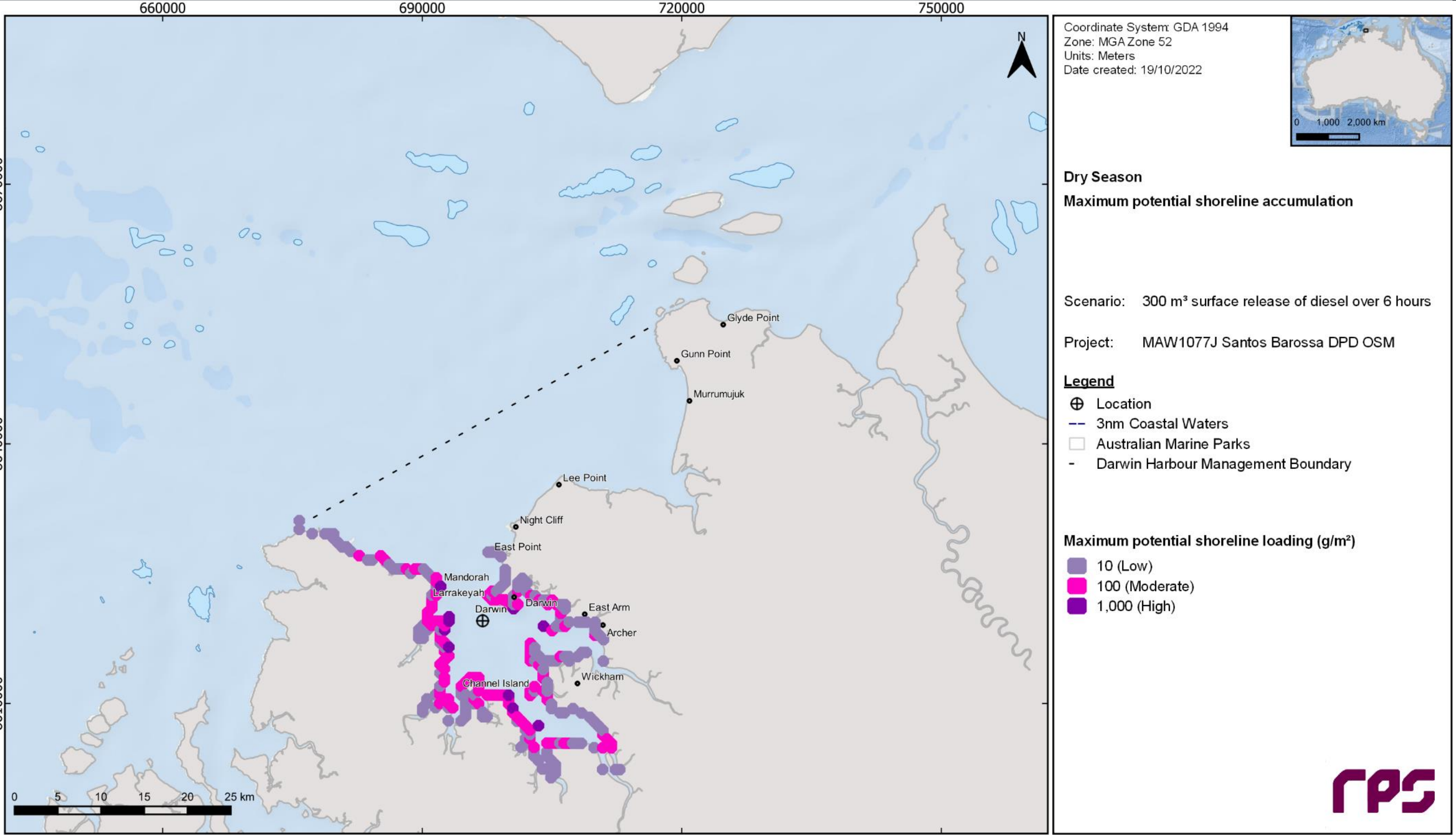


Figure 15.4 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

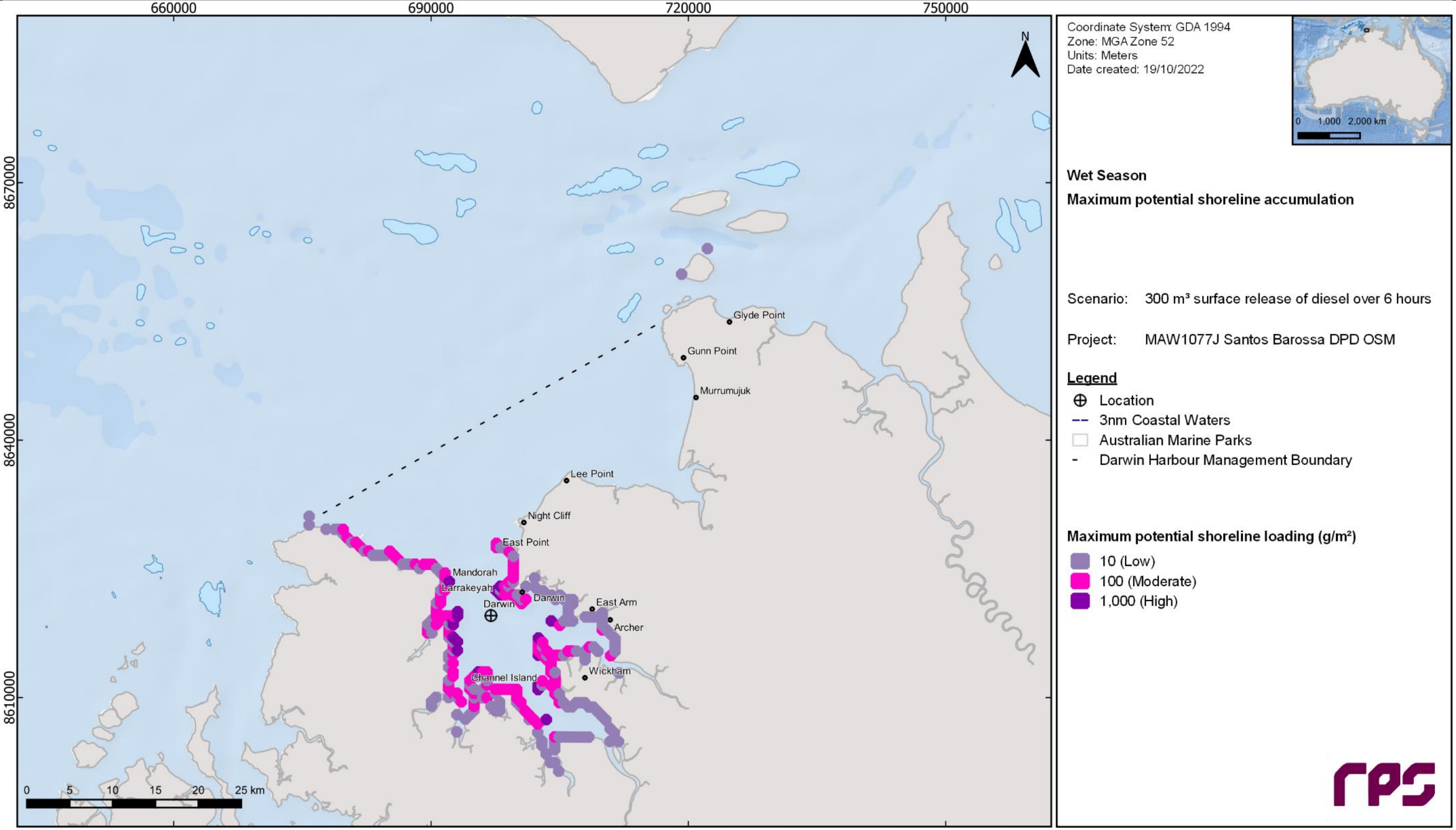


Figure 15.5 Maximum potential shoreline loading from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

15.2.3 In-water exposure

15.2.3.1 Dissolved Hydrocarbons

Table 15.6 summarises the maximum distances and directions travelled by dissolved hydrocarbons from the release location to the low (≥ 10 ppb) and moderate (≥ 50 ppb) thresholds in the 0 – 10 m depth layer. No exposure was predicted for the high (≥ 400 ppb) threshold. The maximum distances from the release location to the low exposure zone was 12.8 km (dry season) and 20.0 km (wet season), whilst distances were reduced to 0.6 km (dry season) and 7.3 km (wet season) for the moderate exposure threshold.

Table 15.7 summarises the potential exposure to receptors from dissolved hydrocarbons in the 0 – 10 m depth layer for each threshold and season. Figure 15.6 and Figure 15.7 illustrate the extent of dissolved hydrocarbon exposure for each season in the 0 – 10 m depth layers.

During both the dry and wet seasons, exposure at the low threshold was predicted at the Anson Beagle IMCRA during the dry and wet seasons with probabilities of 11% and 19%, respectively.

Dissolved hydrocarbon exposure at the low threshold was also predicted at shipwreck receptors during the dry (3) and wet seasons (5), with probabilities ranging from 1 – 10% and between 2 – 17%, respectively. The greatest probability of low threshold exposure during the dry and wet season was predicted for Ham Luong and Mauna Loa USAT, respectively.

Only a single simulation during dry season conditions (1% probability) triggered the low threshold exposure within Restricted Area 6 with a minimum time of exposure of 0.67 days.

During the dry season, 2 WQ Zones recorded exposure at the low threshold with probabilities of 2% (Outer Harbour) and 11% (Middle Harbour), whilst during the wet season, 3 WQ Zones recorded exposure with probabilities ranging between 1% (Middle Arm) and 19% (Middle Harbour, see Table 15.7).

The highest dissolved hydrocarbon concentration was 93 ppb during the wet seasons predicted for Beagle Gulf-Darwin Coast, Anson Beagle IMCRA and Middle Harbour WQO Zone.

Table 15.6 Maximum distances and directions travelled by dissolved hydrocarbons (0 – 10 m depth layer) from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential dissolved hydrocarbon exposure		
		Low 10 ppb	Moderate 50 ppb	High 400 ppb
Dry	Maximum distance (km) from the release location	12.8	0.6	-
	Maximum distance (km) from the release location (99th percentile)	12.3	0.6	-
	Direction	NW	NW	-
Wet	Maximum distance (km) from the release location	20.0	7.3	-
	Maximum distance (km) from the release location (99th percentile)	18.2	7.3	-
	Direction	NW	NNW	-

Table 15.7 Summary of dissolved hydrocarbon exposure for each receptor in the 0 – 10 m depth layer from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry							Wet						
		Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure			Maximum instantaneous concentration (ppb)	Probability of instantaneous dissolved hydrocarbon exposure			Minimum time (days) before instantaneous dissolved hydrocarbon exposure		
			Low	Moderate	High	Low	Moderate	High		Low	Moderate	High	Low	Moderate	High
	Beagle Gulf-Darwin Coast	68	11	1	-	0.04	0.25	-	93	19	3	-	0.04	0.08	-
IMCRA	Anson Beagle	68	11	1	-	0.04	0.25	-	93	19	3	-	0.04	0.08	-
Restricted Areas	6	13	1	-	-	0.67	-	-	8	-	-	-	-	-	-
Shipwrecks	Darwin Harbour Unidentified wreck 2	4	-	-	-	-	-	-	13	3	-	-	0.38	-	-
	Ham Luong	26	10	-	-	0.13	-	-	51	15	2	-	0.04	0.17	-
	Mauna Loa USAT	41	8	-	-	0.13	-	-	55	17	1	-	0.08	0.13	-
	Peary USS	6	-	-	-	-	-	-	12	2	-	-	0.58	-	-
	Shipwrecks - Yu Han 22 (SURF	11	1	-	-	0.38	-	-	21	7	-	-	0.21	-	-
WQ Zones	Middle Arm	6	-	-	-	-	-	-	15	1	-	-	0.38	-	-
	Middle Harbour	68	11	1	-	0.04	0.25	-	93	19	3	-	0.04	0.08	-
	Outer Harbour	16	2	-	-	0.46	-	-	32	8	-	-	0.21	-	-

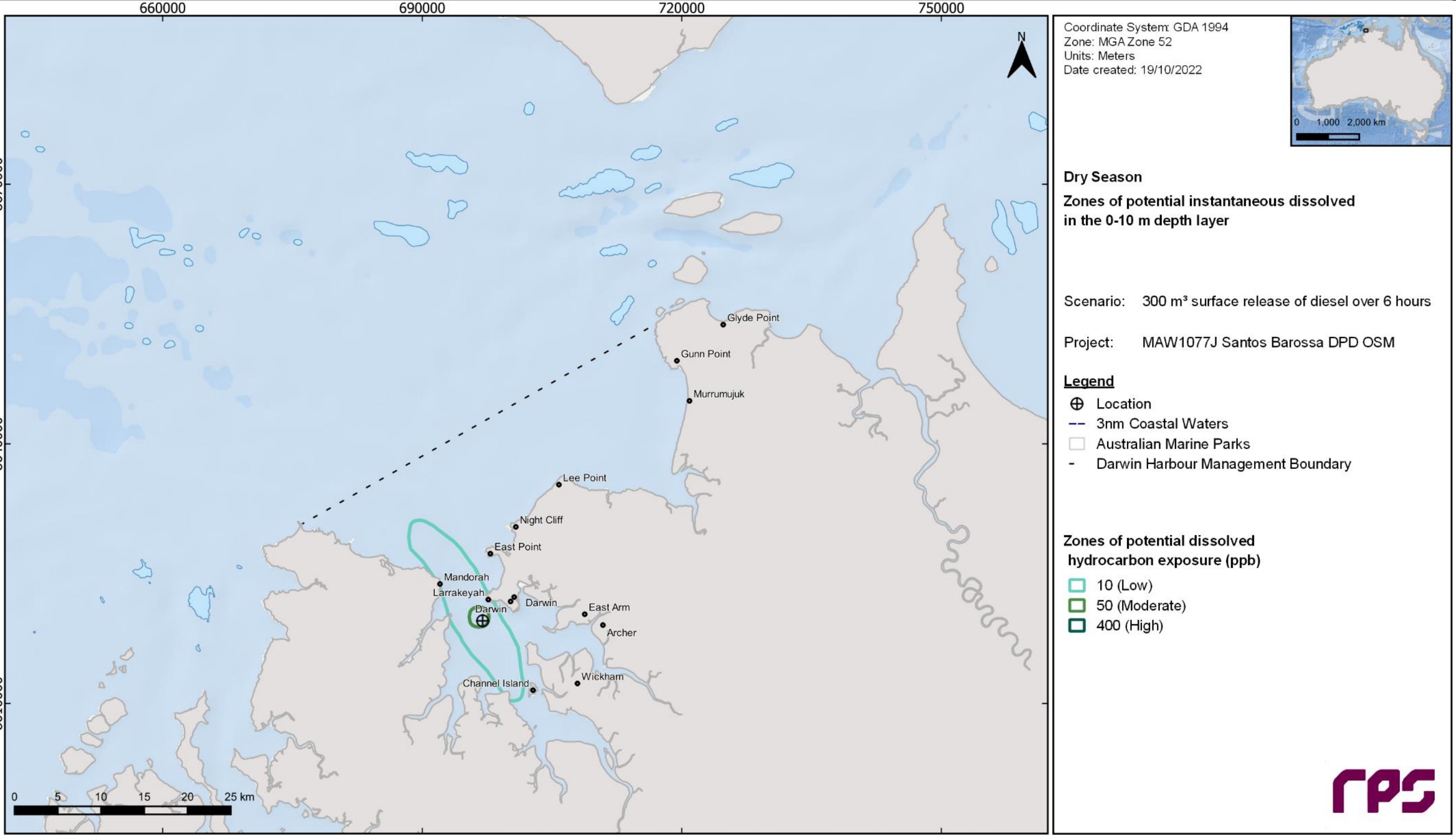


Figure 15.6 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

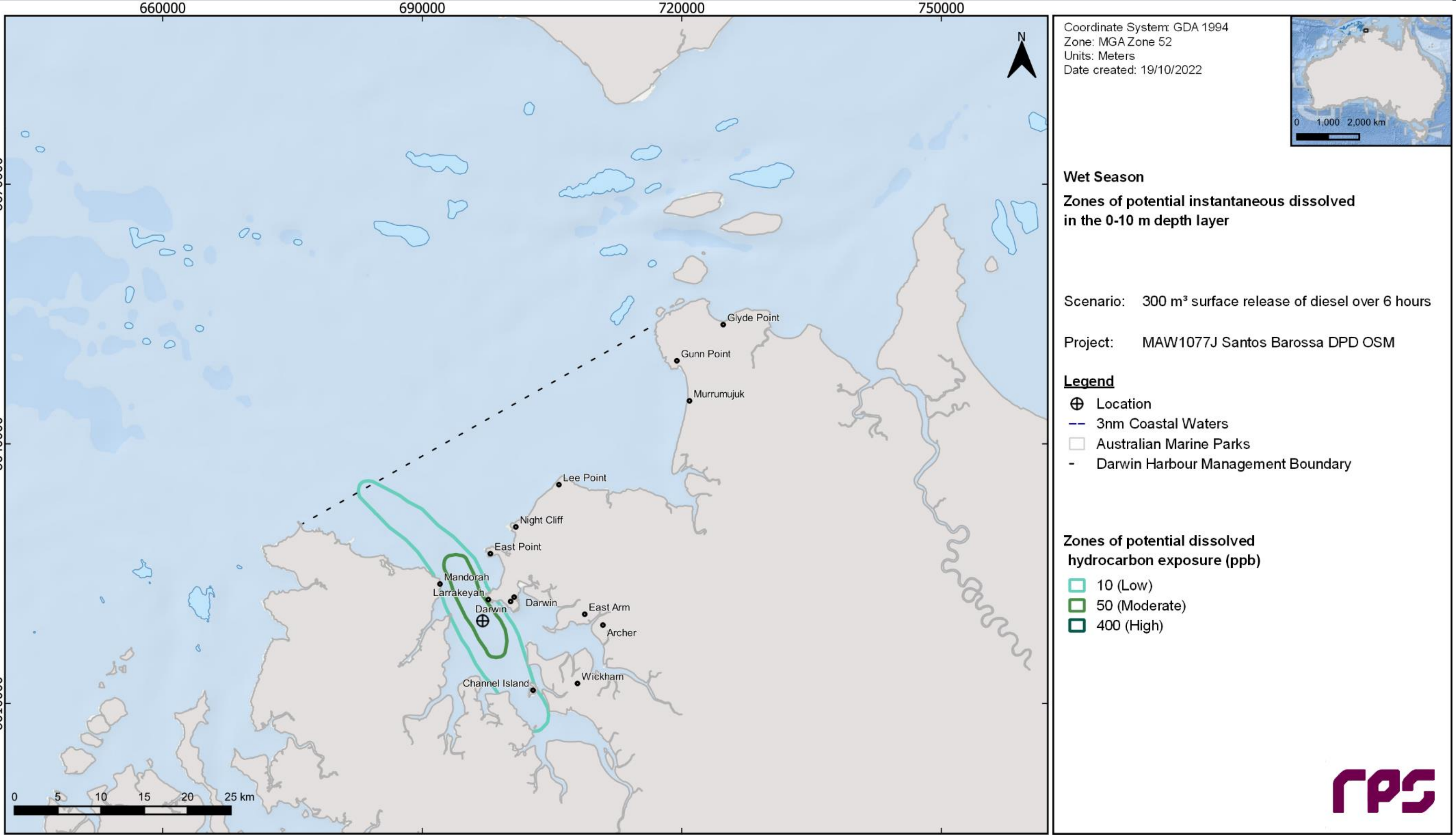


Figure 15.7 Zones of potential dissolved hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

15.2.3.2 Entrained Hydrocarbons

Table 15.8 summarises the maximum distances and directions travelled by entrained hydrocarbons within the 0 – 10 m depth layers at the low (≥ 10 ppb) and moderate (≥ 100 ppb) thresholds. The maximum distances from the release location to the low exposure zone was 41.7 km (dry season) and 48.3 km (wet season), whilst distances were reduced to 30.3 km (dry season) and 32.4 km (wet season) for the moderate exposure threshold. Exposure was limited to the 0 – 10 m depth layer.

Table 15.9 summarises the potential exposure to receptors from entrained hydrocarbons in the 0 – 10 m depth layer for each season. Figure 15.8 and Figure 15.9 illustrate the extent of entrained hydrocarbon exposure for each season in the 0 – 10 m depth layer.

During both seasons the Charles Point Wide RFPA and four Restricted Areas (1, 4, 5 and 6) were predicted to be exposed at the low threshold with probabilities ranging from 14 – 99% and 50 – 94% during the dry and wet seasons, respectively. During both seasons Restricted Area 6 was predicted to have the greatest probability of exposure (99% and 94%, respectively).

Anson Beagle IMCRA was also predicted to experience exposure at the low threshold with probabilities of 100% during the dry season and 96% during the wet season.

Only a single simulation during dry season conditions (1% probability) triggered the low threshold exposure within the Middle Reef and Kelleway Reef RSB receptors. Additionally, only a single simulation (1% probability) was also predicted to trigger the low threshold exposure at Vernon Islands Conservation Reserve during the wet season with a corresponding time of exposure of 12.21 days.

Exposure at the low threshold was predicted at 18 and 19 shipwreck receptors during the dry and wet season, respectively with probabilities ranging from 5% (East Arm Vietnamese Refugee Boat 1) and 100% (Ham Luong, Mauna Loa USAT and Yu Han 22) during the dry season and 4% (Elizabeth River - unidentified wreck) and 95% (Ham Luong) during the wet season.

Furthermore, 8 WQ Zones were predicted to be exposed at the low threshold during the dry and wet season with probabilities ranging from 2% (Myrmidon Creek) and 100% (Middle Harbour) during the dry season. Whilst, under wet season conditions probabilities throughout the 8 WQ Zones ranged from 14% (Myrmidon Creek) and 96% (Middle Harbour, see Table 15.9).

The highest entrained hydrocarbon concentration was 6,826 ppb predicted for Beagle Gulf-Darwin Coast, Anson Beagle IMCRA and Middle Harbour WQO Zone during the wet season.

Table 15.8 Maximum distances and directions travelled by entrained hydrocarbons (0 – 10 m depth layer) from the release location vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Season	Distance and direction travelled	Zones of potential entrained hydrocarbon exposure	
		Low 10 ppb	Moderate 100 ppb
Dry	Maximum distance (km) from release location	41.7	30.3
	Maximum distance (km) from release location (99th percentile)	40.3	29.3
	Direction	WNW	NW
Wet	Maximum distance (km) from release location	48.3	32.4
	Maximum distance (km) from release location (99th percentile)	43.7	31.2
	Direction	NW	NW

Table 15.9 Probability of entrained hydrocarbons exposure to receptors in the 0 – 10 m depth layer from a vessel fuel tank rupture at KP114 during each season. Results were calculated from 100 spill simulations per season.

Receptor		Dry					Wet				
		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure		Maximum concentration (ppb)	Probability of instantaneous entrained hydrocarbon exposure		Minimum time (days) before instantaneous entrained hydrocarbon exposure	
			Low	Mod	Low	Mod		Low	Mod	Low	Mod
	Beagle Gulf-Darwin Coast	5,932	100	91	0.04	0.04	6,826	96	82	0.04	0.04
Conservation Reserve	Vernon Islands	4	-	-	-	-	13	1	-	12.21	-
IMCRA	Anson Beagle	5,932	100	91	0.04	0.04	6,826	96	82	0.04	0.04
RFPA	Charles Point Wide	239	96	10	0.67	0.71	393	90	14	0.67	0.71
Restricted Area	1	28	14	-	0.75	-	87	50	-	0.46	-
	4	495	99	68	0.17	0.29	679	94	42	0.21	0.29
	5	414	98	43	0.17	0.25	354	93	36	0.17	0.21
	6	616	99	77	0.13	0.17	665	94	62	0.21	0.25
RSB	Middle Reef	13	1	-	9.75	-	4	-	-	-	-
	Kelleway Reef	15	1	-	8.34	-	5	-	-	-	-
Shipwrecks	Bell Bird	732	96	22	0.21	0.25	552	90	40	0.21	0.33
	Booya	450	98	32	0.13	0.17	963	89	51	0.13	0.13
	British Motorist	853	97	40	0.17	0.29	850	92	67	0.13	0.21
	Darwin Harbour Unidentified wreck 2	895	98	62	0.13	0.17	1,010	92	74	0.08	0.13
	East Arm Barge 1	13	7	-	1.33	-	34	27	-	0.79	-
	East Arm Vietnamese Refugee Boat 1	23	5	-	1.25	-	103	36	1	0.33	0.83
	East Arm Vietnamese Refugee Boat 2	13	7	-	1.33	-	34	27	-	0.79	-
	Elizabeth River - unidentified wreck	8	-	-	-	-	14	4	-	1.38	-
	Ellengowan	302	92	3	0.21	0.46	344	84	21	0.17	0.25

	Ham Luong	3,673	100	89	0.04	0.04	3,915	95	81	0.04	0.04
	L. Ann	248	97	40	0.29	0.46	240	92	13	0.25	0.58
	Landing Barge	675	95	25	0.29	0.29	607	90	48	0.21	0.21
	Mandorah Unidentified wreck 1	248	97	40	0.29	0.46	240	92	13	0.25	0.58
	Mauna Loa USAT	4,201	100	89	0.04	0.04	6,002	93	81	0.04	0.04
	Middle Arm unidentified wreck	302	92	3	0.21	0.46	344	84	21	0.17	0.25
	Diemen	500	99	67	0.13	0.21	499	92	48	0.13	0.25
	Peary USS	1,055	98	58	0.13	0.21	1,070	93	75	0.08	0.17
	Vietnamese Refugee Boat Pk76	448	95	13	0.21	0.54	320	87	22	0.25	0.50
	Yu Han 22	1,674	100	81	0.08	0.13	1,581	94	73	0.08	0.08
WQ Zones	Elizabeth River	23	5	-	1.25	-	107	36	1	0.33	0.83
	East Arm	604	94	15	0.29	0.33	476	87	34	0.21	0.29
	Middle Arm	1,002	94	11	0.21	0.25	1,090	80	29	0.17	0.17
	West Arm	479	99	58	0.21	0.25	603	95	32	0.17	0.21
	Middle Harbour	5,932	100	91	0.04	0.04	6,826	96	82	0.04	0.04
	Outer Harbour	1,480	99	78	0.08	0.13	2,135	93	68	0.08	0.08
	Shoal Bay	17	24	-	6.21	-	29	22	-	4.25	-
	Myrmidon Creek	14	2	-	2.33	-	68	14	-	0.38	-

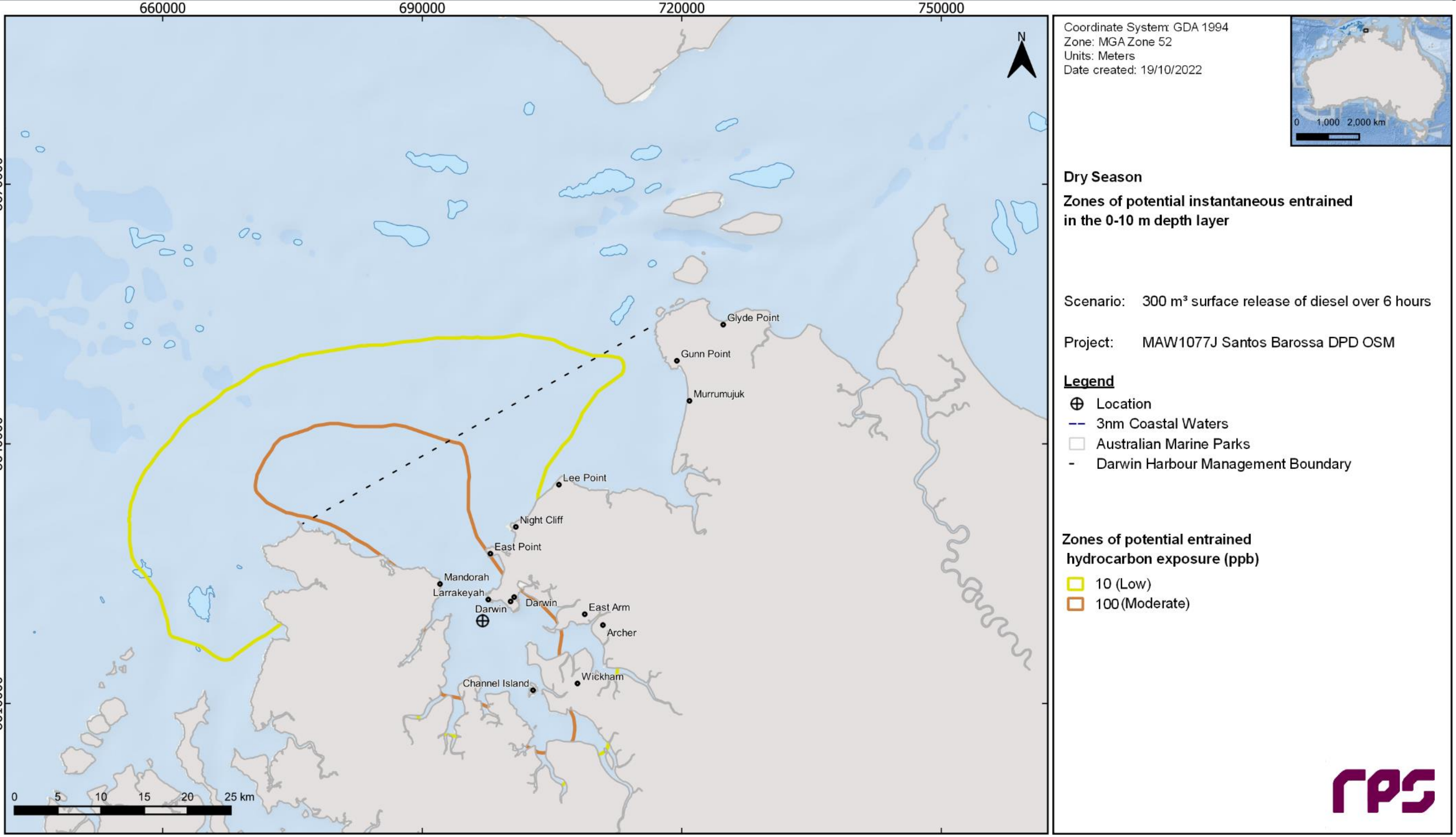


Figure 15.8 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during dry season conditions. The results were calculated from 100 spill simulations.

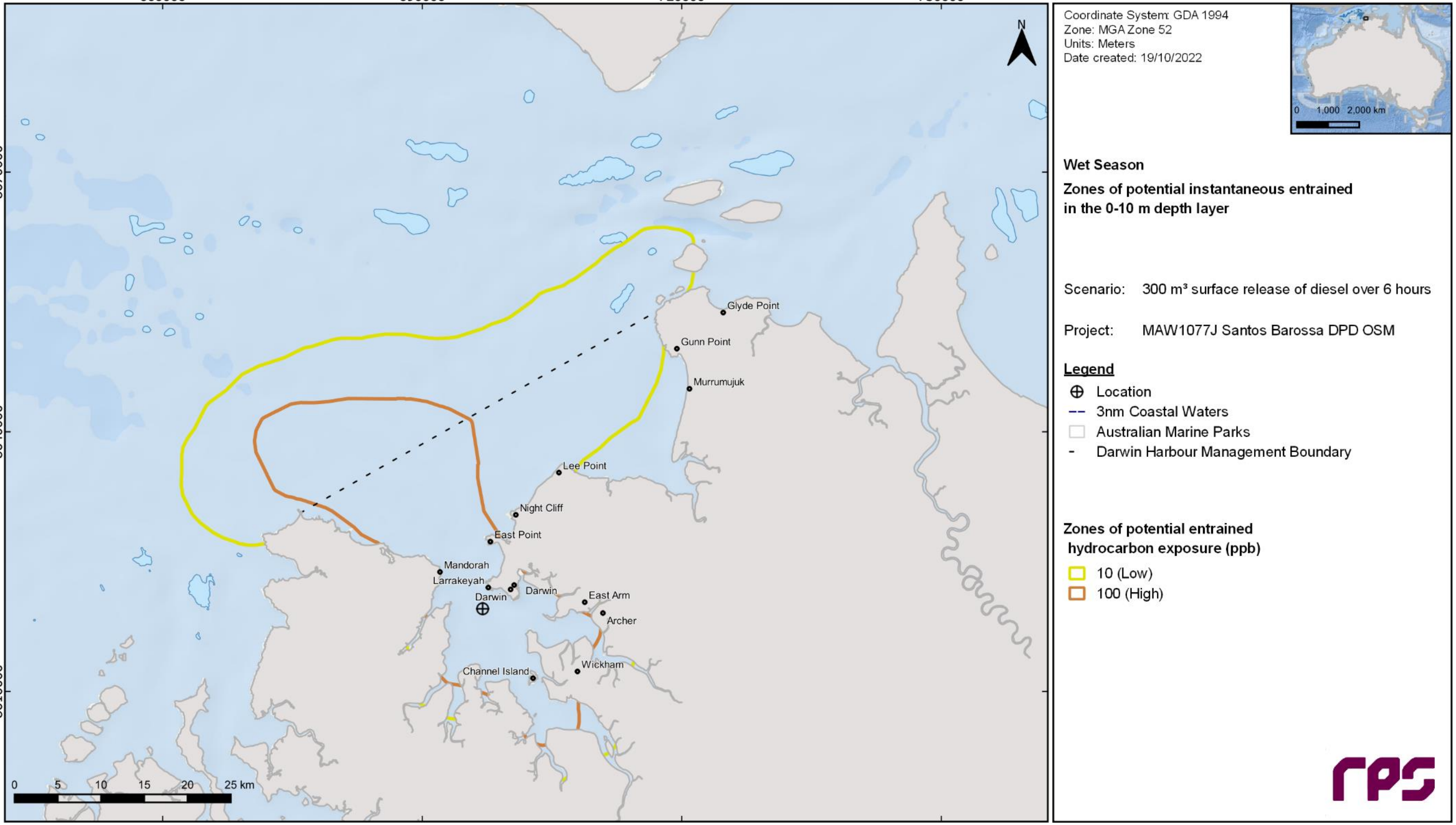


Figure 15.9 Zones of potential entrained hydrocarbon exposure at 0 – 10 m below the sea surface from a vessel fuel tank rupture at KP114 during wet season conditions. The results were calculated from 100 spill simulations.

15.3 Deterministic Analysis

The stochastic modelling results were assessed and the deterministic simulation resulting in the largest volume ashore (115.5 m^3) was identified as run 55, which commenced at 9 am 20 April 2020 during the wet season.

Zones of exposure on the sea surface (swept area) and shoreline accumulation over the entire 30-day simulation are presented in Figure 15.10. The spill drifted predominately south and west from the release location and the oil was predicted to accumulate on the western shoreline up to Mandorah.

Zones of entrained hydrocarbon exposure within the 0 – 10 m depth layer (surface layer) over the 30-day simulation are presented in Figure 15.11.

Figure 15.12 and Figure 15.13 show time series of the area of floating oil and the volume of oil ashore exposure for each threshold during the 30-day simulation.

Figure 15.14 presents the fates and weathering for the corresponding single spill trajectory. At the conclusion of the simulation, approximately 214 m^3 (71%) of the spilled oil was lost to the atmosphere through evaporation and ~75 m^3 (25%) remained on the shoreline. In addition, ~8 m^3 (3%) was predicted to have decayed by the end of the simulation, while there was no oil predicted to remain on the surface.

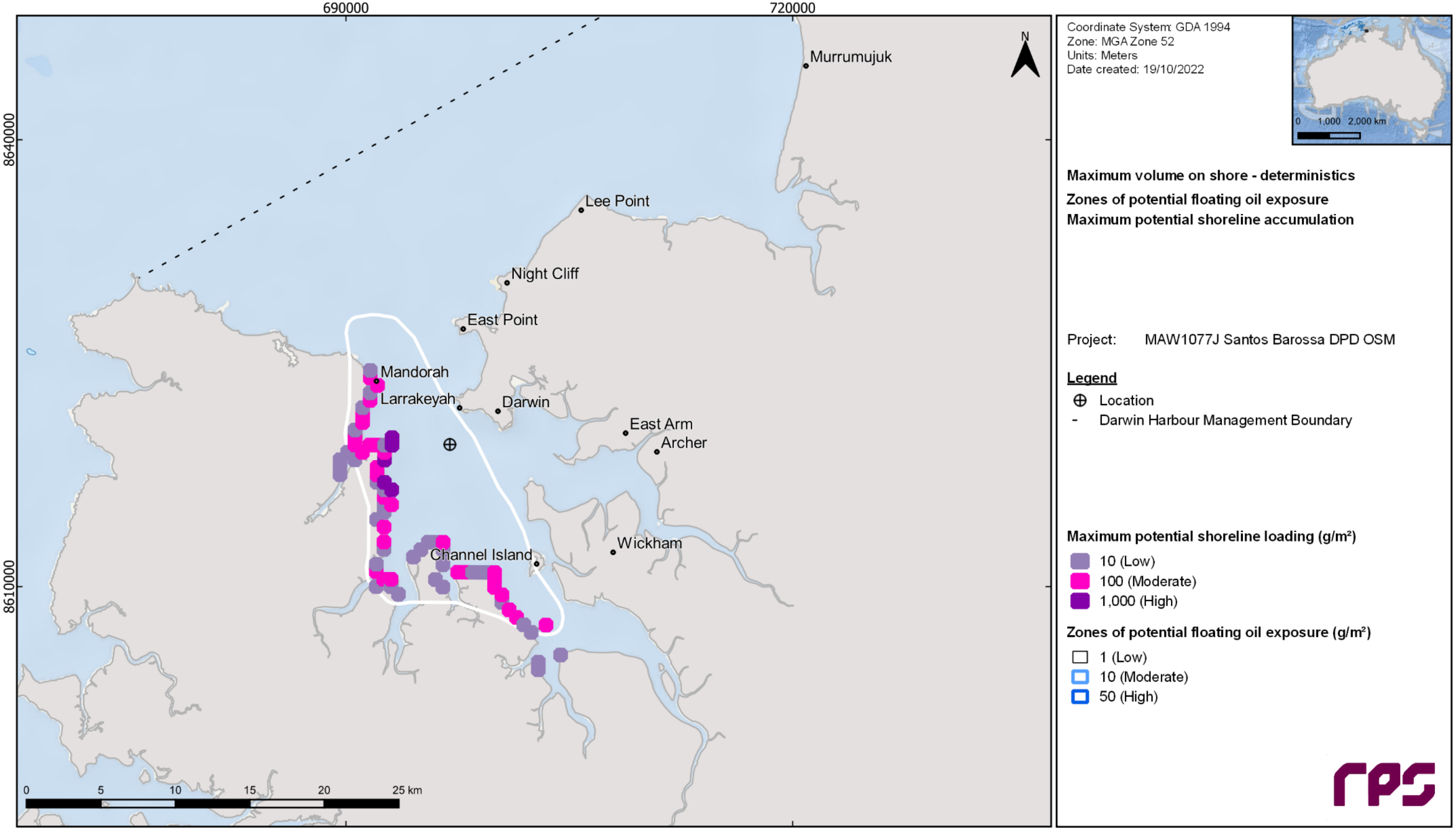


Figure 15.10 Zones of potential exposure on the sea surface and shoreline accumulation (over the 30-days) for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season.

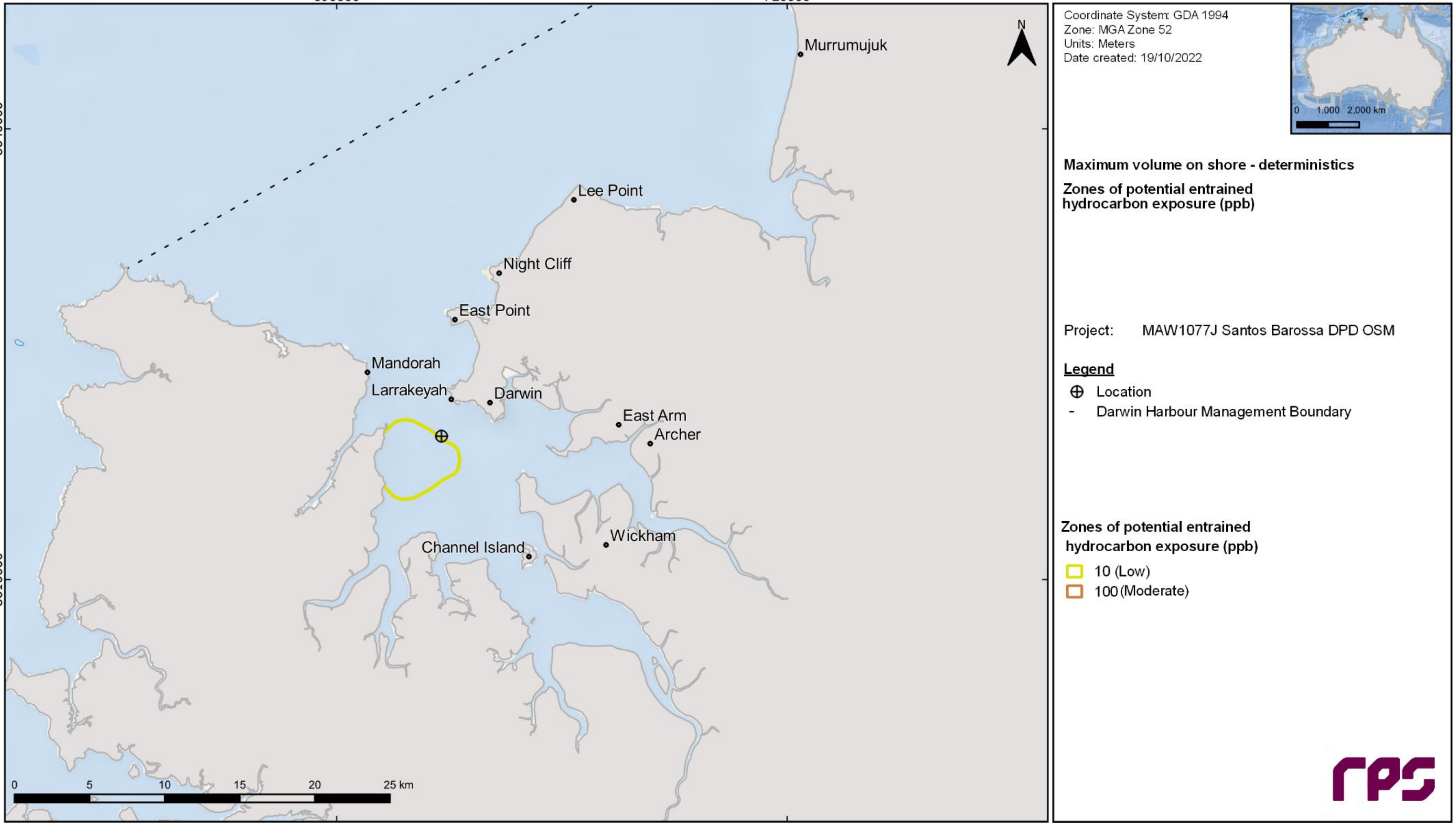


Figure 15.11 Zones of potential entrained hydrocarbon exposure 0 – 10 m below the sea (over the 30-days) for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season.

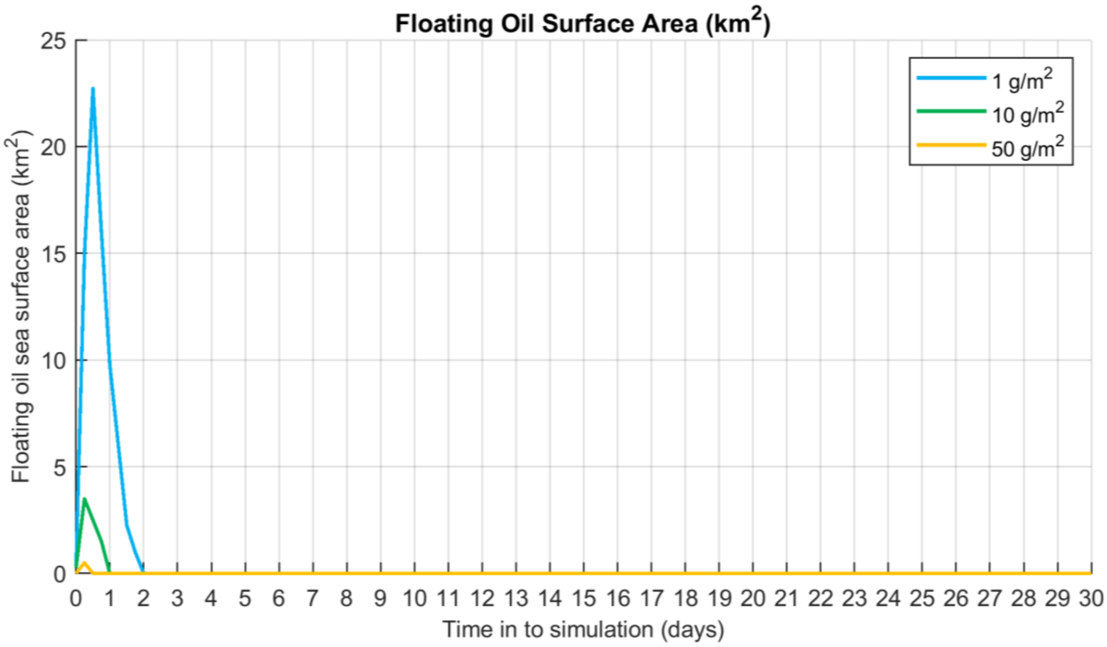


Figure 15.12 Time series of the floating oil surface area exposure for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season.

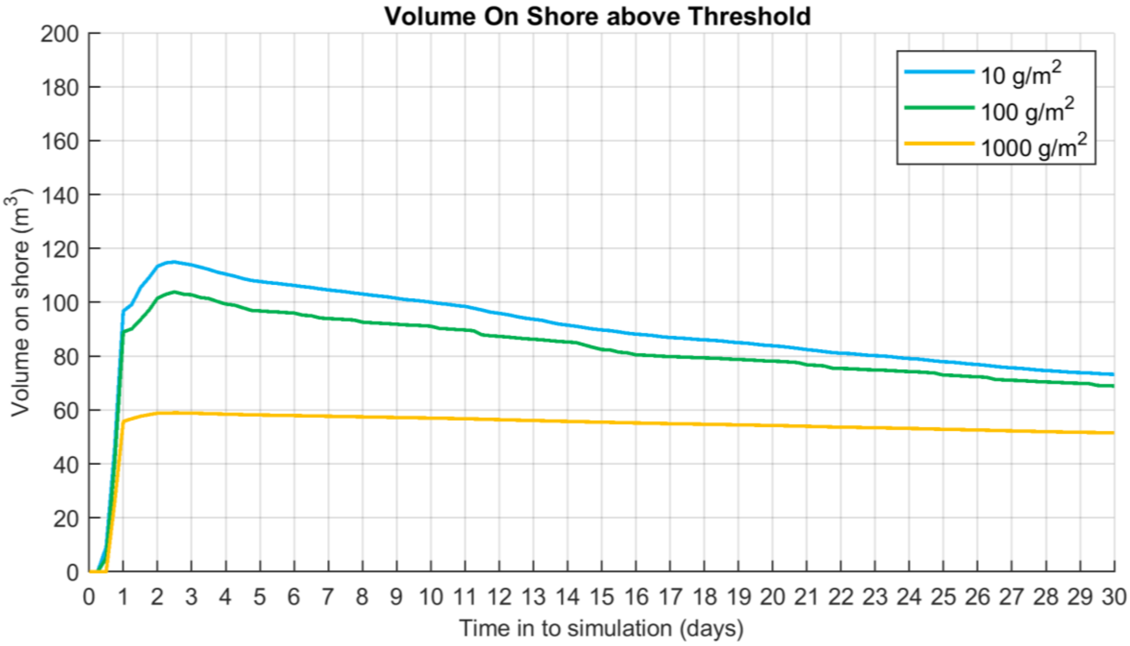


Figure 15.13 Time series of the volume of oil ashore for each threshold for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season.

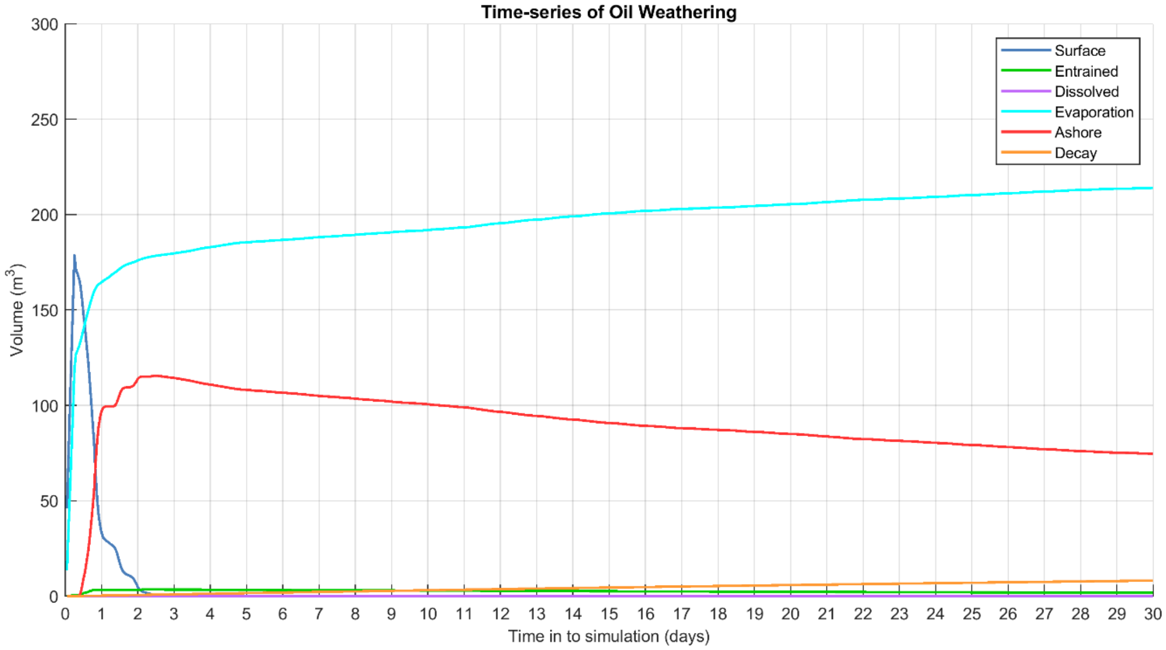


Figure 15.14 Predicted weathering and fates graph for the simulation resulting in the maximum volume of oil ashore starting at 9 am 20 April 2020 during the wet season.

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Appendix 16: Maritime Archaeology Heritage Assessment Report and Route Realignment Technical Memo

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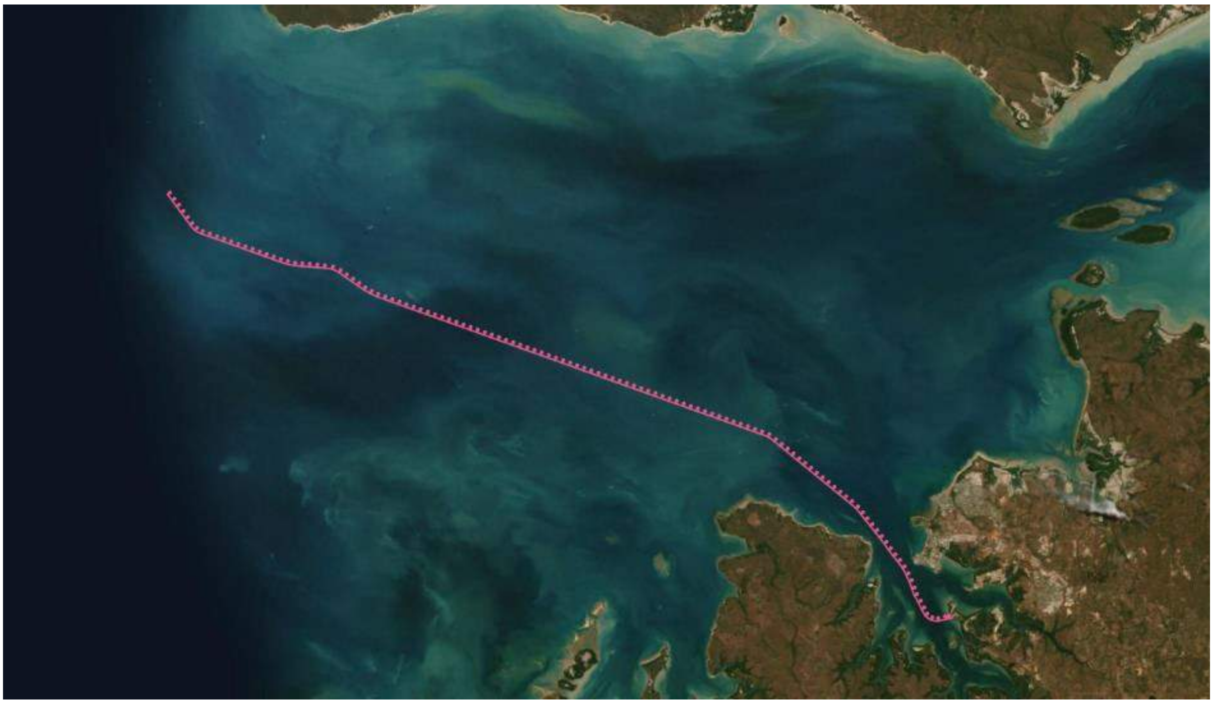
Santos (Barossa) Gas Export Pipeline

Additional and Nearshore Barossa GEP Stage (Beagle Gulf and Darwin Harbour)



Maritime Heritage Assessment

Beagle Gulf and Darwin Harbour

Northern Territory

December 2022

Santos (Barossa) Gas Export Pipeline

Additional and Nearshore Barossa GEP Stage (Beagle Gulf and Darwin Harbour)

Maritime Heritage Assessment

Prepared for:

Santos Pty Ltd

By:

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December 2022

Cosmos Archaeology Job Number J21/22b

Cover Image: Geophysical survey data overlaid on satellite imagery of Tiwi Islands and Darwin.

Revision	Description	Date	Originator	Reviewer	Approver
V0	Draft Report	8/02/2022	CM, CW	CW, CC	CC
V1	Draft with comments addressed	24/02/2022	CM	CC	CC
V2	Draft included review of additional geophysical data, review FUGRO report, and review of targets	26/05/2022	CM	CC	CC
V3	Inclusion of ROV survey results	06/07/2022	CM	CC	CC
V4	Client comments addressed, addition of anchoring and trenching zones	10/19/2022	CM	CC	CC
V5	Client comments addressed	05/12/2022	CM	CC	CC
V5.1	Appendix B comments addressed	08/12/2022	CM	CC	CC
V5.2	Finalised report	12/12/2022	CM	CC	CC

EXECUTIVE SUMMARY

Santos Pty Ltd is proposing to install a gas export pipeline (GEP) off the northwest coast of the Northern Territory (NT). The proposed GEP begins at the Barossa gas field, north of the Tiwi Islands, and extends south to feed the Darwin LNG plant, located in Middle Arm, Darwin Harbour. Two stages are proposed for the GEP. The first stage is a GEP from the Barossa gas field to a point at the existing Bayu-Undan to Darwin pipeline southwest of Bathurst Island. The second stage is to extend the GEP from this point to the Darwin LNG plant. This maritime archaeological heritage assessment (MAHA) examines the second stage, with the first stage being the subject of a separate report.

A review of historical sources, databases and marine geophysical information has found that within the study area, Larrakia and Tiwi people conducted maritime travel and subsistence activities – likely concentrated in coastal environments. Macassan trepang fishing and trade occurred throughout the 18th to early 20th centuries.

British exploration and surveying began in the early 19th century, following which a wide range of colonial shipping including Government and commercial cargo and passenger transport, fishing and pearling industry trade and transport, and recreational shipping occurred, from the establishment of colonial settlement in Darwin in the 1860s to present. In the 1870s and 1880s, three subsea telegraph cables were laid. Quarantine and leper station transport and service supply were established in Middle Arm throughout the late 19th to early 20th century.

The study area saw significant military action during World War II, including air and sea combat between Allied and Japanese forces, which resulted in the sinking of numerous ships and aircraft within Beagle Gulf and Darwin Harbour. Areas near and adjacent to the study area have been designated as live-fire ranges, and the pipeline route enters a gazetted air-to-air range, though it is unknown if live fire exercises have been undertaken.

There are seventeen located shipwrecks, six instances of maritime infrastructure, and five instances of UXO within the study area. There are no known aircraft wrecks or sea dumping sites within the study area. There are twenty-nine unlocated shipwrecks recorded to have wrecked within the vicinity of the study area. Any of these could possibly be wrecked within the study area. There are twenty-five known, but unlocated, aircraft wrecks in Beagle Gulf and Darwin Harbour that could potentially occur within the study area based on historical accounts of the wreck event and general wreck location.

The remains of these vessels, and their contents and fittings, are automatically protected under the Cwlth *Underwater Cultural Heritage Act 2018*. Remains within the coastal waters boundary (3nm seaward from the Territorial Sea Baseline 'TSB' – see Section 3.1) are protected under the NT *Heritage Act 2011,* and United States military shipwrecks and aircraft wrecks are protected under the US *Sunken Military Craft Act 2004.*

Side scan sonar data and MBES data from a marine geophysical survey conducted by Fugro in 2021 were reviewed, as well as 1 m resolution MBES data collected between 2011 and 2015, published by Geosciences Australia, covering the entirety of Darwin Harbour. Thirty-nine sonar and magnetometer contacts were identified from the Fugro survey data as being possibly cultural and hence of potential cultural heritage significance. These anomalies could be natural features, remains of anti-submarine defences, 19th century telegraph cables, shipwrecks, possible aircraft wreckage, debris fields, or isolated instances of debris and/or discard.

Santos has advised that an 1800 m wide corridor, located between KP 91.5 and the GEP terminus, has been proposed for anchoring of work vessels during GEP installation. Because this corridor is wider than the Fugro geophysical survey corridor, CA conducted a review of the Geosciences Australia MBES data to cover this gap. Clear evidence of eight shipwrecks were identified within the anchoring corridor. Two of these wrecks, USAT *Mauna Loa* and USAT *Meigs,* are protected under the NT *Heritage Act 2011* and may be protected under the

US *Sunken Military Craft Act 2004.* The remaining six shipwrecks identified during review of geophysical survey data are not protected under statutory regulations. No aircraft wrecks were identified within the anchoring corridor. In addition to the geophysical targets and Fugro geophysical survey targets identified, an additional 135 targets were identified within the gap between the geophysical survey corridor and the anchoring corridor. 90 of these targets are between KP 107 and 108, known to be the location of the WWII anti-submarine boom net moorings. It is believed that most, if not all, of these are large cement mooring blocks. The remaining 45 targets have been identified as most likely debris, with some instances of isolated discard and possible cable remains. These targets are scattered along the length of the anchoring corridor.

An ROV survey was conducted in June 2022 on 16 geophysical targets located within 50m of the proposed GEP route. Additionally, three transects were conducted on the likely location of WWII anti-submarine boom net moorings. The ROV survey identified three anti-submarine net mooring trots, Trots 16, 17, and 18. Trot 17 directly crosses the path of the proposed GEP route. The northern-most clump of Trot 16, identified as a repurposed ship's anchor, is located approximately 37m from the proposed GEP route, and the southernmost chain section of Trot 18 is located 32m from the proposed GEP route. The location of Clump 1, Trot 18, if still extant would likely be located within 25m of the proposed route.

In addition to the anti-submarine net trots, four isolated objects were observed during ROV surveys. Target MA_007 is located 6m from the proposed GEP route. Targets 174, MA_001, and NCL_SC_016 are located 15-35m from the proposed GEP route. While Target MA_001 was determined to be the remains of a modern buoy mooring, of minimal heritage significance. Targets 174, MA_007, and NCL_SC_016 could not be conclusively identified through ROV survey. Target 174 appears to be a ship's bollard with rope attached and MA_007 is a rectangular metal structure consisting of metal beams. NCL_SC_016 appears to be a subsea cable of unknown provenance but is not believed to be part of a DP&W or Telstra cable between Mandorah and Darwin, as the object is disarticulated and severed at both ends.

The identity, and hence cultural heritage significance of targets MA_007, 174, and NCL_SC_016, as well as other uninspected anomalies is not known. If identified geophysical anomalies and cultural heritage objects cannot be avoided, then a detailed heritage impact assessment will need to be conducted, consistent with the Heritage Branch of the Northern Territory Government (NT Heritage Branch) Archaeological Scope of Works.[1] This would inform a Maritime Heritage Management Plan, that would include specific mitigation measures and management recommendations for each anomaly, such as, but not confined to, archaeological recording, clearance, removal, and/or recovery. For example, any clearance of cultural material from the seabed should be recorded by a maritime archaeologist on-site. For the INPEX project, this involved maritime archaeologists with suitable diving qualifications embedded with the commercial dive teams.

It is recommended that if further remote sensing surveys of the proposed GEP are undertaken – i.e., to fill in data gaps or assess the risk of UXO – the additional survey data should be reviewed by a qualified maritime archaeologist.

In the unlikely event of significant maritime archaeological remains being discovered during the construction phase, an Unexpected Maritime Archaeological Finds Protocol to responsibly manage such finds should be prepared and implemented. If a Maritime Heritage Management Plan is deemed necessary, this would be a component of such a plan.

Based on the findings above, the recommendations made in this report are as follows:

[1] **NT Heritage Branch, 2021,** Archaeological Scope of Works: Gas export pipeline Barossa gas field to Middle Arm, Darwin Harbour.

Recommendation 1	***If feasible, the proposed GEP alignment be altered to avoid the WWII anti-submarine net mooring Trot 17 as well as cultural heritage objects identified at Target MA_007.***
Recommendation 2	***If potentially cultural anomalies and objects identified in this assessment are likely to be impacted, undertake a detailed heritage impact assessment by a qualified maritime archaeologist.***
Recommendation 3	***Establish no-anchoring zones around protected shipwreck locations, the anti-submarine net moorings, and unverified geophysical anomalies within the anchoring corridor.***
Recommendation 4	***If additional remote sensing data is collected for the proposed GEP it should be reviewed by a qualified maritime archaeologist.***
Recommendation 5	***Prepare and implement an Unexpected Maritime Archaeological Finds Protocol.***
Recommendation 6	***Review of this assessment if proposed alignment of pipeline changes.***

TABLE OF CONTENTS

Executive Summary ii

1 Introduction 7

1.1 Background 7

1.2 The Maritime Archaeological Study Area 7

1.3 Scope of the Study 8

1.4 Previous Work 9

2 METHODOLOGY 10

2.1 General Statements on site locations 10

3 LEGISLATION 12

3.1 Commonwealth *Underwater Cultural Heritage Act 2018* 12

3.2 Sunken Military Craft Act 2004 (USA) 14

3.3 Northern Territory *Heritage Act 2011* 15

3.4 UNESCO 2001 *Convention on the Protection of Underwater Cultural Heritage* 16

4 KNOWN AND POTENTIAL MARITIME ARCHAEOLOGY 19

4.1 Environment and Morphology 19

4.2 Cultural Activities in Darwin Harbour and Beagle Gulf 21

4.3 Known Maritime Archaeological Sites in the Study Area 34

4.4 Potential Maritime Archaeological Sites in the Study Area 43

5 PREDICTED CONDITION OF MARITIME ARCHAEOLOGICAL SITES 48

5.1 Introduction 48

5.2 Site Environment 48

5.3 Shipwrecks 48

5.4 Aircraft Wrecks 50

5.5 Sea dumping and UXO 52

5.6 Maritime Infrastructure 52

6 REVIEW OF GEOPHYSICAL SURVEY DATA 54

6.1 Introduction 54

6.2 Geophysical survey data provided 54

6.3 Anomaly Identification 63

6.4 Summary of Fugro Geophysical Survey Data Review 95

7 ROV SURVEY 109

7.1 Conduct of field survey 109

7.2 Summary of ROV survey findings 110

7.3 Interpretation of survey results 117

8 DISCUSSION 128

8.1 Assessing cultural significance 128

8.2 Preliminary evaluation ... 129
8.3 Potential impacts ... 130
8.4 Legislative compliance ... 139
8.5 Mitigation measures ... 139
9 CONCLUSION ... 142
9.1 Summary of findings ... 142
9.2 Recommendations ... 144
REFERENCES ... 146
10 ANNEX A: ROV SURVEY TECHNICAL MEMO ... 150

Abbreviations

AHS SD	Australian Hydrographic Service Sea Dumping Database
AUCHD	Australasian Underwater Cultural Heritage Database
CA	Cosmos Archaeology Pty Ltd
GEP	gas export pipeline
GPS	global positioning system
IJNAF	Imperial Japanese Navy Air Force
IJN	Imperial Japanese Navy
KP	Kilometres along proposed pipeline route
.kmz	keyhole markup file
MHA	maritime archaeological heritage assessment
MBES	multi-beam echosounder
NT	Northern Territory
RAAF	Royal Australian Air Force
ROV	remotely operated underwater vehicle
SMCA	USA *Sunken Military Craft Act 2004*
SSS	side scan sonar
UCH	underwater cultural heritage
UCHA	Cwth *Underwater Cultural Heritage Act 2018*
USAAF	United States Army Air Force
USN	United States Navy
UXO	unexploded ordnance
WWII	World War II

1 INTRODUCTION

1.1 Background

Cosmos Archaeology (CA) has been commissioned by Santos Pty Ltd to undertake a maritime archaeological heritage assessment (MAHA) for the proposed installation of a gas export pipeline (GEP) off the northwest coast of the Northern Territory. The proposed GEP begins at the Barossa gas field, north of the Tiwi Islands, and extends south to feed the Darwin LNG plant, located in Middle Arm, Darwin Harbour. The first proposed route is a GEP from the Barossa gas field to a point at the existing Bayu-Undan to Darwin pipeline southwest of Bathurst Island. Cosmos Archaeology prepared and delivered a maritime heritage assessment for this offshore GEP route, issued for use 30 June 2022.[2]

The second proposed route is to extend the GEP to the Darwin LNG plant. This will include an additional 123 km of seabed pipeline, running through the harbour to the Darwin LNG plant, parallel to the existing Bayu-Undan pipeline.

This MAHA assesses only the second stage, the proposed new pipeline parallel with the existing Bayu-Undan pipeline from Beagle Gulf to the Darwin LNG plant. A MAHA for the first stage will be presented in a separate report.

1.2 The Maritime Archaeological Study Area

A project survey area has been provided by Santos Pty Ltd. This area has been subject to a marine geophysical survey, which will be discussed further in Section 6. The survey area consists of a corridor of variable width, between 700 and 180 m across, primarily around the centreline of the proposed pipeline alignment. The maritime archaeological study area defined by CA for this report is larger than the marine geophysical or project survey area. This is because the exact positions of many of the documented shipwrecks and aircraft wrecks in Beagle Gulf are not known, and some could potentially be located within a wider area. Historical or estimated positions for some wrecks could have a margin of error of a few kilometres. The maritime archaeological study area has been defined as a 1000 m buffer on either side of the proposed GEP centreline (Figure 1). The proposed pipeline route has been provided with markers (KPs) at each kilometre along the length from KP 0 at the junction with the GEP from proposal 1, to KP 122.475 where the pipeline terminates at the Darwin LNG plant.

[2] **Cosmos Archaeology, 2022,** *Santos (Barossa) Gas Export Pipeline, Original Barossa GEP Stage (Timor Sea and Tiwi Islands): Maritime Heritage Assessment.* Prepared for Santos Ltd (BAS 210-0017).

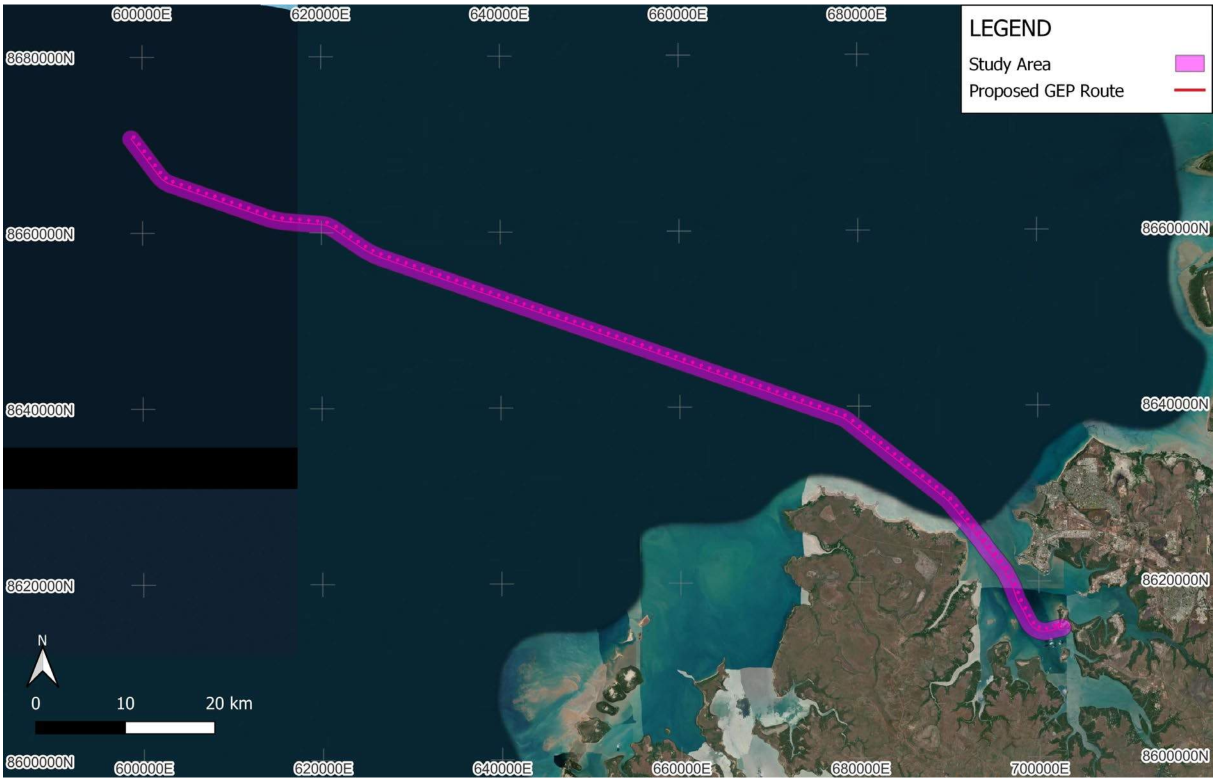

Figure 1: Maritime archaeological study area, 1000 m either side of pipeline centre route.

The coordinates for the survey area were provided by Santos Pty Ltd in the Geophysical survey reports for the Barossa Pipeline.[3] A .kmz file was provided by Santos displaying the centreline of the proposed pipeline route along with geotiff and shapefiles of the geophysical survey data. Additionally, the coordinates for the pipeline routes were provided by Santos Pty Ltd in the same report.[4]

1.3 Scope of the Study

This study addresses the Archaeological Scope of Works for the GEP Barossa Gas Field to Middle Arm, Darwin Harbour, prepared by the NT Heritage Branch in November 2021 and includes the following:

- Provide a list of located and potential maritime archaeological sites (including shipwrecks, aircraft wrecks and dump sites) known to be, or possibly located, within the study area
- Provide an outline of potential impacts from the pipeline installation.
- Provide a description of the different types of potential maritime archaeological sites on the seabed.
- Provide an expert analysis of geophysical survey data in regard to anomalies indicating potential maritime archaeological remains.
- Review of relevant legislative requirements.
- Provide mitigation measures for potential impacts on maritime archaeological remains.

This study examines maritime archaeological sites which are defined as wrecks (ship or aircraft) and associated material, dumped material, maritime infrastructure, and associated deposits on or under the seabed below the highest astronomical tide. While this report

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[3] **Fugro, 2022,** *Barossa Pipeline to Shore Project – Survey Results Report – Offshore Geophysical Survey – (Work Package 1) North Route 2,* provided for Santos Pty Ltd. (BAS-200 0629).
[4] *Op. Cit.* **Fugro, 2022.**

addresses only the potential cultural heritage aspects of dumped and spent munitions, more information about unexploded ordnance (UXO) should be obtained from a suitably qualified UXO specialist or the Department of Defence. This heritage assessment should not be considered a UXO assessment.

1.4 Previous Work

CA has undertaken previous maritime cultural heritage surveys and assessments of the study area as part of the Darwin INPEX project between 2010 and 2014. The following is a list of reports previously completed by CA with a focus on the study area:

Cosmos Archaeology, 2011, *Ichthys Gas Field Development Project: Nearshore Development Area, Assessment of Marine Heritage Survey Methods,* report prepared for INPEX Browse Ltd.

Cosmos Archaeology, 2012, *Ichthys Project Darwin Harbour, East Arm Gas Export Pipeline: Assessment of Heritage Impact of 7 side scan targets.* Prepared for Tek Ventures Pty Ltd.

Cosmos Archaeology, 2014, *INPEX Ichthys LNG Project: Nearshore Development – Dredging. East Arm, Darwin Harbour, Northern Territory. Relocation of Heritage Objects and Removal of debris.* Prepared for Tek Ventures Pty Ltd.

Cosmos Archaeology, 2016, *INPEX Ichthys Project, Catalina Flying-Boat Monitoring 2012 to 2015,* Prepared for Tek Ventures Pty Ltd.

Cosmos Archaeology, 2022, *Santos (Barossa) Gas Export Pipeline, Original Barossa GEP Stage (Timor Sea and Tiwi Islands): Maritime Heritage Assessment.* Prepared for Santos Ltd.

2 METHODOLOGY

This desktop study has used various sources to prepare a list of known and potential shipwrecks, as well as other maritime archaeological sites in the study area (Table 1). Research is confined to what is available online and in the consultant's extensive library. Additionally, the Northern Territory Department of Heritage has been consulted for the location of sites which may not be publicly available.

Table 1: Historic resources consulted in this report.

Source	Description
Australasian Underwater Cultural Heritage Database (AUCHD)	The Australasian Underwater Cultural Heritage Database, maintained by the Commonwealth Department of Agriculture, Water and the Environment, is an online database of known and potential shipwrecks, aircraft wrecks and other maritime heritage sites and objects in Australian and Commonwealth waters.
Australian Government Department of Defence and Australian Hydrographic Service – Sea Dumping in Australia (AHS SD)	This database of sea dumping sites is managed by the Australian Government Department of Defence with information supplied by the Australian Hydrographic Service. http://www.hydro.gov.au/n2m/dumping/dumping.htm
NT Heritage Register	The NT Heritage Register is a register of all declared heritage places and objects (as declared under Part 2.2 of the NT *Heritage Act 2011*), and all heritage places and objects that have been nominated to the register. The register includes places and objects within NT waters. However, the public NT Heritage Register does not include heritage places and objects that are automatically declared under Part 2.1 of the NT *Heritage Act 2011*, including Aboriginal and Macassan places and objects.
Northern Territory Heritage Branch	Direct consultation with the Heritage Branch of the Northern Territory to determine the location of located heritage sites within the study area. *Email received from Heritage Branch on 28/3/2022 with recommendations for potential heritage items that might be located within study area.
Archival sources and heritage reports	A review of a wide range of primary and secondary historical sources held by NT Library and Archives, the National Library of Australia, the National Archives of Australia, and various published and unpublished heritage reports and articles was undertaken.
Previous reports completed by Cosmos Archaeology	A review of numerous reports on projects Cosmos Archaeology has conducted within the Northern Territory in Darwin Harbour and surrounds.

In addition to the heritage inventories, databases, historical resources, and previous reports, a detailed review of available geophysical survey data was also conducted. Section 6 details the results of the geophysical survey review and includes a table of targets identified to be potentially cultural in origin.

2.1 General Statements on site locations

Locations are known for 17 shipwrecks, six instances of maritime infrastructure, and four instances of UXO, however, there are many more sites that are known from the historical record but have not been located. At least 29 shipwrecks and 25 aircraft wrecks are known to have occurred within Beagle Gulf and Darwin Harbour but have not been located. The location data for these wrecks provided by heritage inventories and historical records are not always accurate.

As for the wrecks which have been located, designating accurate positions was not always possible as, in most cases, it is not known how their positions were recorded, such as with global positioning systems (GPS) or a compass/sextant. Furthermore, positions of known wrecks may have been taken off the charts and, therefore, reductions in precision due to plotting and scaling could be expected. Coordinates provided in some databases could also have been inferred from vague historical accounts which in fact could place the site within a relatively large area. This issue is proportionately compounded for sites that are lost at increasingly greater distances from the coast of Australia.

GPS coordinates have become increasingly reliable, but it must be noted that positions recorded with GPS in the 1980s to 1990s had accuracies of 100-300 metres. Those sites found and recorded by GPS closer to shore are likely to have had their location updated over time, but sites further from the coast and/or less accessible may still be listed with old and inaccurate coordinates. There are also different geodetic datums used by GPS units, but if datum is not recorded with the coordinates this can lead to errors when using the same coordinates with a different datum. User error can also occur when a recorder, or someone copying the location records, interprets the coordinates in the wrong style, such as reading coordinates in degrees, minutes, seconds rather than degrees and decimal minutes, for example. Based on these scenarios, it is safe to assume that there is always a degree of inaccuracy with the provision of site coordinates.

Australasian Underwater Cultural Heritage Database (AUCHD) [5]

Information presented in the AUCHD is compiled from each of the State and Territory historic shipwreck agencies or supplied by collecting institutions holding historic shipwreck objects. The integrity or source of the information held by these agencies is unknown. The size of the area in which an individual wreck could be found varies depending on the historical information available. Some wrecks which have been found have a latitude and longitude position, but the accuracy of that position could not be determined as the method used in obtaining the position is not known.

Department of Defence and Australian Hydrographic Service – Sea Dumping in Australia (AHS SD) [6]

The locations of sea dumped materials are provided by the Department of Defence Australian Hydrographic Service. Dumped materials of heritage value can include abandoned vessels and historic munitions, such as WWII-era aircraft components and Lend-Lease material.[7] It is unclear where the Australian Hydrographic Service obtained the positions of the dumped materials. It is important to note that these locations are where the materials were designated to be dumped, but it has been found that those dumping the materials may not have been particular about the final location. An example of this was identified in a previous CA study that found the Narrabeen Dumping Ground, Sydney (a ships graveyard), despite having a high concentration of wrecks within its boundary, also had a dense concentration of sites between four to five kilometres to the east, outside of the designated dumping area.[8]

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[5] **Department of Agriculture, Water and the Environment, 2020**, *Australasian Underwater Cultural Heritage Database*, available at https://www.environment.gov.au/heritage/underwater-heritage/auchd

[6] **Department of Defence and Australian Hydrographic Service, 2020**, *Sea Dumping in Australia*, available at http://www.hydro.gov.au/n2m/dumping/dumping.htm

[7] **Cosmos Archaeology, 2014,** INPEX Ichthys LNG Project : Nearshore Development – Dredging. East Arm, Darwin Harbour, Northern Territory. Relocation of Heritage Objects and Removal of debris. Prepared for Tek Ventures Pty Ltd.

[8] **Cosmos Archaeology, 2007b,** Submarine Cable System, Landfall Option – Collaroy: Underwater Heritage Impact Assessment Baseline Review, report prepared for Patterson Britton and Partners.

3 LEGISLATION

The proposed subsea pipeline route passes through Northern Territorian waters. The NT Heritage Branch administers both the NT *Heritage Act 2011* and the Commonwealth *Underwater Cultural Heritage Act 2018* (under delegation from the Commonwealth Department of Agriculture, Water and the Environment). Both the *Heritage Act 2011* and the *UCH Act 2018* apply to NT waters including harbours, rivers, and estuaries.

3.1 Commonwealth *Underwater Cultural Heritage Act 2018*

The Commonwealth *Underwater Cultural Heritage* (UCH) *Act 2018* (replacing the *Historic Shipwrecks Act 1976*) provides for the protection, conservation, and management of Australia's historic shipwrecks, sunken aircraft, and other types of underwater cultural heritage. The Act is also designed to enable the cooperative implementation of national and international maritime heritage responsibilities, and to promote public awareness, understanding, appreciation, and appropriate use of Australia's underwater cultural heritage.

Under Part 1, Division 2 of the *UCH Act 2018*, underwater cultural heritage is defined as "any trace of human existence that has a cultural, historical or archaeological character; and is located under water." Traces of human existence are considered to be located under water whether they are located partially or totally under water, and whether they are under water periodically or continuously. A "trace of human existence" is further defined to include:

(a) sites, structures, buildings, artefacts and human and animal remains, together with their archaeological and natural context; and

(b) vessels, aircraft and other vehicles or any part thereof, together with their archaeological and natural context; and

(c) articles associated with vessels, aircraft or other vehicles, together with their archaeological and natural context.

Seabed pipelines and cables, and other installations that are placed on the seabed and are still in use, are not considered to be underwater cultural heritage under the Act.

Different articles of underwater cultural heritage are, or can be, protected under the *UCH Act 2018*, depending on the kinds of articles, their heritage significance, and their location. Part 2, Division 1 of the Act provides that certain articles of underwater cultural heritage are automatically protected, including:

(a) all remains of vessels that have been in Australian waters for at least 75 years;

(b) every article that is associated with a vessel, or the remains of a vessel, and that has been in Australian waters for at least 75 years;

(c) all remains of aircraft that have been in Commonwealth waters for at least 75 years;

(d) every article that is associated with an aircraft, or the remains of an aircraft, and that has been in Commonwealth waters for at least 75 years.

These articles of underwater cultural heritage are automatically protected whether or not the existence or location of the article is known, and even if the article is or has been removed from Australian or Commonwealth waters – after the passage of 75 years.

The term "associated with" is defined under Part 1, Division 2 of the Act whereby an article is considered to be associated with a vessel, aircraft, or other vehicle if the article:

(a) appears to have formed part of the vessel, aircraft or other vehicle; or

(b) appears to have been installed or carried on the vessel, aircraft or other vehicle; or

(c) is remains of humans or animals that appear to have been on board the vessel, aircraft or other vehicle; or

(d) appears to have been constructed or used by a person associated with a vessel.

"Australian waters" and "Commonwealth waters" have different meanings under the *UCH Act 2018* (Part 1, Division 2), whereby "Australian waters" extend from the seaward limits of a State to the outer limit of Australia's continental shelf, and "Commonwealth waters" extend from waters 3 nautical miles seaward of the Territorial Sea Baseline adjacent to the States and the NT – i.e., beyond State or Territory coastal waters – to the outer limit of Australia's continental shelf. Specifically, under Part 1, Division 2 of the Act:

"Australian waters" means:

(a) any waters on the landward side of the territorial sea of Australia that are not within the limits of a State; and

(b) the territorial sea of Australia; and

(c) the sea above the continental shelf of Australia; and

(d) the seabed and subsoil beneath any such sea or waters.

"Commonwealth waters" means:

(a) the territorial sea of Australia, other than coastal waters of a State or the Northern Territory; and

(b) the sea above the continental shelf of Australia; and

(c) the seabed and subsoil beneath any such sea or waters.

The Territorial Sea Baseline generally corresponds with the low water line along the coast, measured to the level of Lowest Astronomical Tide. However, in some cases, straight baselines have been established in areas where the coastline is deeply indented and cut into, or where there is a fringe of islands along the coast in its immediate vicinity.

The Territorial Sea Baseline in the region of the current study area incorporates straight baselines that connect the mainland to the Tiwi Islands. As such, the Beagle Gulf forms part of the coastal waters of the NT – see Figure 2.

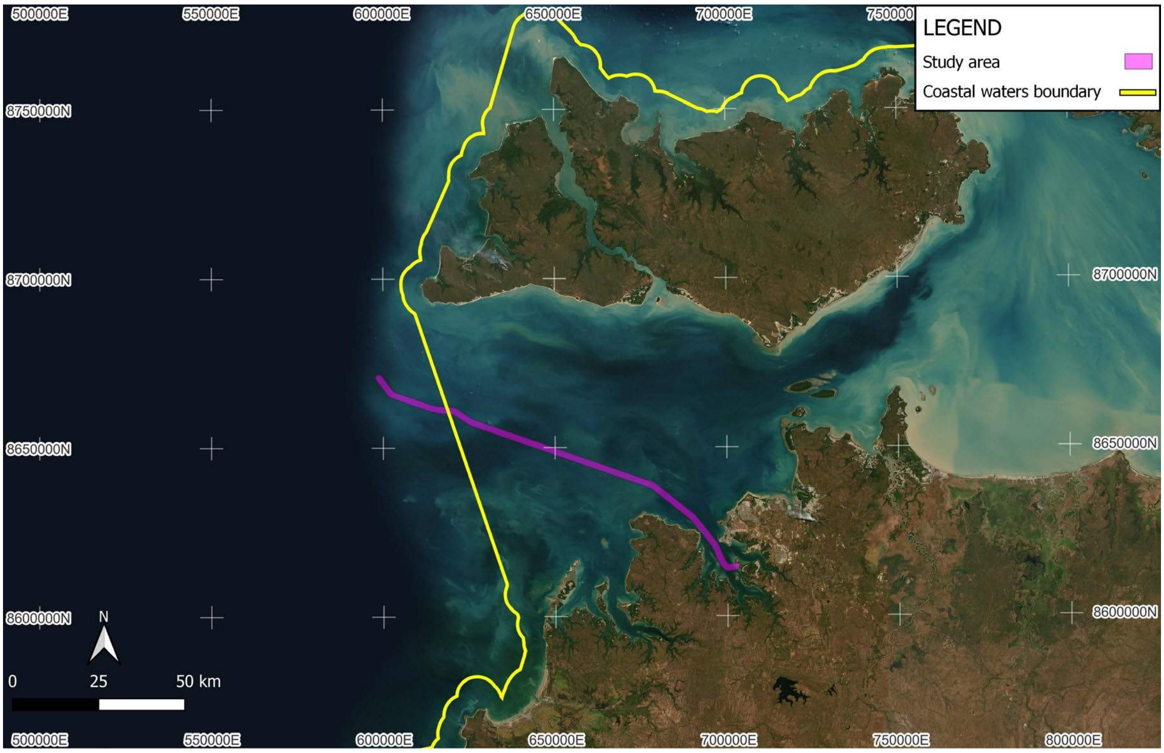

Figure 2: Boundary of NT coastal waters around Darwin and Tiwi Islands.[9]

[9] **Australian Government Geoscience Australia**. **2022.** *Coastal Waters (State / Territory Powers) Act 1980.* Australian Marine Spatial Information System (AMSIS).

These definitions of Australian and Commonwealth waters in the *UCH Act 2018* have been carried over from the *Historic Shipwrecks Act 1976.* In its original form, the *Historic Shipwrecks Act 1976* applied to waters adjacent to a State's coasts upon Commonwealth proclamation and applied automatically to waters adjacent to a Territory's coast. In 1980, the Act was amended to apply to waters adjacent to a State only with the consent of the State, however, the automatic application to waters adjacent to a Territory's coast remained.

As such, NT waters – including coastal waters, bays, rivers, and bodies of water within the jaws of the land and inland waters, below the low water mark – i.e., all waters on the landward side of the NT coastal water boundary shown above in Figure 2.

The study area is situated within "Australian waters" as defined in the *Underwater Cultural Heritage Act 2018*, and as such, shipwrecks and all associated articles that have been in the water for over 75 years are automatically protected, and other forms of underwater cultural heritage sites can be declared protected.

Part 3, Division 2 of the *Underwater Cultural Heritage Act 2018* provides for the regulation of activities relating to protected underwater cultural heritage. Specifically, any conduct that has or is likely to have an adverse impact on protected underwater cultural heritage is prohibited unless carried out in accordance with a permit granted under the Act. Conduct is considered to have an adverse impact on protected cultural heritage if it:

(a) directly or indirectly physically disturbs or otherwise damages the protected underwater cultural heritage; or

(b) causes the removal of the protected underwater cultural heritage from waters or from its archaeological context.

3.2 Sunken Military Craft Act 2004 (USA)

The United States (US) *Sunken Military Craft Act* enacted in 2004 (as Title XIV of the "Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005") provides for the protection of sunken US military vessels and aircraft and the remains of their crews from unauthorized disturbance, salvage, or recovery. The Act applies to sunken US military ships and aircraft wherever located around the world and preserves the sovereign status of sunken US military vessels and aircraft by codifying both their protected sovereign status and permanent US ownership, regardless of the passage of time.

Under Section 1408 of the *Sunken Military Craft Act*, the term "sunken military craft" is defined as:

(A) any sunken warship, naval auxiliary, or other vessel that was owned or operated by a government on military non-commercial service when it sank;

(B) any sunken military aircraft or military spacecraft that was owned or operated by a government when it sank; and

(C) the associated contents of a craft referred to in subparagraph (A) or (B), if title thereto has not been abandoned or transferred by the government concerned.

"Associated contents" are defined as:

(A) the equipment, cargo, and contents of a sunken military craft that are within its debris field; and

(B) the remains and personal effects of the crew and passengers of a sunken military craft that are within its debris field.

Under Section 1402 of the *Sunken Military Craft Act* it is prohibited for any person to engage in or attempt to engage in any activity directed at sunken military craft that disturbs, removes, or injures the craft, or possess any articles of sunken military craft, except in accordance with prior permission from the US Department of the Navy. As authorised by the Act, the Department of the Navy has established a permitting program to allow for controlled site disturbance of sunken military craft for archaeological, historical, or education purposes.

However, as sunken military craft and their associated contents represent a collection of non-renewable and significant historical resources that often serve as war graves, carry unexploded ordnance, or contain oil or other hazardous materials, it is the overall policy of the Department of the Navy that its sunken military craft remain in place and undisturbed, and non-intrusive *in situ* research is preferred. Sunken military craft that serve as the maritime grave sites of lost crew in particular are accorded the highest respect and protection by the Department of the Navy.

The Naval History and Heritage Command's (NHHC) Underwater Archaeology Branch (UAB) manages sunken military craft and research permit applications on behalf of the US Department of the Navy.

> This Act is of relevance to this study as a number of US military craft – planes and vessels – were lost in the Northern Territory during WWII. As a matter of precedence, the INPEX project obtained a permit from the NHHC to relocate the remains of sunken USN Catalinas that were to be impacted by dredging off Blaydin Point.

3.3 Northern Territory *Heritage Act 2011*

The NT *Heritage Act 2011* (replacing the *Heritage Conservation Act 1991)* provides for the conservation of the Territory's natural and cultural heritage, including places and objects within NT waters.

The aim is achieved under the Act by:

(a) declaring places and objects of heritage significance to be heritage places and objects; and

(b) declaring classes of places and objects of heritage significance to be protected classes of heritage places and objects; and

(c) establishing the Heritage Council; and

(d) providing for heritage agreements to encourage the conservation, use and management of heritage places and objects; and

(e) regulating work on heritage places and objects; and

(f) establishing enforcement and offence provisions.

Under Part 2.1 of the NT *Heritage Act 2011*, all Aboriginal and Macassan archaeological places and objects are provided automatic protection under the Act, regardless of whether their existence or location is known.

An Aboriginal or Macassan archaeological places is defined under the Act as a place that:

(a) relates to the past human occupation of the Territory by Aboriginal or Macassan people; and

(b) has been modified by the activity of those people.

An Aboriginal or Macassan archaeological object is defined as a relic that:

(a) relates to the past human occupation of the Territory by Aboriginal or Macassan people; and

(b) is:

(i) in an Aboriginal or Macassan archaeological place; or
(ii) stored in a place in accordance with Aboriginal tradition, including, for example, in an Aboriginal keeping place.

A relic is defined under the Act as:

(a) an artefact or thing given shape by a person; or
(b) human or animal skeletal remains; or
(c) something else prescribed by regulation.

Under Part 2.2. of the NT *Heritage Act 2011,* other places and objects – i.e., non-Aboriginal and non-Macassan places and objects – can be declared by the Minister as protected heritage places and objects.

A place is defined as an area of land, and includes:

(a) a building or, a part of a building, on the place; and
(b) an item historically or physically associated with the place if the primary importance of the item derives (completely or partly) from that association; and
(c) equipment, furniture, fittings and articles on, or historically or physically associated with, the place.

Examples of places, as provided in the Act, include

1. A reef or a cliff, cutting, gorge, spring or other landform
2. A plant or animal community
3. Fossil beds
4. A park or garden
5. A lighthouse, church, homestead, railway station or gaol
6. A stock well
7. A cemetery, burial site or grave
8. An airstrip, magazine, storage tunnel or other military installation
9. The site of a shipwreck or aircraft crash.

The process for declaring heritage places and objects involves a nomination or Heritage Council initiation for assessment of the heritage significance – including aesthetic, historical, scientific, and social significance of a place or object. The Heritage Council then considers whether the place or object is of heritage significance and make a decision whether or not to recommend that the Minister declare the place or object to be a protected heritage place or object.

Under Part 5.5 of the Act, it is an offence to knowingly engage in conduct that results in damage to a heritage place or object, removes a part of the place, or removes a heritage object from the NT, unless the conduct is carried out in accordance with a relevant heritage agreement, work approval, repair order, or exemption.

3.4 UNESCO 2001 *Convention on the Protection of Underwater Cultural Heritage*

The United Nations Educational, Scientific and Cultural Organization (UNESCO) 2001 *Convention on the Protection of the Underwater Cultural Heritage* is an international treaty that was developed to provide a common framework for States Parties on how to better identify, research, and protect underwater heritage whilst ensuring its preservation and sustainability. The UNESCO 2001 *Convention* consists of a main text that sets out basic principles for the protection of underwater cultural heritage and provides a detailed State cooperation system, and an Annex that outlines widely recognised practical rules for the treatment and research of underwater cultural heritage. The UNESCO 2001 *Convention* entered into force in 2009.

The Commonwealth of Australia supported the principles and drafting of the UNESCO 2001 *Convention* and is currently considering ratification of the Convention in accordance with requirements under Australia's *Treaty Making Guidelines.* The *Underwater Cultural Heritage Act 2018* was also developed specifically to align with the UNESCO 2001 Convention.

In 2010, the Commonwealth, States, and the NT signed the *Australian Underwater Cultural Heritage Intergovernmental Agreement* that would enable the Australian Government to ratify the UNESCO Convention 2001, should it so choose. The Agreement establishes the roles and responsibilities of Commonwealth, State and NT governments for the identification, protection, management, conservation, and interpretation of Australia's underwater cultural heritage. One of the key aims of the Agreement is for all parties to meet internationally recognised best practice management of Australia's underwater cultural heritage as outlined in the Rules in the Annex to the UNESCO 2001 *Convention*.

The main principles of the UNESCO 2001 Convention are as follows:

- Obligation to Preserve Underwater Cultural Heritage – States Parties should preserve underwater cultural heritage and take action accordingly. This does not mean that States would necessarily have to undertake archaeological excavations; they only have to take measures according to their capabilities. The Convention encourages scientific research and public access.
- *In Situ* Preservation as first option – The *in situ* preservation of underwater cultural heritage (i.e., in its original location on the seafloor) should be considered as the first option before allowing or engaging in any further activities. The recovery of objects may, however, be authorized for the purpose of making a significant contribution to the protection or knowledge of underwater cultural heritage.
- No Commercial Exploitation – The 2001 Convention stipulates that underwater cultural heritage should not be commercially exploited for trade or speculation, and that it should not be irretrievably dispersed. This regulation is in conformity with the moral principles that already apply to cultural heritage on land. It is not to be understood as preventing archaeological research or tourist access.
- Training and Information Sharing – States Parties shall cooperate and exchange information, promote training in underwater archaeology and promote public awareness regarding the value and importance of underwater cultural heritage.

The general principles concerning activities directed at underwater cultural heritage as contained in the Annex of the UNESCO 2001 *Convention* are

Rule 1. The protection of underwater cultural heritage through in situ preservation shall be considered as the first option. Accordingly, activities directed at underwater cultural heritage shall be authorized in a manner consistent with the protection of that heritage, and subject to that requirement may be authorized for the purpose of making a significant contribution to protection or knowledge or enhancement of underwater cultural heritage.

Rule 2. The commercial exploitation of underwater cultural heritage for trade or speculation or its irretrievable dispersal is fundamentally incompatible with the protection and proper management of underwater cultural heritage. Underwater cultural heritage shall not be traded, sold, bought or bartered as commercial goods.

Rule 3. Activities directed at underwater cultural heritage shall not adversely affect the underwater cultural heritage more than is necessary for the objectives of the project.

Rule 4. Activities directed at underwater cultural heritage must use non-destructive techniques and survey methods in preference to recovery of objects. If excavation or recovery is necessary for the purpose of scientific studies or for the ultimate protection of the underwater cultural heritage, the methods and techniques used must be as non-destructive as possible and contribute to the preservation of the remains.

Rule 5. Activities directed at underwater cultural heritage shall avoid the unnecessary disturbance of human remains or venerated sites.

Rule 6. Activities directed at underwater cultural heritage shall be strictly regulated to ensure proper recording of cultural, historical and archaeological information.

Rule 7. Public access to in situ underwater cultural heritage shall be promoted, except where such access is incompatible with protection and management.

Rule 8. International cooperation in the conduct of activities directed at underwater cultural heritage shall be encouraged in order to further the effective exchange or use of archaeologists and other relevant professionals.

4 KNOWN AND POTENTIAL MARITIME ARCHAEOLOGY

4.1 Environment and Morphology

The proposed GEP route is planned to cross through Beagle Gulf, between the Tiwi Islands and the Northern Territory mainland, before turning south into Darwin Harbour to terminate at the Darwin LNG plant. Based on this route, the environment can generally be separated into two sections, Beagle Gulf and Darwin Harbour.[10]

4.1.1 *Beagle Gulf*

Beagle Gulf is characteristic of an offshore marine environment. The seabed in the vicinity of the proposed GEP route is composed of clay/silts and is featureless, though sand waves in places can reach 4.9m in height.[11] Geophysical surveys conducted confirm this characterisation of the area as a flat, featureless seabed at depths ranging 53 – 20m.

Beagle Gulf is exposed to greater swells and localised wind-generated waves than in Darwin Harbour. Relatively protected to the east and to some extent from the north by the Tiwi Island, the greatest fetch is from the western quadrants. Highest ambient wave activity takes place in the summer months when westerly winds are constant.[12] Wave heights during this season vary between 1 to 2m. Cyclones can increase wave heights by 50% to 100% with accompanying increases in current velocities.

Water temperature in the area is a constant 23.5°C with salinity close to the global average of 35 ppt.[13]

4.1.2 *Darwin Harbour*

Darwin Harbour is subject to large diurnal tidal variations (macrotidal). The difference between low and high tide during springs can be up to 7.5m.[14] This can result in current velocities between 2 to 2.5m/s (4 to 5kts). The tidal flows are the strongest in the narrowest sections of the harbour; the area most relevant to this study being the stretch of water between Tale Head and Emery Point (Larrakeyah).

The waters of Darwin Harbour are relatively well protected. The greatest fetch is to the northwest, from Beagle Gulf, thereby making the coastline around the western side of Wickham Point the most exposed within the study area. Having noted this, the ambient wave height in the harbour in the summer months can reach around 1m.[15] Waves generated by localised cyclonic activity can be much higher. It has been modelled that some waves reached heights of 4.5m in the harbour during Cyclone Tracy but were substantially lower – 0.7m – within the inner parts of the harbour.[16] During such events, tidal heights can potentially increase up to 9.1m LAT, which is around 2m higher than the highest annual spring high tide.[17]

Water temperatures in the near shore development area of Darwin Harbour are typically high, ranging from 23.5°C to 32.7°C.[18] Salinity varies within the harbour during the year. The large influx of fresh water from adjacent streams during the wet season is responsible for this variation. During the months of February and March, salinity levels can be as low as 19 parts per thousand (ppt), while during the dry season levels rise to around 37 ppt.[19] The global

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[10] **Cosmos Archaeology, 2011,** Ichthys Gas Field Development Project: Nearshore Development Area, Assessment of Marine Heritage Survey Methods, report prepared for INPEX Browse Ltd.
[11] **Fugro Survey Pty Ltd, August 2008** Volume 1a, 2-40.
[12] *Op. Cit.* **Fugro, 2008**:2-36.
[13] *Op. Cit.* **Fugro, 2008**:2-42.
[14] **INPEX**, **2010**, Ichthys Gas Field Development Project: Draft environmental impact statement, 33.
[15] *Op. Cit.* **INPEX, 2010:**56.
[16] *Op. Cit.* **INPEX, 2010:**56.
[17] *Op. Cit.* **INPEX, 2010:**56.
[18] *Op. Cit.* **INPEX, 2010:**62.
[19] *Op. Cit.* **INPEX, 2010:**62.

average for salinity is 35 ppt. During the wet season, water stratification can occur where freshwater intrusions from the adjoining streams can form a layer over the denser saline waters of the harbour.

The large tidal variations within the harbour result in the waters remaining well oxygenated, ranging from 74 to 96%.[20] There are some differences in dissolved oxygen levels from the mouth of the harbour where they are the highest, to waters closer to the streams at low tide where they are the lowest. Higher dissolved oxygen levels are also found closer to the water surface than at the base of the water column.

Darwin Harbour is well known for its poor visibility for diving due to suspended sediments in the water. Turbidity is at its highest during wet season spring tides due to the capacity of the spring water flows to mobilise sediments that have been flushed into the harbour from the land.[21] During these times, light levels at the bottom of the harbour can be 1% of that at surface levels.

The strong tidal flows coupled with the large volumes of water flowing out from the streams entering the harbour, have had a scouring effect on the seabed, creating and/or enlarging relatively deep channels, which are drowned Pleistocene river courses.

The main channel through Darwin Harbour mostly ranges between 15-25m deep, with a maximum depth of 36m. At Wickham Point the channel forks, with the western and shallower channel/tributary trending southwards into the Middle Arm. A smaller channel separates Channel Island from Wickham Point.[22] The eastern and deeper channel shapes a course to the southeast between East Arm to the north and Wickham and Blaydin Points to the south.

The sides of the main drainage channels are mostly rocky and the sediments within the study area are coarse sands with some gravels, silt and clay.[23] In the portion of the study area between Larrakeyah and Mica Beach, the seabed is more gravelly and provides a thin covering over sandstone and phyllite formations of which large weathered sand veneered expanses are also exposed in the form of relatively flat/level pavements. [24] At the entrance to Darwin Harbour there are numerous cemented ridges.[25] The thickness of the sediments over the sandstone and phyllite substrate varies. In the same area, where there are extensive areas of exposed sand veneered bedrock, there are pockets of sediments up to 6m thick.[26]

A sandbank is also located in the study area between Channel Island and the Darwin LNG plant on Wickham Point.[27] The bank is over 1.5km long, 12m high and has a minimum of 0.6 m of water over it.

Sand waves are also present throughout the northern part of the entrance to Darwin Harbour.[28] Silty to sandy seabed is present in the study area close to the landfall of the proposed pipeline with coarser sediments covering shallower waters towards the south.[29]

Silty seabed surfaces are found in the shallower waters adjacent to the mangrove flats around Wickham Point; their occurrence signifying sheltered waters not greatly affected by strong tidal currents.[30] More carbonate (shell) based sediments mixed with sand and gravels

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[20] *Op. Cit.* **INPEX, 2010:**62.
[21] *Op. Cit.* **INPEX, 2010:**63.
[22] *Op. Cit.* **INPEX, 2010:**Figure 3-11
[23] *Op. Cit.* **INPEX**, **2010**:64, 69 and Figure 3-16.
[24] *Op. Cit.* **INPEX, 2010:**71.
[25] **Fugro Survey Pty Ltd March 2010** Report on the Offshore Pipeline Route Unexploded Ordnance (UXO) Survey. Volume 1 – Survey Results, 5
[26] *Op. Cit.* Fugro Survey Pty Ltd, August 2008 Volume 1a, 2-25
[27] *Op. Cit.* **Fugro, 2008**:2-32.
[28] *Op. Cit.* **Fugro, 2008**:2-54.
[29] *Op. Cit.* **Fugro, 2008**:2-36.
[30] *Op. Cit.* **Fugro, 2008**:2-19.

are situated in the spits and shoals close to the entrance to the harbour.[31] Mudflats are also present, adjacent to the western shore of Wickham Point. [32]

4.2 Cultural Activities in Darwin Harbour and Beagle Gulf

4.2.1 *Larrakia*

The Darwin region was traditionally occupied by the Larrakia people, whose country stretches along the NT coast from Finniss River and Fog Bay in the west to Gunn Point and Adelaide River in the east and extends inland along the Charlotte River. The waters of Darwin Harbour, Bynoe Harbour, Shoal Bay, Adam Bay, and parts of Beagle Gulf also form part of Larrakia country. Larrakia people refer to themselves as “Saltwater People,” and traditional society and subsistence was largely centred around their coast and sea country.

Regional archaeological evidence suggests that Larrakia people have occupied the NT coastal region for at least 7-8,000 years, throughout the early to recent late Holocene, and likely further back through periods of lower sea level during the terminal Pleistocene when Darwin Harbour would have been a down-cut river valley.[33]

Various ethno-historical accounts dating back to the 19th century describe extensive Larrakia knowledge of the marine environment and a long tradition of the use of bark canoes and dugout canoes for estuarine and coastal subsistence fishing and hunting of dugong and turtles. Canoes were also used to travel throughout the waters of Larrakia sea country, and occasionally to travel and trade with neighbouring groups along the NT coast and across the Beagle Gulf to the Tiwi Islands.[34]

4.2.2 *Macassan traders*

In the early to mid-1700s, Indonesian traders began visiting parts of the northern coast of Australia to fish for trepang – sea cucumber or *bêche-de-me*r – prized for its culinary and medicinal values in Chinese markets. The term “Macassan” – originally denoting people from Macassar, the major fishing port in south-west Sulawesi, is generally used to apply to all the trepangers who came to Australia, even though some were from other islands in the Indonesian Archipelago, including Timor, Rote and Aru.

Throughout the latter 1700s to early 1900s, fleets of Macassan *perahus* or *praus*, timber multi-hulled sailing vessels, travelled to the north Australian coast with the north-westerly winds during the tropical wet season, and departed with the south-easterly winds of the dry season. A single fleet could be composed of thirty or more vessels, and in some periods up to 200 *perahus,* amounting to over 2,000 men, were estimated to be fishing the coastline from Cobourg Peninsula to south-eastern Arnhem land.

The sea route from the Indonesian archipelago took the Macassans through the Timor Sea and along the north coast of the Tiwi Islands and on to the Cobourg Peninsula. There is no clear evidence in historical accounts that Macassan trepangers travelled into Beagle Gulf or Darwin Harbour; however, artefacts believed to be of Macassan origin have been found on beaches in the wider Darwin region, including a cast iron swivel gun collected from an

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[31] *Op. Cit.* **Fugro, 2008**:2-55.
[32] *Op. Cit.* **INPEX**, **2010:**Figure 3-16.
[33] **Burns, T. 1999.** “Subsistence and settlement patterns in the Darwin coastal region during the late Holocene period: a preliminary report of archaeological research.” *Australian Aboriginal Studies.* Issue 1; pp. 59-70.; **Brockwell, S., P. Faulkner, P. Bourke, A. Clarke, C. Crassweller, D. Guse, B. Meehan & R. Sim. 2009.** “Radiocarbon dates from the Top End: A cultural chronology for the Northern Territory coastal plains.” *Australian Aboriginal Studies*. Volume 1, pp. 54–76.; **Sim, R. & L. A. Wallis. 2008.** “Northern Australian offshore island use during the Holocene: The archaeology of Vanderlin Island, Sir Edward Pellew Group, Gulf of Carpentaria.” *Australian Archaeology*. Volume 67, pp. 95–106.
[34] **Foelsche, P. 1882.** “Notes of the Aborigines of North Australia.” *Transactions of the Royal Society of South Australia.* Vol 2; pp, 1-18.; **Hodgson, R. 1997.** *Aboriginal use of natural resources in the Darwin region – past and present.* Report to the Australian Heritage Commission. **Parkhouse, T. A. 1895.** “Native tribes of Port Darwin and its neighbourhood.” *Australasian Association for the Advancement of Science.* Vol. 6; pp. 638-647.;

unknown location on the shoreline of Darwin Harbour in 1908, and a bronze swivel gun found at Dundee Beach, south-west of Darwin in 2010.[35]

4.2.3 *European exploration*

The first documented European exploration of Darwin Harbour and Beagle Gulf occurred in 1839 by a British Admiralty survey expedition led by Royal Navy Commander John Clements Wickham and Lieutenant John Lort Stokes aboard the HMS *Beagle.*

The harbour and surrounding coastline were surveyed in detail (see Figure 3) and numerous features named – Wickham named the harbour Port Darwin after famed naturalist Charles Darwin, with whom he had sailed on earlier expeditions of HMS *Beagle,* Beagle Gulf was named after the vessel itself. Wickham and Stokes both wrote of the advantages of the protected nature of the "splendid stretch of water" of Port Darwin; however, the area saw little further visitation for several decades.[36]

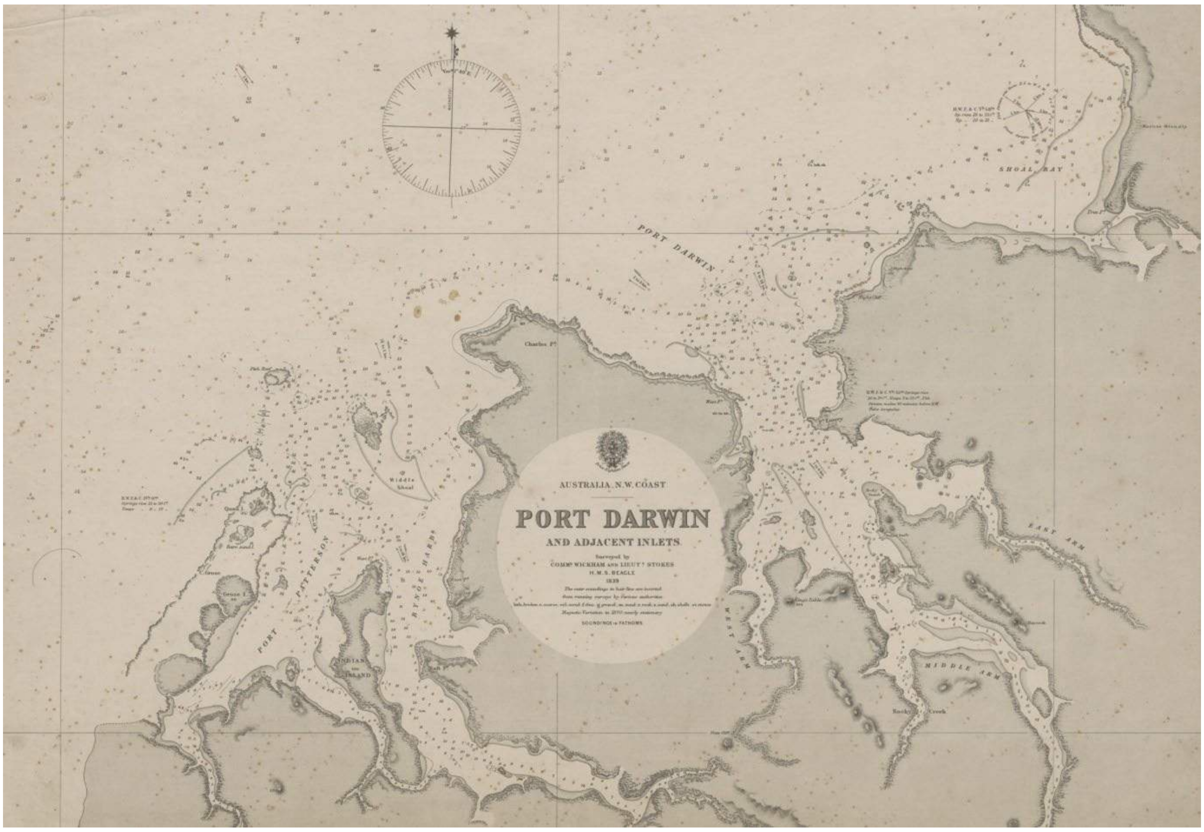

Figure 3: Chart of Beagle Gulf, Port Darwin, and surround from HMS Beagle 1839 survey.[37]

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[35] **Clark, M. & S. K. May (eds). 2013** *Macassan History and Heritage – Journeys, Encounters and Influences.* Australian National University Press, ACT.; **Coroneos, C. 1996.** "The shipwreck universe of the Northern Territory." *Bulletin of the Australian Institute for Maritime Archaeology.* Vol. 20; pp. 11-22.; **Jung, S. 1992.** *Annotated Bibliography of Macassan Perahu Wrecks & Sightings.* Maritime Archaeology & History, Northern Territory Museum of Arts and Sciences, Darwin, NT. **Jateff, E. 2011.** "An Oddity in South Australia. An Indonesian imitation swivel gun?" *AIMA Newsletter.* Volume 30, Issue 1.; **MacKnight, C. C. 1976.** *The Voyage to Marege; Macassan Trepangers in Northern Australia.* Melbourne University Press, VIC.

[36] **Bolton, G. C. 1967.** "Stokes, John Lort (1812-1885)." *Australian Dictionary of Biography.* Vol. 2. Australian National University Press, ACT.; **Ingleton, G. C. 1944.** *Charting a Continent – A Brief Memoir on the History of Marine Exploration and Hydrographical Surveying in Australian Waters from the Discoveries of Captain James Cook to the War Activities of the Royal Australian Navy Surveying Service.* Sydney.; **Morrison, A. A. 1967.** "Wickham, John Clements (1798-1864)." *Australian Dictionary of Biography.* Vol. 2. Australian National University Press, ACT.

[37] **Great Britain. Hydrographic Department / Richards, G. H., J. L. Stokes, E. Weller & J. C. Wickham. 1839.** *Australia - N.W. coast, Port Darwin and adjacent inlets.* Published at the Admiralty 1st March 1870 under the Superintendence of Capt'n G.H. Richards, R. N., F. R. S., Hydrographer, London, UK.

4.2.4 *Initial colonial settlement at Port Darwin*

In the late 1850s, the beginnings of a network of telegraph lines linking capital cities across Australia was being established, and speculation soon arose regarding a possible international connection between Australia and the new telegraph line from Europe to the East Indies. Competition between the Australian colonies over the route was fierce, with both the Victorian and South Australian governments organising expeditions to cross the continent from south to north and identify potential overland telegraph routes. In 1863, following John McDouall Stuart's successful expedition from Adelaide to Chambers Bay (east of Darwin), the SA Government annexed the Northern Territory – an area that had previously been a nameless part of New South Wales, with the aim of securing the land as a potential telegraph bridge to Asia and thence Europe. In 1865, the Australian Parliament authorised the construction of a telegraph line between Adelaide and Port Augusta (322km north of Adelaide), strengthening SA's position in the race for the cross-country telegraph connection.

In the meantime, SA Government surveyors were sent to the north coast of the NT to select a potential landing site for the telegraph and establish a supporting settlement. The first site, selected in 1864 by Surveyor Boyle Travers Finniss at Escape Cliffs near the mouth of the Adelaide River, was abandoned in 1867. After examination of several other suggested areas, a settlement was finally laid out by Surveyor-General George Goyder at Fort Point headland in Port Darwin in 1869. The township was named "Palmerston" after the then British Prime Minister Lord Palmerston.

The final telegraph contract was secured in 1870 when the SA Government proposed to extend the line from Port Augusta to Palmerston and the British-Australian Telegraph Company agreed to lay the undersea cable from Java to Port Darwin.[38]

The undersea cable was constructed in 1871 by a team of marine engineers and electricians from the British Telegraph Construction and Maintenance Company (Telcon) and the British-Australian Telegraph Company (BAT). The cable was first landed at Palmerston, at Fort Point – considered the most suitable site for the telegraph buildings – before being laid out across the seabed to Banjowangie, Java. The landward-end of the cable was carried from cable-ship SS *Hibernia* to the shore in bights held up by boats, hauled up the beach to the cable-house and buried in a shallow trench (see Figure 5 and Figure 6). Hibernia then commenced paying the cable out along the seabed; travelling north-east to east around Point Emery, then northwards past Fannie Bay and gradually veering north-east towards the entrance to the harbour (see Figure 4). The cable consisted of seven small copper wires – including a central wire with six twisted around it – insulated by gutta-percha latex and tarred hemp, covered with a sheathing of galvanised iron wire and another outside covering of tarred hemp. The cable was ¾" (19 mm) in diameter in the deep-sea sections, 1" (25 mm) in diameter in the intermediate sections and 3" (76 mm) in diameter at the shore end.[39]

In 1879, a duplicate telegraph cable was laid between Darwin and Java, which allowed for increased telegraph capacity and the establishment of a day and night service between Australia and Britain. The second cable was again laid by Telcon, this time under contract to the Eastern Extension Australasia and China Telegraph (EEACT) Company, which had absorbed BAT in 1873. The duplicate cable was of the same composition as the original

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[38] **Clune, F. 1955.** Overland telegraph: the story of a great Australian achievement and the link between Adelaide and Port Darwin. Angus and Robertson, Sydney, NSW.; **Cross, J. 2011.** Great Central State – The Foundation of the Northern Territory. Wakefield Press, South Australia. **Reece, R. 1989.** "Palmerston (Darwin); Four Expeditions in Search of a Capital." Statham, P. (ed.) The Origins of Australia's Capital Cities. Cambridge University Press, Cambridge, UK.;

[39] **Anon 23 January 1872** "The Australian Submarine Cable." *The Argus.*; **Nicols, J. 1870-1874** *Notebook.* Transcribed by Vickers, M. 2005. http://atlantic-cable.com/CableStories/Nicol/index.htm; **NT Heritage Branch. 2019.** *The Darwin Subsea Telegraph Cables – Heritage Assessment Report.*; **Wildey, W. B. 1876.** *Australasia and the Oceanic Region, With Some Notice of New Guinea, From Adelaide – Via Torres Straits – to Port Darwin, Thence Round West Australia.* George Robertson, Melbourne, Victoria.

1871 cable, and was laid out in the same manner; this time with the majority of the work being carried out by cable ship SS *Siene.*[40] The duplicate cable was laid to the west of the 1871 cable within Darwin Harbour, before crossing over the 1871 cable towards the harbour entrance and then running along the northern side of the 1871 cable through Beagle Gulf (see Figure 4).

In 1884, EEACT decided to renew the eastern end of the original 1871 Darwin to Java telegraph cable. EEACT had found that this section of cable, particularly where it passed through shallow waters, was being frequently damaged by marine borers – namely teredo worm (*Teredo navalis*). A new cable was thus designed with a patent brass ribboned core to prevent teredo attack and was laid out by cable ship SS *Siene* in early 1884. The replacement cable was laid between the 1871 cable and the 1879 duplicate cable through Darwin Harbour, crossing over near the harbour entrance and then running along the southern side of the 1871 cable (see Figure 4). Some broken sections of the original 1871 cable were recovered by *Siene* during the process, however, most of the original cable appears to have been left on the seabed.[41]

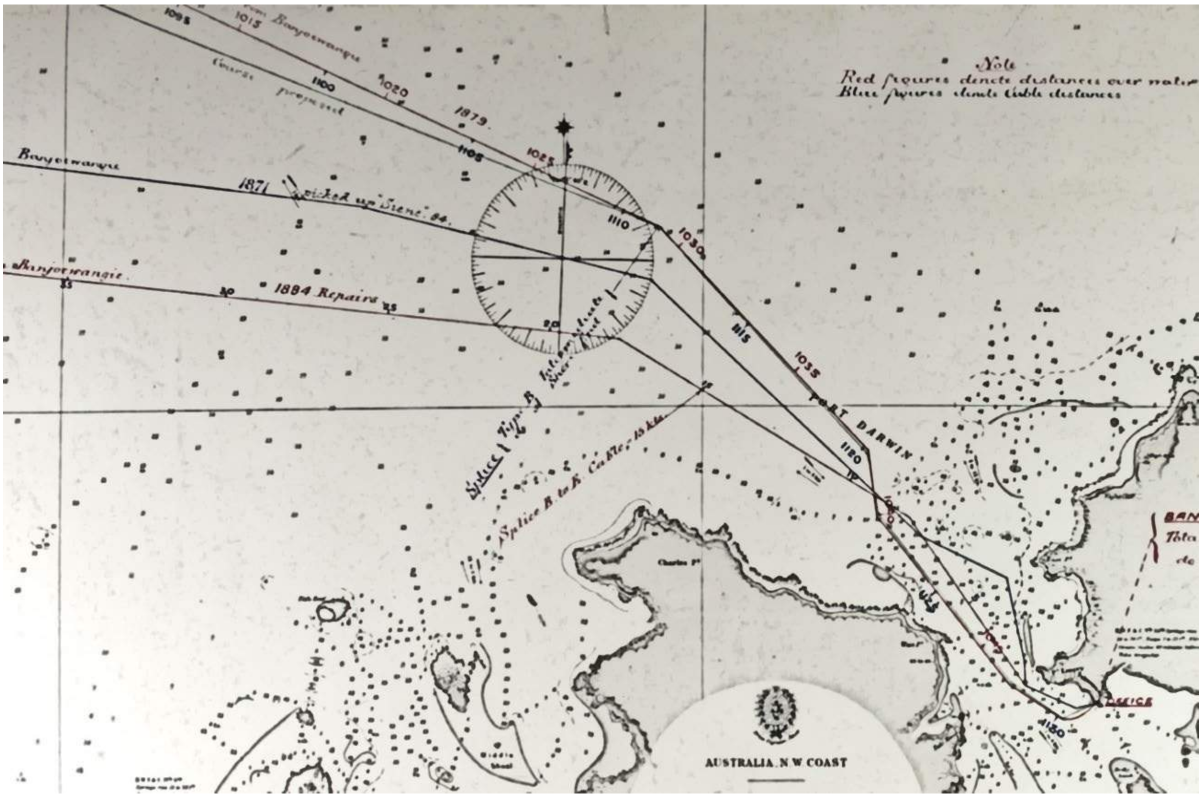

Figure 4: 1870 map of Port Darwin with annotations showing proposed and actual routes of 1871, 1879, and 1884 subsea telegraph cables.[42]

[40] Anon. 13 September 1879. "The New Cable." *The Week*. p. 11.; NT Heritage Branch. 2019.
[41] **Anon. 5 January 1884.** "The Port Darwin Cable." *The Telegraph.* p. 5.; **NT Heritage Branch. 2019.**
[42] **Stokes, J. L., E. Weller, & J. C. Wickham. 1870.** *Port Darwin and Adjacent Inlets.* Great Britain Hydrographic Department – annotated with proposed and actual routes of the Darwin-Java subsea telegraph cables 1871, 1879, and 1884. PK Porthcurno Museum of Global Communications, Cornwall, UK. Item CH3.4 Map 13. Reproduced in **NT Heritage Branch 2019**.

Figure 5: Telegraph cable fleet in Port Darwin, 1871.[43]

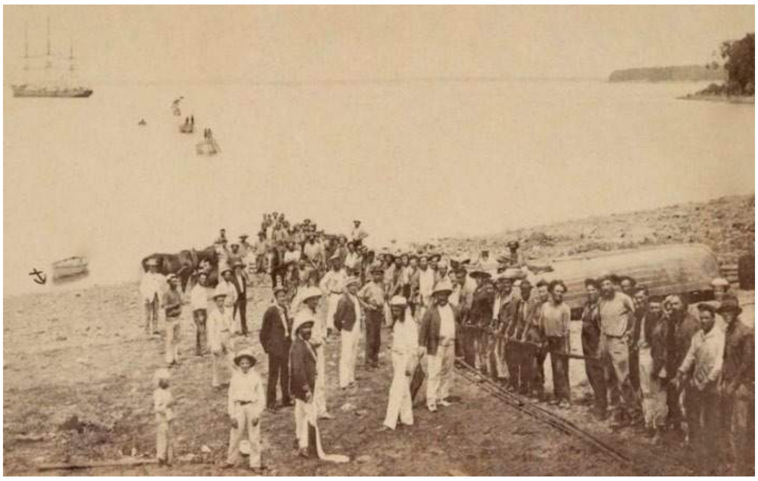

Figure 6: Landing the telegraph cable, Darwin, 1871.[44]

4.2.5 *Late 19th - early 20th century development*

Throughout the 1870s, Palmerston developed from a telegraph constructor's camp to a small township and the landing at Fort Point served as the focus of trade and transport to supply the new settlement. Early growth was spurred by the discovery of gold near Pine Creek (225 km south of Darwin) in 1871 during the construction of the overland telegraph, sparking a gold rush in surrounding areas that attracted thousands of prospectors and pioneers to the NT. Development was further facilitated throughout the 1880s by the establishment of a railway line between Palmerston and the Pine Creek goldfields, and the construction of a railway jetty at Stokes Hill. The population continued to expand and regional industries, including tin mining, cattle rearing, coastal fishing, and pearling, began to emerge – the latter attracting fleets from Japan, Timor, Malaysia, and the Philippines.[45]

Port Darwin was described during this period as one of the safest and best in the world; with a wide entrance and large port doubly sheltered by the outer headlands of East Point and West Point and the inner headlands of Point Emery and Talc Head. Shipping was centred around the port facilities at Fort Hill and Stokes Hill – see Figure 7. The maritime economy during this period was dominated by coastal sailing vessels and steam ships, with a wide range of smaller craft used in the fishing and pearling industry, regional trade and transport, and recreational vessels (see Figure 8 and Figure 9).

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[43] **Sweet, S. W. 1871.** "Palmerston. Cable fleet in the harbour below Fort Hill: Gulnare, Bengal, Hibernia, Investigator, Edinburgh." State Library of South Australia, Image No. B 9745.
[44] **Anon. 1871.** "Port Darwin - landing the cable ashore - 7 November 1871." National Archives of Australia, Image No. 32018586.
[45] **Cross, J. 2011; Wade-Marshall, D. 1988.** *The Northern Territory: settlement history, administration and infrastructure.* Strategic and Defence Studies Centre, Australian National University, Canberra.

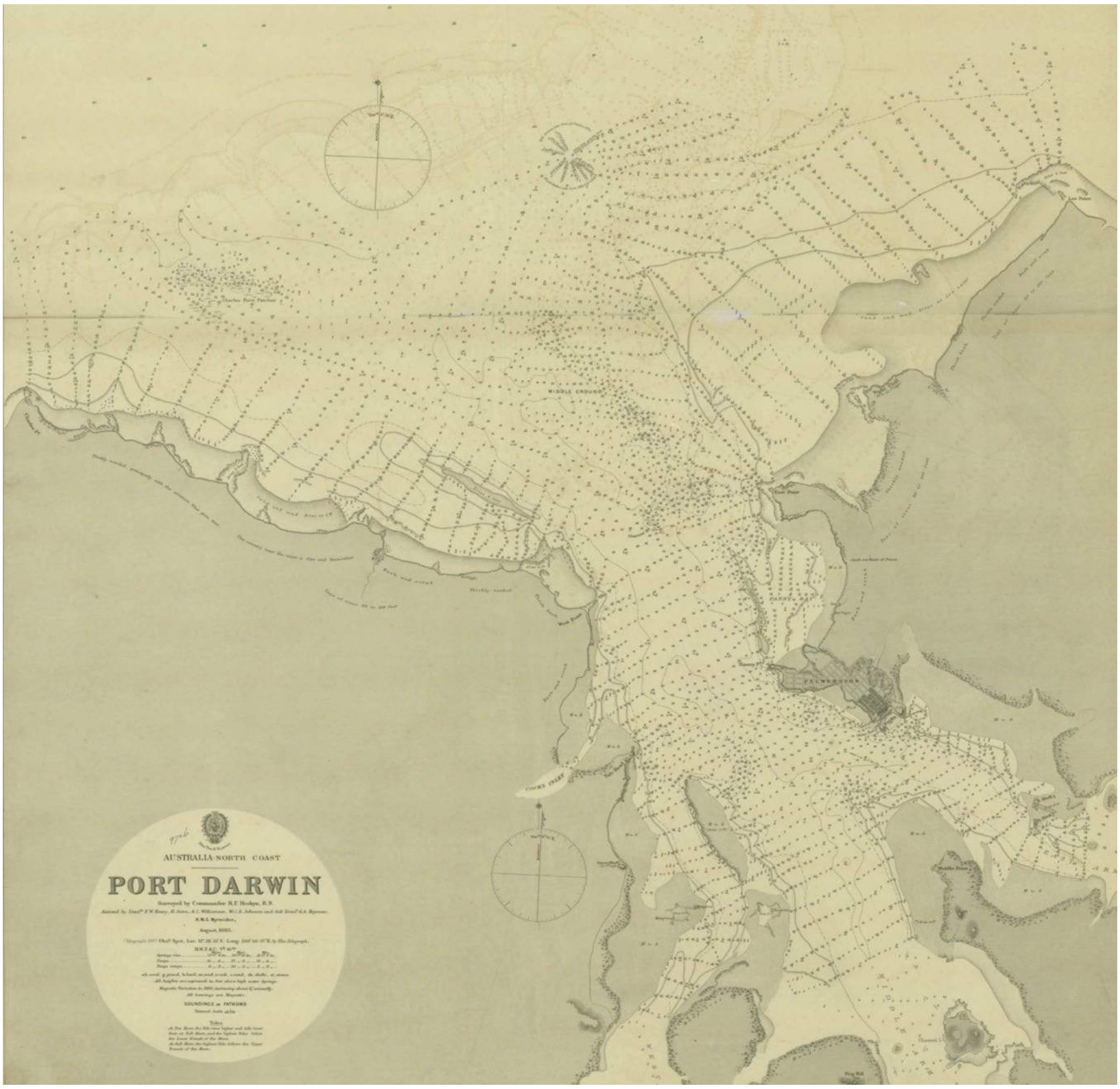

Figure 7: 1886 chart of Port Darwin, showing port facilities at Fort Hill and Stokes Hill.[46]

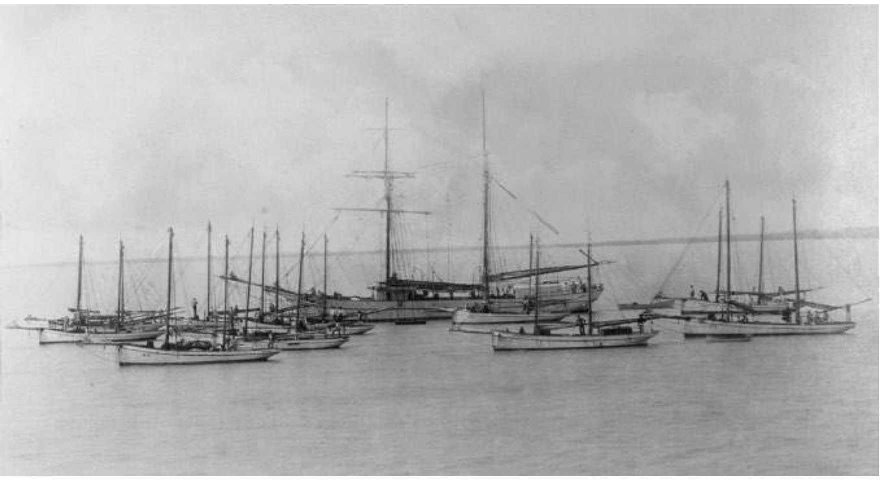

Figure 8: Pearling fleet of luggers and mothership at Port Darwin, 1895.[47]

[46] **Comm'r R. F. Hoskyn RN, Great Britain Hydrographic Department 1886** *Australia – North Coast Port Darwin.* State Library of Victoria, Map 50901638.
[47] **Anon 1895.** "Pearl shelling fleet at Palmerston." State Library of South Australia, Image No. B2418.

Figure 9: steam ships and sailing vessels moored alongside the Port Darwin railway jetty, 1892.[48]

A number of vessels were wrecked in Darwin Harbour in the late 19th century to early 20th century – most consisting of small to moderate timber sailing vessels and composite steam and sail vessels lost in sudden squalls and strong monsoons during the tropical wet season. A single event of devastating loss occurred in January 1897, when Port Darwin was hit with one of the worst cyclones ever recorded at the time. Palmerston township was torn apart with almost every building destroyed or severely damaged, and at least thirteen people killed. The cyclone also wreaked havoc in the harbour, coinciding with high tide and causing massive storm surges. Vessels of all types were wrecked or blown ashore and a further fifteen people were killed. Eighteen pearling luggers, three steam launches, a cutter, and three sampans are amongst the vessels recorded as lost. Many of these vessels were swept off their moorings in Port Darwin and found driven into mangroves at the mouths of East Arm and Middle Arm; several were never recovered.[49]

In 1911, a decade after Australian Federation, the NT was separated from SA and transferred to Commonwealth control as a result of the *Northern Territory Surrender Act 1908* in South Australia and the Federal *Northern Territory Acceptance Act 1910.* The township of Palmerston was subsequently officially renamed "Darwin." Around this time, the importance of Port Darwin as a potentially valuable naval strategic position began to be realised; although there were no immediate plans to establish military facilities due to the still relatively small size and isolation of the Darwin settlement. A 1911 Royal Navy recommendations report stated that once the north to south transcontinental railway line was completed, Port Darwin should be developed into a Naval Fleet secondary base, complete with reserves of coal, oil and naval stores and provisions, and docks capable of receiving the largest ships and machine shops adequate for carrying out repairs to warships. Such plans were put into abeyance following the advent of World War I, during which Darwin was only periodically used as an anchorage and coaling station.[50]

Middle Arm and Middle Point, far removed from the centre of the Palmerston settlement and Port Darwin facilities, saw little use during the late 19th and early 20th centuries. In 1884, Channel Island in Middle Arm was declared by the Government as a site for a quarantine

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[48] **Edwardes, A. D. 1892.** "Shipping in Port Darwin in 1892 with the ships 'Falkland Hill', 'S.S. Tsinan', 'Menmuir' and 'Catterthun.'" State Library of South Australia, Image No PRG 1373/34/49.

[49] **Anon 16 January 1897.** "The Port Darwin Cyclone. Details of the Damage." *The South Australian Register.*; **Anon 5 February 1897.** "Terrible Hurricane at Port Darwin." *The Northern Territory Times and Gazette.;* **Murphy, K. 1984.** *Big Blow Up North (A History of Tropical Cyclones in Australia's Northern Territory).* University Planning Authority, Darwin, NT.

[50] **Dermoudy, P. & P. Cook. 1991.** *East Point. A History of the Military Precinct, East Point, Darwin.* National Trust of Australia and Royal Australian Artillery Association of the Northern Territory, NT.; **Admiral Sir Henderson, R. 1911** "The Naval Forces of the Commonwealth – Recommendations." Reproduced in *The Time Documentary History of the War.* (1917) The Times Publishing Company, London.

station – see Figure 10. No permanent structures were established on the island until the early 1900s, however, and throughout the late 19th century most quarantine patients were held onboard quarantine hulks moored in an anchorage set up around Channel Island. One of these hulks, schooner rigged steamship *Ellengowan,* sank at its moorings in 1888, and the wreck – situated to the south of the current study area – is the oldest known shipwreck in Darwin Harbour.[51]

In 1889, a small spit of land extending from the tip of Middle Point was proclaimed as a leper station – see Figure 10. The station, known as Mud Island Lazaret – or colloquially as Living Hell Lazaret due to the exceedingly poor living conditions – was in operation from the 1880s through to the early 1930s. The lazaret consisted of a single galvanised iron building and treatment consisted of weekly visit from a health officer who travelled by vessel to Mud Island.[52] In 1931, the quarantine station at Channel Island was converted into a leprosarium and Mud Island Lazaret was permanently closed. Several new accommodation buildings, and medical clinic, and associated facilities were constructed at Channel Island, and a twice-weekly supply service via launch from Darwin was established. The Channel Island Leprosarium remained in operation until 1955, when a new leprosarium was established at East Arm.[53]

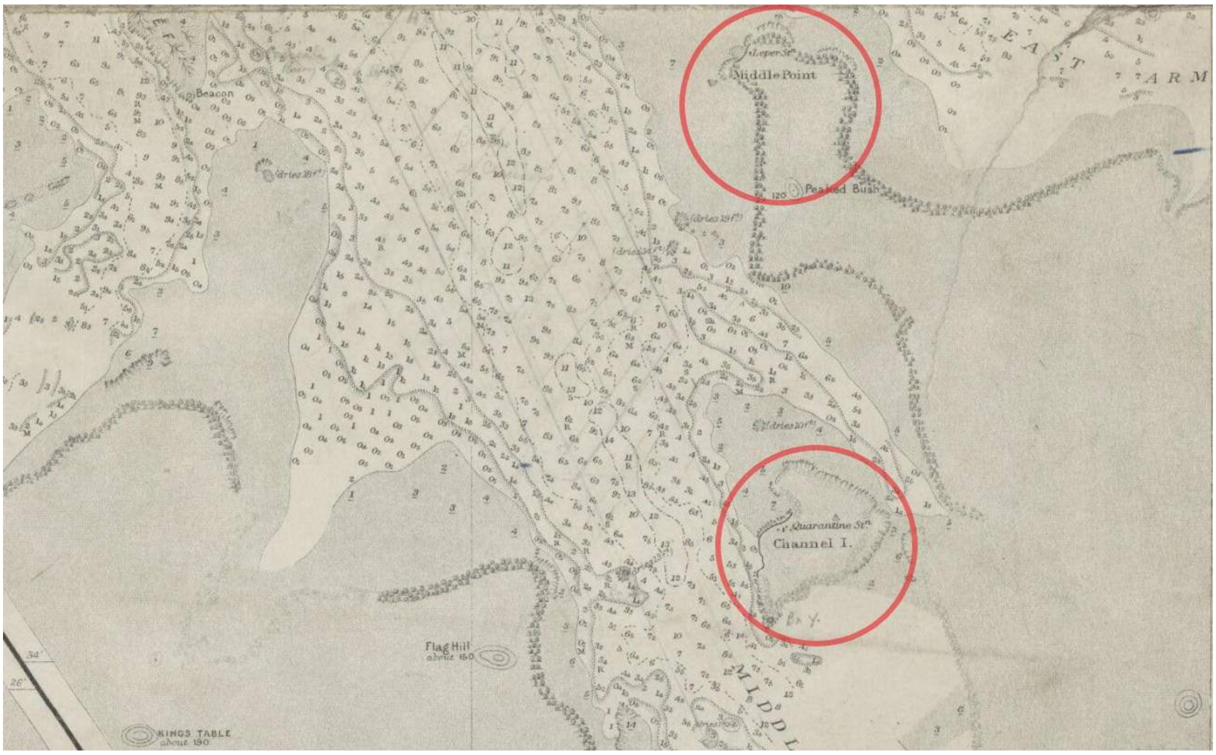

Figure 10: 1929 chart of Port Darwin, showing location of Mud Island lazaret and Channel Island quarantine station / later leprosarium near East Arm (shown by red circles).[54]

[51] **Anon. 11 February 1886.** "Quarantine at Port Darwin." *South Australian Register*. p. 3.; **Jung, S. 2008.** "Ellengowan 1866-1888: a 19th century transitional iron steamship sunk at Middle Arm." in Clark, P. (ed.) *Ten Shipwrecks of the Northern Territory*. Museum and Art Gallery of the Northern Territory, Darwin, NT.; **Kettle, E. 1991.** *Health Services in the Northern Territory – A History 1824-1970*. Australian National University, Darwin, NT.

[52] **George, G. & K. George. 2014.** "Mud Island Lazaret (1889-1931)" https://www.findandconnect.gov.au/ref/nt/biogs/YE00283b.htm; **Kettle, E. 1991.**

[53] **George, G. & K. George. 2011.** "Channel Island Leprosarium (1931-1955)" https://www.findandconnect.gov.au/ref/nt/biogs/YE00047b.htm#related; **Kettle, E. 1991.**

[54] **Great Britain Hydrographic Department. 1929.** *Australia - North coast, Port Darwin from a survey by Lieut-Comm'r. Harry T. Bennett, D. S. O., R. N. and the officers of H. M. Australian surveying ship "Geranium" 1925, with additions from a survey by Comm'r. R.F. Hoskyn, R. N., and the officers of H. M. S. "Myrmidon" 1885.* National Library of Australia, MAP RM 3394.

4.2.6 *World War II*

In the aftermath of World War I, and particularly following the demise of the Anglo-Japanese Alliance in 1921, the British Empire began to evolve a series of war plans crafted for various predicted contingencies. A British Imperial Conference in 1923 led to the development of the Royal Navy "Singapore Strategy," which made Singapore the pivot of British defence against potential aggression from the Empire of Japan. Under this strategy, Darwin was seen as the southern end of the Singapore-Australia defence line. Following subsequent recommendations made by the Royal Australian Navy, plans were put in place to develop Port Darwin as a naval refuelling depot and support base. Throughout the 1920s to early 1930s, naval fuel tanks were constructed at Stokes Hill and development of a coastal defence battery commenced at East Point. By the mid-1930s, a worsening international situation, particularly in Europe and Japan, led to further increases in Port Darwin's defences and the establishment of a Royal Australian Air Force (RAAF) base, an Australian Army barracks, and Royal Australian Navy (RAN) depot. Naval infrastructure within was further expanded, including the construction of additional naval fuel tanks at Stokes Hill, a battery at Emery Point, and establishment of additional shipping, mooring and maintenance facilities.[55]

In 1938, following harbour defence advice from the British Admiralty, plans were drawn up by the RAN to construct an anti-submarine boom net across the entrance to Port Darwin between East Point and Dudley Point (see Figure 11), along with anti-submarine indicator loop installations that would operate in conjunction with the coastal defence batteries. The Australian Naval Board initiated the construction of two boom working vessels required to lay the boom net, and the establishment of a boom depot yard at Fort Hill to manufacture and assemble components for the boom net and indicator loop systems. The boom net was designed by the British Admiralty and consisted of high tensile wire rope mesh floating nets supported by a series of trots consisting of cylindrical buoys that were anchored to the seabed via concrete mooring clumps. A gate was set into the middle of the net that could be opened to allow passage of friendly vessels. The indicator loops – designed to provide magnetic sensing of enemy vessels whereby an induced current was passed through each loop that triggered a signal when a ship or submarine passed overhead – were formed of steel and copper cable linked to an onshore indicator loop hut erected at Dudley Point.

In late 1940, transit markers for the anti-submarine boom net were erected at Dudley Point and West Point, and marker buoys, moorings for boom gate vessels and net trot moorings began to be laid out, and two indicator loops were laid to the seaward side of the net. The construction of the net was initially scheduled to be completed by the end of 1940. However, due to delays in the assembly of the net and difficulties in laying the moorings due to strong tides, the net was not fully installed until late 1942.[56]

In September 1940, Japan entered the World War II "Axis" military alliance with Germany and Italy, and in late 1941, launched direct attacks on British holdings in Malaya, Singapore and Hong Kong and the United States military base at Pearl Harbour, Hawaii. These actions led Britain, America, and Australia to formally declare war on Japan, initiating the Asia-Pacific War. Over the following few months, Darwin underwent a significant metamorphosis.

Organised evacuation programs of women and children from Darwin and surrounding areas quickly commenced under the orders of the Commonwealth War Cabinet and the township rapidly emptied of civilians. Australian and Allied forces were sent to defend Australia's northern coastline and by early 1942, almost 15,000 troops were stationed in Darwin. Port

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[55] **Dennis, P. 2010.** "Australia and the Singapore Strategy". in Farrell, .B P. & S. Hunter (eds.) *A Great Betrayal?: The Fall of Singapore Revisited*. Marshall Cavendish Edition, Singapore. pp. 20–31.; **Lockwood, D. 2005.** *Australia Under Attack; The Bombing of Darwin – 1942.* New Holland Publishers (Australia) Pty Ltd.; **Rayner, R. J. 2001.** *Darwin and the Northern Territory Force.* Rudder Press, NSW.

[56] **Forster, P. 2007.** *Fixed Naval Defences in Darwin Harbour 1939-1945; how the Navy secured Darwin Harbour against submarine attacks between 1939 and 1945.* Museum & Art Gallery of the N.T. Darwin.; **Walding, R. 2006.** *Indicator Loops, Royal Australian Navy Harbour Defences – Darwin.*

Darwin became an important staging point for Allied naval shipping and aircraft engaged in battles throughout Southeast Asia and Netherlands East-Indies.

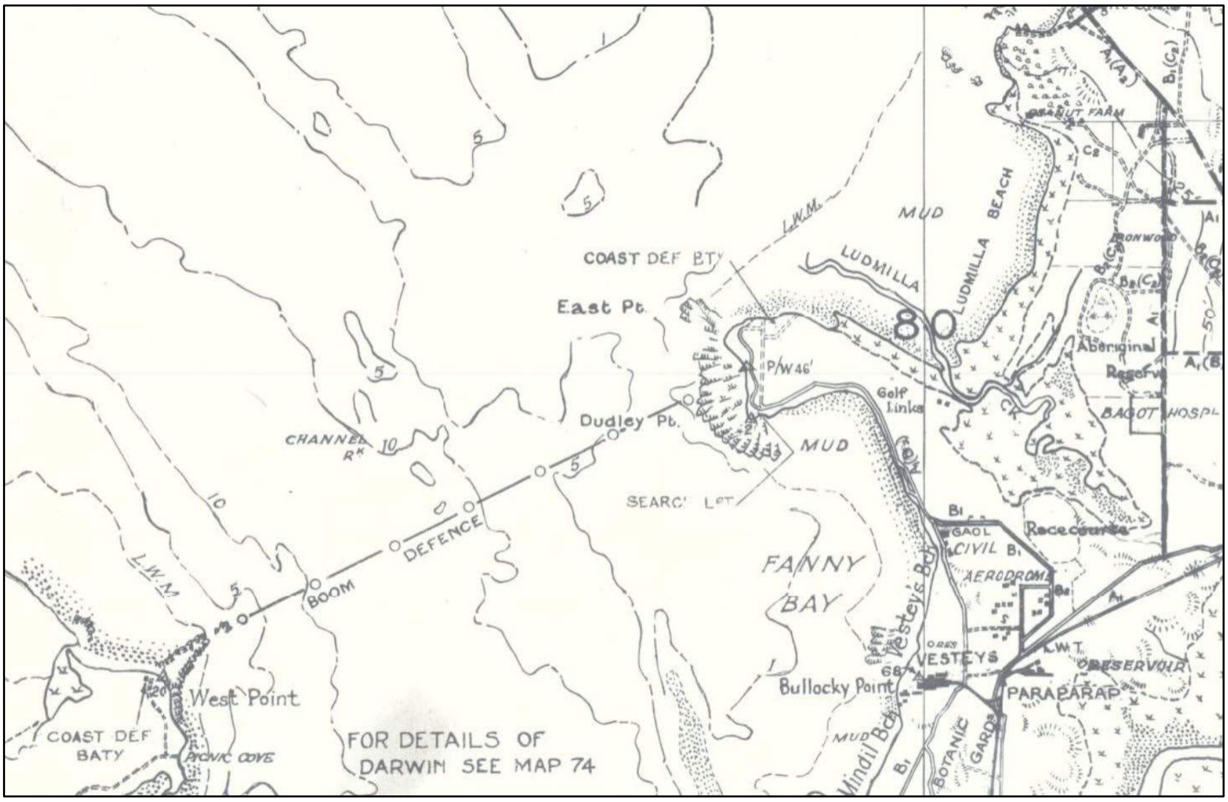

Figure 11: 1941-1945 plan of Darwin showing alignment of anti-submarine boom net.[57]

Figure 12: Boom vessel working on the Darwin anti-submarine boom net – showing detail of the net and buoys.[58]

Figure 13: Darwin anti-submarine boom net – showing gates opening to allow the passage of a ship.[59]

On 19 February 1942, Japan mounted a two-wave air raid on Darwin, marking the first attacks on the Australian mainland in World War II. The first raid consisted of a carrier-based

[57] **Australia. Army. Australian Survey Corps. 1941-1945** *Darwin and environs.* National Library of Australia, Map G9040 194-.

[58] **Turner, H.** 1943. "The Royal Australian Navy on boom defence duty at Darwin Harbour." Australian War Memorial, Image No. 014523.

[59] **McInnes, G.** 1943. "Darwin, NT. 1943-07-06. Boom gates open to allow the passage of a ship. Australian War Memorial, Image No. 053443.

aerial strike force of 188 bomber and fighter aircraft launched from a Japanese Imperial Navy fleet stationed approximately 350 km north-west of Darwin in the Timor Sea. The second raid comprised fifty-four land-based aircraft launched from the newly acquired Imperial Japanese Navy bases and Kendari and Laha, Ambon, Netherlands East-Indies. The raids attacked port facilities and shipping in Darwin Harbour, Darwin township, military installations, and aerodromes. The two raids killed at least 243 people and 300-400 were wounded. Eight Allied military vessels were sunk in the harbour – including United States Army Transport (USAT) *Mauna Loa*, USAT *Meigs*, and United States Navy destroyer USS *Peary*, situated within the current study area. Twenty-seven Allied military aircraft were also destroyed, and most civil and military facilities in Darwin suffered extensive damage. This raid was the first of many; during the course of World War II, Darwin and surrounds endured a total of sixty-four airborne Japanese attacks and several attempted submarine attacks. [60]

Following a Commission of Inquiry into the events of 19 February 1942 held by Commissioner Sir Charles John Lowe that concluded Darwin could not be defended without substantial reinforcements, the Commonwealth Government decided to place Darwin and the portion of the NT north of Alice Springs, under direct military administration. Extensive military re-organisation took place and substantial strengthening of military units and construction of new military bases occurred around Darwin Harbour.[61]

Extensions and improvements to the anti-submarine boom net and indicator loop system were conducted throughout 1942. By this time, it had been ascertained that the high variation and strength of the tides in Darwin was causing unforeseen problems in the maintenance of the boom net, and the current alignment left a strip of unprotected water at both ends of the net during high tide that would be deep enough to allow enemy vessels to pass around the boom and gain entrance to the harbour. A series of pylons were subsequently erected across the shallow and reefs at Dudley Point and West Point, connecting the boom directly to land (see Figure 15 and Figure 16). It had also been determined that the two indicator loops installed seaward of the boom net were giving frequent cable faults due to the rough seabed on which they were laid and the force of the changing tides. Following seabed surveys conducted by the Royal Australian Navy, a decision was made to replace these loops with a set of five positioned approximately 3 nm further north, between Midway on the western side of the entrance and Nightcliff on the East, and to move the Indicator Loop Control Station from East Point to Nightcliff. Works on these modifications to both the boom net and the indicator loops commenced in mid to late 1942, however, would not be completed for almost two years.[62]

An expansion of coastal defences around Darwin Harbour in 1943 saw the construction of several military facilities at Middle Point. In early 1943, an anti-aircraft search light station was established at the northern tip of Middle Point. In mid-1943, construction of a heavy anti-aircraft gun station and a satellite training camp for the Lugger Maintenance Section of the Allied Intelligence Bureau Services Reconnaissance Department commenced at Peak Hill on Middle Point. The Lugger Maintenance Section, established at East Arm in 1942, was an advance base for covert espionage, intelligence gathering, and raiding operations against Japanese forces throughout Indonesia, Timor, and the Philippines. By mid-1944, both the anti-aircraft gun station and Services Reconnaissance Department training camp were established and operational.[63]

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[60] **Alford, B. 2017.** *Darwin 1942. The Japanese Attack on Australia. Campaign 304.* Osprey Publishing Ltd., Oxford, UK.; **Lockwood, D. 2005.** *Australia Under Attack: The Bombing of Darwin – 1942.* New Holland Publishers, Sydney, NSW.
[61] Ibid.
[62] *Op. Cit.* **Forster, P. 2007**; Walding, R. 2006.
[63] *Op. Cit.* **Rayner, R. J. 2001**.

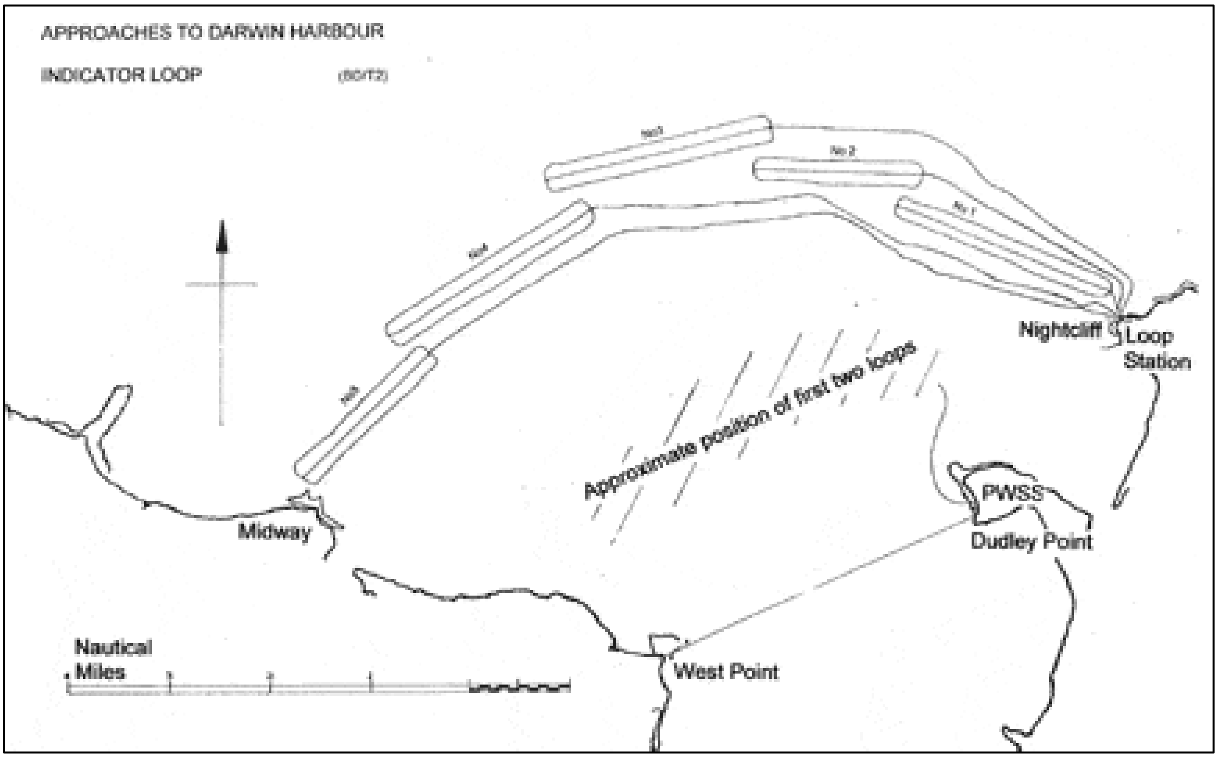

Figure 14: Sketch map showing position of anti-submarine boom net and indicator loops, Darwin Harbour.[64]

Figure 15: Anti-submarine boom net pylon, East Point.[65]

Figure 16: Anti-submarine boom net pylons, West Point.[66]

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[64] *Op. Cit.* **Forster, P. 2007.**
[65] **Anon 1946** "Darwin, NT. 1946-03-05. East Point, Darwin, on which are situated the main part of Darwin's coastal defences." Australian War Memorial, Image No. 126154.
[66] **Woodrow, B. 1944** "Pylons for defence boom net, West Point." Northern Territory Library, Image No. PH0168/0082.

Figure 17: Middle Point anti-aircraft gun emplacement.[67]

From mid-1944, the Australian military was largely relegated to subsidiary fronts and the NT force was reduced in strength. However, work on some of Darwin's defence installations, including the extensions to the anti-submarine boom net and laying of the second set of indicator loops, continued throughout late 1944. These installations were finally fully operational in December 1944 – just over eight months before Allied victory and the end of World War II in 1945.[68]

4.2.7 *Post war*

After the end of World War II, control of the NT was handed back to the Commonwealth and the military units stationed in Darwin began to be demobilised and disbanded. By the late 1940s to early 1950s, most military structures and facilities were either removed or converted to civilian use. The NT economy shifted back towards pastoral, fishing, and mining industries. By the early 1960s, the Darwin population had increased over five-fold and commercial expansion and development had led to a significant increase in exports and shipping in the harbour.

The most significant event in the history of post-war Darwin was the destruction of the town by Cyclone Tracy on Christmas morning, 1974. Cyclone Tracy was the most compact cyclone on record in the Australian basin, with winds officially recorded at 217km per hour prior to the Bureau of Meteorology anemometer being destroyed. Waves in Darwin Harbour reached up to 4.5m in height. Seventy-one people were killed during the cyclone, including sixteen lost at sea. More than 70% of Darwin buildings were destroyed, all public services, including communications, power and water, were severed and the overall damage caused has been estimated at $837 million (1974 value). At least twenty-six vessels in Darwin Harbour, including a RAN patrol boat, a pilot boat, a fuel tanker, several prawn trawlers, traders, work boats, and passenger vessels, were wrecked or lost without a trace. A further twenty-one vessels were damaged.[69] Three of the known Cyclone Tracy wrecks – the Northern Research prawner *NR Diemen*, and passenger ferries *Darwin Princess* and *Mandorah Queen* – are situated within the current study area.

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[67] **Anon. 1945.** "Middle Point, Darwin, NT. 1945-04-14. Officers from 134 Anti-Aircraft Battery, 54 Anti-Aircraft Regiment inspect the gun positions after a king tide of 27 feet had lapped its base." Australian War Memorial, Image No. 088694.

[68] *Op. Cit.* **Forster, P. 2007**; Walding, R. 2006.

[69] **Attorney-General's Department Disasters Database. 2021.** "Cyclone Tracy." Australian Emergency Management Institute. http://www.emknowledge.gov.au/disaster-information; **Murphy, K. 1984.** *Big Blow Up North (A History of Tropical Cyclones in Australia's Northern Territory).* University Planning Authority, Darwin, NT.

4.2.8 *Summary of cultural activities within the study area*

From the review of the known history of the study area the following activities can be identified:

- Larrakia and Tiwi people maritime travel and subsistence activities – although these activities would likely be concentrated closer to coastal environments;
- Macassan trepang fishing and trade throughout the 18th to early 20th centuries;
- British exploration and surveying in early 19th century;
- A wide range of colonial shipping including Government and commercial cargo and passenger transport, fishing and pearling industry trade and transport, and recreational shipping, from the establishment of colonial settlement in Darwin in 1860s to present;
- Laying of subsea telegraph cables (x 3) in 1870s and 1880s;
- Quarantine and leper station transport and service supply in Middle Arm throughout late 19th to early 20th century;
- Military shipping – transport and mooring – throughout World War II;
- Air and sea combat between Allied and Japanese forces during World War II;
- Installation of anti-submarine boom net and indicator loops during World War II;
- A wide range of post war commercial, industrial, and recreational shipping activities.

4.3 Known Maritime Archaeological Sites in the Study Area

4.3.1 *Shipwrecks*

There are seventeen known shipwrecks located within the study area – refer to Table 2 and Figure 18 to Figure 20.

Four of these shipwrecks are military vessels sunk during battle in World War II, including three Allied vessels lost during the first Japanese air raid on Darwin on 19 February 1942 – United States Army transport vessels USAT *Mauna Loa* and USAT *Meigs*, and United States Navy destroyer USS *Peary*, and an Imperial Japanese Navy submarine *I-124* sunk by Allied forces on 20 January 1942. All of these shipwrecks are protected under the *Underwater Cultural Heritage* (UCH) *Act 2018*, and USAT *Mauna Loa*, USAT *Meigs*, and USS *Peary* are also protected under the NT *Heritage Act 2011.*

Three shipwrecks within the study area were lost in Cyclone Tracy, 25 December 1975, including passenger ferries *Darwin Princess* and *Mandorah Queen*, and a Northern Research prawn trawler *NR Diemen.*

Five vessels were intentionally scuttled in the 1970s and 1980s, including Taiwanese fishing vessel *Yu Han 22*, Thai fishing vessel *Medkhanun 3*, Vietnamese refugee vessels *Ham Luong* and *Song Saigon*, and workboat *John Holland Barge.*

The remaining five shipwrecks include a World War II LVT Buffalo amphibious tracked landing craft sunk in the 1960s, and three unidentified wrecks including three timber hulled vessels, and a steel barge.

Table 2: Known shipwrecks within the study area. Shipwrecks with names highlighted in gold located within proposed anchoring corridor.[70]

Name	Type	Year lost	Wreck event	Location (WGS84)	Approx. distance from proposed GEP	Statutory heritage protection
Barge - Unknown No. 1	Steel barge; likely WWII era	Not known	Not known	-12.44830° 130.81038°	1700 m	N/A
Buffalo Amphibian	Steel LVT Buffalo amphibious tracked landing craft – 16.5 tons, 7.95 m in length	1960s	Foundered whilst being used as support vessel for Mandorah Ferry	-12.41033° 130.80294°	1380 m	N/A
Darwin Harbour Unidentified Wreck 2	Timber hulled vessel – 30 m in length, carrying 10 tons of steel cargo	Not known	Not known	-12.48333° 130.83333°	2000 m	N/A
Darwin Princess	Steel motor vessel passenger ferry – 22.8 m in length	1974	Wrecked in Cyclone Tracy	-12.39815° 130.76535°	1300 m	N/A
NR Diemen	Motor vessel prawn trawler – 124 tons, 20.4 m in length	1974	Wrecked in Cyclone Tracy	-12.42660° 130.76528°	700 m	N/A
Ham Luong	Steel Vietnamese refugee motor vessel – 15 m in length	1983	Scuttled to form an artificial reef	-12.47509° 130.80067°	1140 m	N/A
John Holland Barge	Steel work barge – 18 m long by 12 m wide	1982	Scuttled to form an artificial reef	-12.47386° 130.80139°	930 m	N/A
Medkhanun 3	Steel Thai fishing motor vessel – 25 m in length	2007	Scuttled to form an artificial reef	-12.47870° 130.80236°	850 m	N/A
Mandorah Queen	Steel and aluminium motor vessel passenger ferry – 22 m in length	1974	Wrecked in Cyclone Tracy	-12.442722° 130.778306°	690 m	N/A
Mandorah Unidentified Wreck 1	Timber hull motor vessel	Not known	Not known	-12.446660° 130.766950°	2000 m	N/A
Mandorah Unidentified Wreck 2	Timber hull motor vessel	Not known	Not known	-12.448100° 130.766100°	2000 m	N/A
Song Saigon	Steel Vietnamese refugee motor vessel – 200 tons, 38 m in length	1982	Scuttled to form an artificial reef	-12.474722° 130.801278°	755 m	N/A
USAT *Mauna Loa*	Steel single screw steamship, former passenger cargo vessel commissioned as a United States Army transport during World War II. 5436 tons, 125 m in length	1942	Sunk by enemy action during first Japanese air raid on Darwin Harbour on 19 February 1942	-12.49704° 130.81936°	15 m*	*UCH Act 2018* and *NT Heritage Act 2011* – 100 m radius (under *NT Heritage Act 2011*)
USAT *Meigs*	Steel single screw steamship, former cargo vessel commissioned as a United States Army transport during World War II. 12568 tons, 131.3 m in length	1942	Sunk by enemy action during first Japanese air raid on Darwin Harbour on 19 February 1942	-12.48765° 130.81838°	270 m*	*UCH Act 2018* and *NT Heritage Act 2011* – 100 m radius (under *NT Heritage Act 2011*)

[70] All data obtained from the Australian Underwater Cultural Heritage Database (AUCHD)

Name	Type	Year lost	Wreck event	Location (WGS84)	Approx. distance from proposed GEP	Statutory heritage protection
USS *Peary*	Steel twin screw steamship, United States Navy Clemson Class destroyer – 1190 tons, 95.8 m in length	1942	Sunk by enemy action during first Japanese air raid on Darwin Harbour on 19 February 1942	-12.47533° 130.82982°	2000 m*	*UCH Act 2018* and *NT Heritage Act 2011* – 100 m radius (under *NT Heritage Act 2011*)
Yu Han 22	Timber Taiwanese fishing motor vessel – 25 m in length	1975	Partially burned and scuttled	-12.5175° 130.82166°	730 m	N/A
I-124	Steel Imperial Japanese Navy I-121 Class minelaying submarine – 1470 tons, 85.2 m in length	1942	Sunk during counterattack by Allied forces on 20 January 1942.	-12.120091° 130.106561°	100 m*	*UCH Act 2018* – 800 m radius (under *UCH Act 2018*)

Note – distances with asterisk are measured from closest boundary of heritage protection zone to GEP route. Locations highlighted in yellow have been determined by examination of MBES data and differ from locations provided on AUCHD.

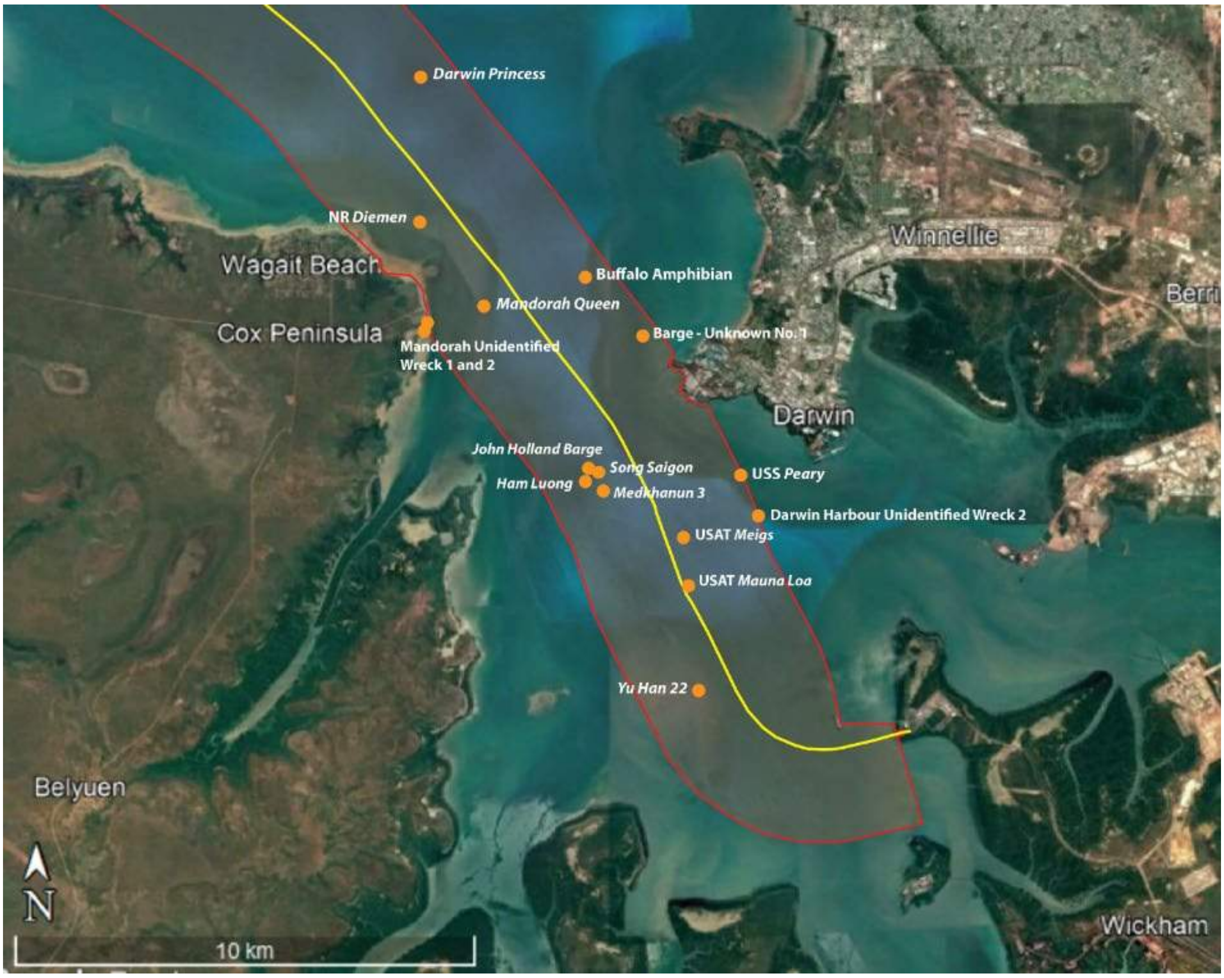

Figure 18: Location of known shipwrecks in study area – Darwin Harbour.

Figure 19: Detail of proximity of USAT Mauna Loa and USAT Meigs to proposed GEP.

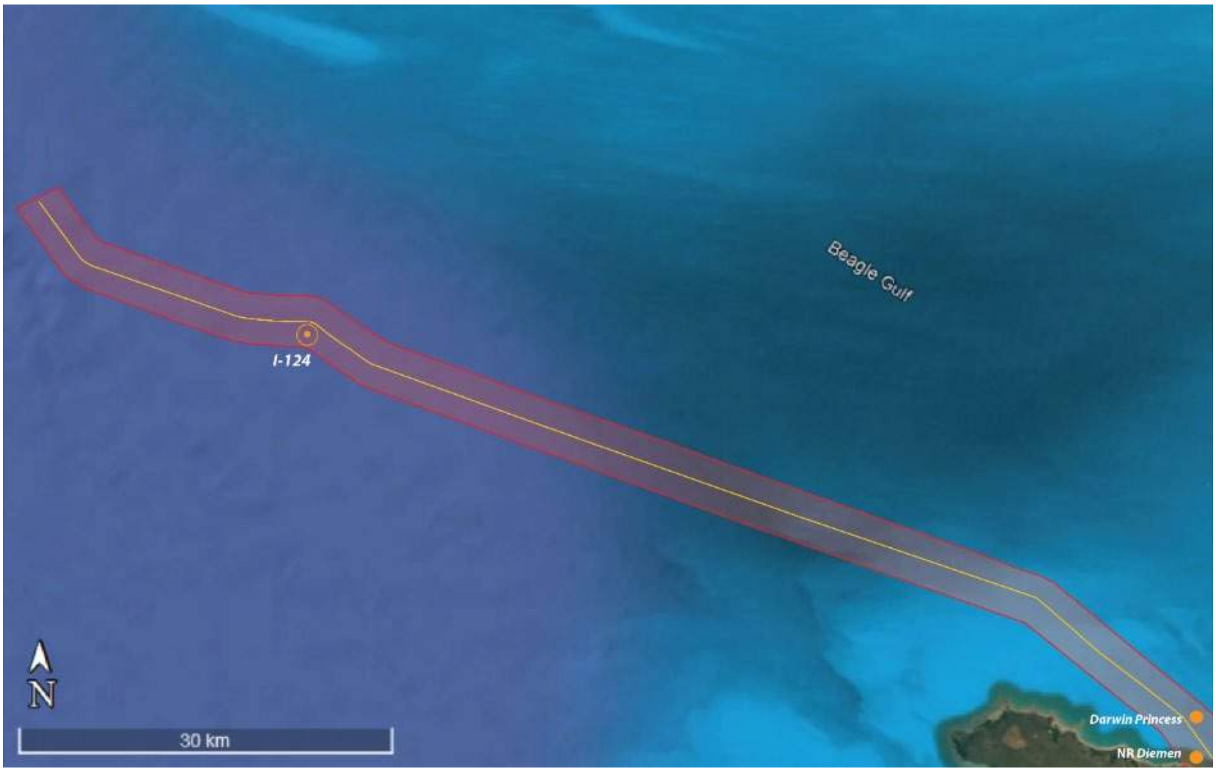

Figure 20: Location of known shipwrecks in study area – Beagle Gulf.

Figure 21: USAT Mauna Loa.[71]

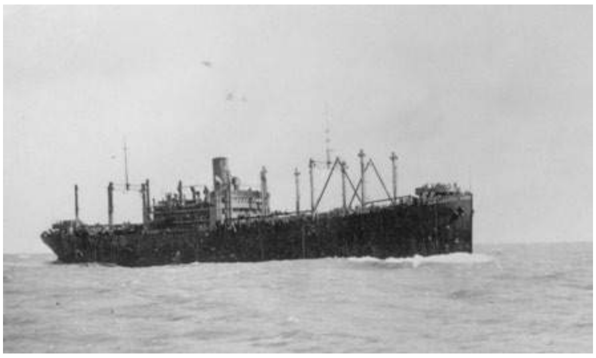

Figure 22: USAT Meigs.[72]

Figure 23: Darwin Princess.[73]

Figure 24: Song Saigon being scuttled.[74]

4.3.2 *Aircraft wrecks*

There are no known aircraft wrecks located within the study area. The closest known aircraft wreck is the wreck of a Douglas C-47 Dakota, RAAF A65-115, that was forced to ditch into the harbour due to engine failure during a test flight in 1946. The wreck of the C-47 is situated in Fannie Bay, approximately 2km north-east of the study area.

4.3.3 *Maritime infrastructure*

Six historical maritime infrastructure installations are known to occur within parts of the study area, including three 19th century subsea telegraph cables, a World War II anti-submarine boom net installation, and two groups of World War II indicator loops – see Table 3, Figure 25 and Figure 26.

Table 3: Known historical maritime infrastructure within the study area.[75]

Name	Type	Year built	Statutory heritage protection
Subsea telegraph cable - original	First installation of an approximately 1,561 km long subsea telegraph cable linking Darwin cable station to Banjoewangi cable station, Java, Indonesia. The cable consists of seven stranded copper wires, insulated with gutta-percha latex, sheathed in galvanised iron wire armour, and an outside covering of tarred hemp. The cable ranges in diameter from 3” at shore ends, 1” in intermediate portions, and ¾” in deep sea portions.	1871	The subsea cable landing at Darwin is protected under the NT *Heritage Act 2011*.

[71] **Frost, W. E. 1932.** “S.S. *Golden Eagle.”* City of Vancouver Archives, Item AM1506-S3-2-: CVA 447-2246.
[72] **Anon. 1942.** “The United States Army Transport (USAT) Meigs underway in Darwin Harbour some days before the Japanese air raid on 19 February 1942.” Australian War Memorial, Image No. P05303.019.
[73] **Anon. 1973.** “*Darwin Princess.”* Library and Archives NT, Image No. PH0366/0017.
[74] **Anon. 1982.** “*Song Saigon* being scuttled.” Darwin Sub-Aqua Club files; https://www.dsac.com.au/Divesite_files/Song.htm
[75] Data obtained from **Forster, P. 2007.** *Fixed Naval Defences in Darwin Harbour 1939-1945; how the Navy secured Darwin Harbour against submarine attacks between 1939 and 1945.* Museum & Art Gallery of the N.T. Darwin.; **NT Heritage Branch.**

Name	Type	Year built	Statutory heritage protection
Subsea telegraph cable - duplicate	Duplicate subsea telegraph cable linking Darwin cable station to Banjoewangi cable station, Java, Indonesia. The duplicate cable was of the same composition as the original 1871 cable.	1879	The subsea cable landing at Darwin is protected under the NT *Heritage Act 2011*.
Subsea telegraph cable - replacement	Replacement subsea telegraph cable linking Darwin cable station to Banjoewangi cable station, Java, Indonesia. Cable is of similar composition to the earlier two but contained an additional layer of brass tape around the core to protect the cable from marine borer (namely *teredo navalis)* attack.	1884	The subsea cable landing at Darwin is protected under the NT *Heritage Act 2011*.
Anti-submarine boom net	A 6km-long anti-submarine boom net constructed between Dudley Point and East Point, across the entrance to Port Darwin. The boom consisted of high tensile wire rope (1-2" diameter), 8' mesh floating nets. The nets were supported by a series of trots laid out 195' (60 m) apart, each consisting of three cylindrical buoys anchored via 1 ½ - 2"chain cable to eight 5-8 ton reinforced steel concrete mooring clumps laid on the seabed – four on the seaward side of the net, four on harbour side. A total of 265 clump moorings were laid. A permanently guarded gate was set into the net within the Port Darwin shipping channel. The boom net and buoys were largely cleared at the end of World War II; however the concrete clump moorings and chains were left *in situ*. ***Anti-submarine boom net mooring trots were located and identified during ROV survey. Refer to Section 7 and Annex A for details.**	1940-1942	N/A
Indicator loops – original (x2)	Initial installation of two indicator loops between Dudley Point and West Point, across the entrance to Port Darwin on the seaward side of the anti-submarine boom net. The loops provided magnetic sensing of enemy vessels, whereby an induced current was passed through each loop that triggered a signal when a ship or submarine passed overhead. The loops were formed of 33 mm diameter cable consisting of a single core of tinned copper wire, insulated with India rubber, hessian tape, tarred jute yarn, steel armour wires, hot pitch and resin coating. Each loop was typically 5000 yards long by 400 yards wide, with a central cable running the length of the loop, connected to a 25 mm diameter tail cable linked to the onshore indicator loop hut. The loops were dismantled and lifted following the end of World War II, however, it is not known if all components were recovered.	1940	N/A
Indicator loops - replacement (x 5)	Following several breakages of the initial two indicator loops due to strong tides and rough seabed, a replacement set of five indicator loops was installed ca. three miles further seaward, stretching between Midway and Nightcliff. The loops were of the same design and construction as the original set. The loops were dismantled and lifted following the end of World War II, however, it is not known if all components were recovered.	1943	N/A

2019. *The Darwin Subsea Telegraph Cables – Heritage Assessment Report.*; **Walding, R. 2006.** *Indicator Loops, Royal Australian Navy Harbour Defences – Darwin.*

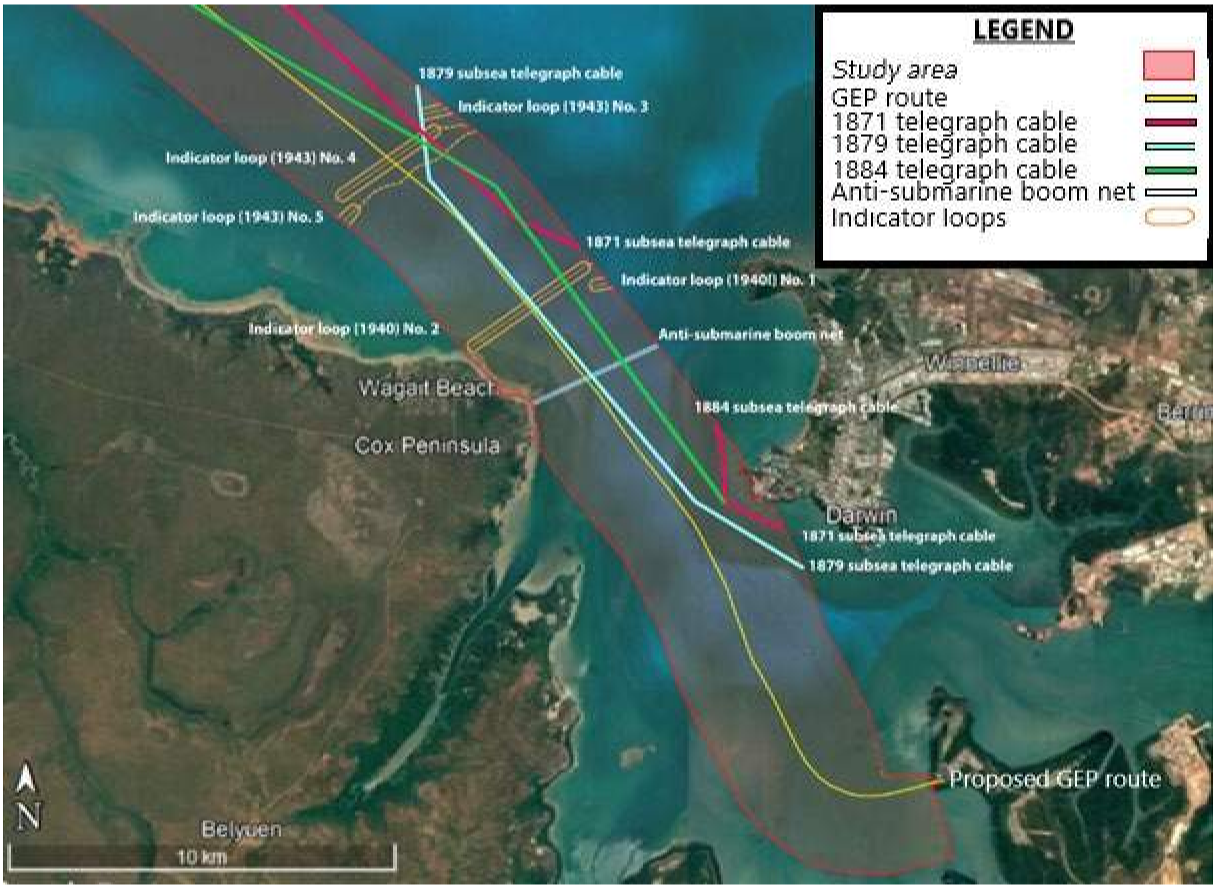

Figure 25: Location of historical maritime infrastructure in study are a (based on historical map overlays) – Darwin Harbour.

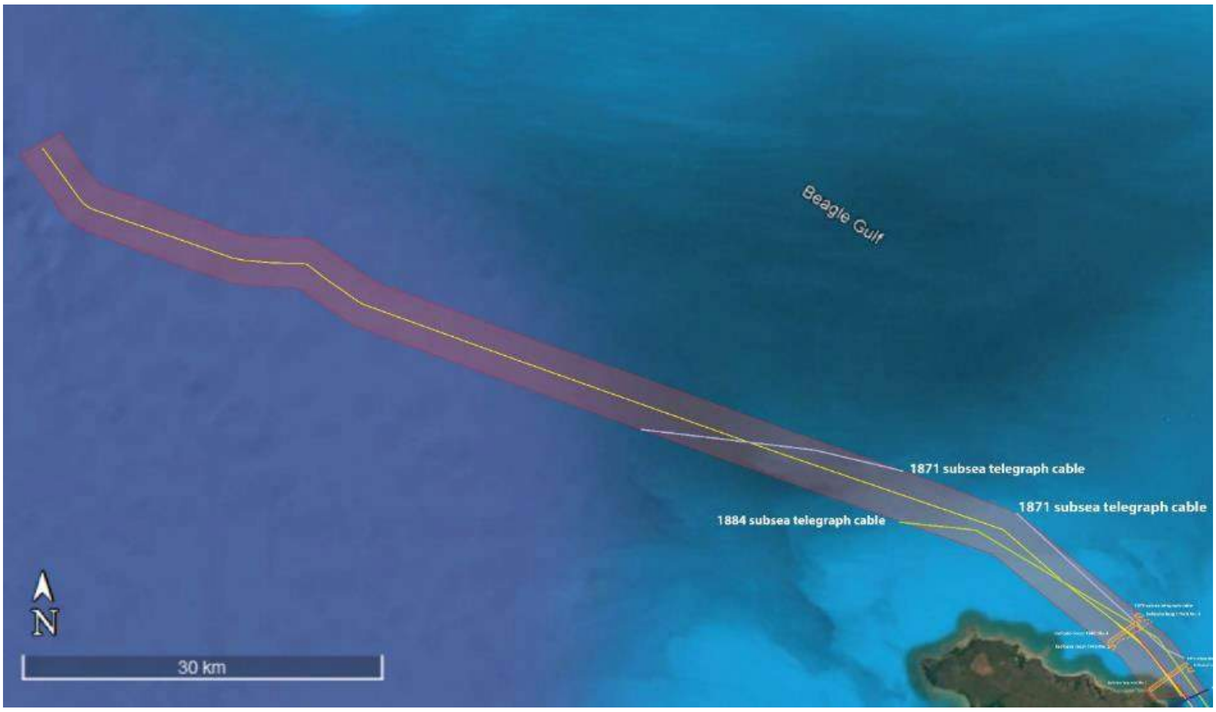

Figure 26: Location of historical maritime infrastructure in study area (based on historical map overlays) – Beagle Gulf.

Figure 27: Section of the 1871 Darwin to Java subsea telegraph cable recovered from Timor Sea in 2016.[76]

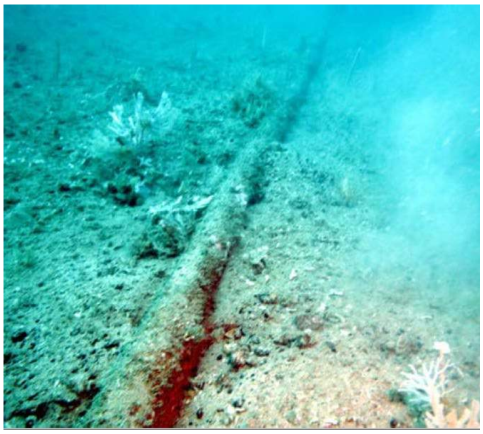

Figure 28: Surviving section of 1871 subsea telegraph cable, Darwin Harbour.[77]

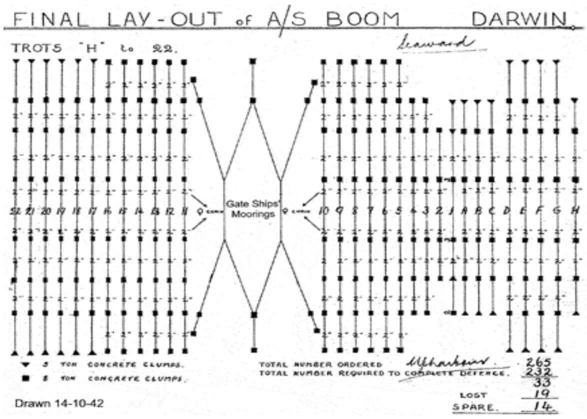

Figure 29: Layout of the Darwin anti-submarine boom net.[78]

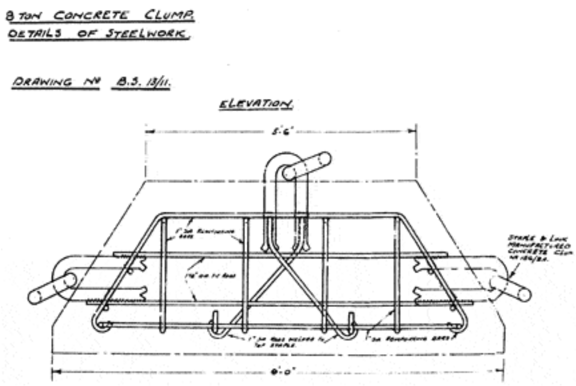

Figure 30: Construction details of the Darwin anti-submarine boom net mooring blocks.[79]

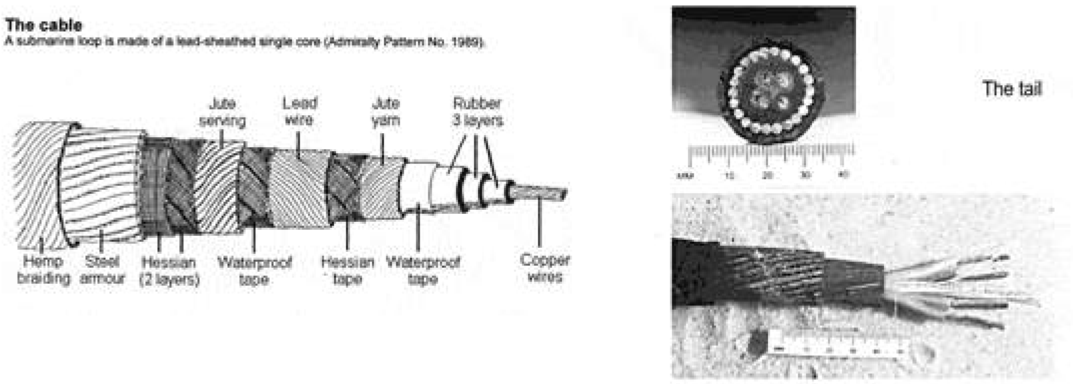

Figure 31: Construction details of the Darwin indicator loop cables.[80]

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[76] **"A section of the Port Darwin to Java underwater telegraph cable, 1871-1872." Held at the National Museum of Australia.**
[77] **NT Heritage Branch. 2019.**
[78] **Forster, P. 2007.**
[79] **Forster, P. 2007.**
[80] **Forster, P. 2007.**

4.3.4 *Sea dumping*

Other than the intentional scuttling of vessels and UXO located during INPEX surveys – discussed in Section 4.3.1 and 4.3.5 respectively – no known episodes of sea dumping are located within the study area.

4.3.5 *Unexploded Ordnance*

*** This section looks at UXO only from a heritage perspective. It is not intended to provide UXO specialist advice or to constitute a detailed UXO risk assessment.*

Documented unexploded ordnance (UXO) is known to occur at four shipwrecks located within the study area – see Table 4.

In each instance, this UXO consists of munitions cargo and unfired / unexploded naval ordnance payload associated with World War II military vessels wrecked in 1942. All items of UXO associated with these four shipwrecks are protected under the *UCH Act 2018.*

Table 4: Known UXO within the study area.[81]

Shipwreck	UXO type	Wreck location (WGS84)	Approx. distance to proposed GEP*	Statutory heritage protection
USAT *Mauna Loa*	.303 calibre and .45 calibre ammunition, and 3" mortars	-12.49704° 130.81936°	15 m	*UCH Act 2018* and *NT Heritage Act 2011* – 100 m radius (under *NT Heritage Act 2011*)
USAT *Meigs*	.303 calibre ammunition and possible depth charges or land mines	-12.48765° 130.81838°	270 m	*UCH Act 2018* and *NT Heritage Act 2011* – 100 m radius (under *NT Heritage Act 2011*)
USS *Peary*	3" and 4" artillery shells	-12.47533° 130.82982°	2000 m	*UCH Act 2018* and *NT Heritage Act 2011* – 100 m radius (under *NT Heritage Act 2011*)
I-124	5.5" artillery shells and 21" torpedoes	-12.120091° 130.106561°	100 m	*UCH Act 2018* – 800 m radius (under *UCH Act 2018*)
Contact 2	Mechanical time fuses and fuse cones	-12.416111° 130.762500°	175 m	No statutory protection, no heritage protection radius.
***Note – distances highlighted in yellow are measured from closest boundary of heritage protection zone to GEP route.**				

Figure 32: Artillery shell within the wreck of USS Peary.[82]

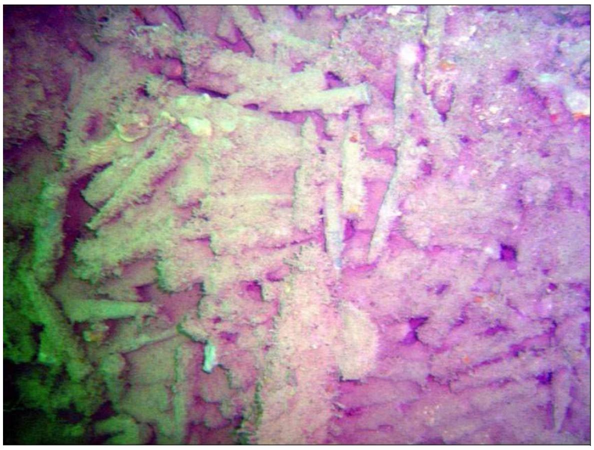

Figure 33: Small arms ammunition inside cargo hold of USAT Mauna Loa wreck.[83]

[81] All data obtained from the Australian Underwater Cultural Heritage Database (AUCHD)
[82] **Steinberg, D. 2015.** The World War II Shipwrecks of Darwin Harbour; a report on the archaeological inspection and assessment of seven historic shipwrecks. NT Heritage Branch.
[83] Ibid.

Additionally, one location of dumped UXO was recorded during the INPEX GEP survey conducted by CA in 2012.[84] This consisted of a collection of dumped mechanical time fuses and fuse cones located near KP 105 at 691614 m E and 8626792 m N, approximately 175 m from the proposed GEP route (see Section 6.4.1.2, Figure 34).

Figure 34: Collection of mechanical time fuses and fuse cones located at Contact 2, on the alignment of the INPEX GEP. Contact 2 is located approximately at location of KP 105 along proposed Barossa GEP route. (Source: CA 2012).

4.4 Potential Maritime Archaeological Sites in the Study Area

4.4.1 *Shipwrecks*

There are twenty-nine known but unlocated shipwrecks in Darwin Harbour and Beagle Gulf that could potentially occur within the study area based on historical accounts of the wreck event and wreck location – see Table 5.

The majority of these shipwrecks comprise small timber-hulled sailing vessels lost during the late 19th to early 20th centuries – in many cases due to extreme weather events, such as nine pearling luggers and a Chinese junk wrecked during a major cyclone that struck Darwin in January 1897, two sailing vessels lost in strong gales during the 1880s, and a launch lost in a cyclone that hit Darwin in March 1915. The remainder includes a composite clipper ship / Royal Australian Navy (RAN) coal hulk scuttled in 1932, three workboats lost during World War II, mid-20th century wrecks of a motor launch and a barge, and a timber-hulled motor vessel sloop lost in Cyclone Tracy in December 1974.

There is also potential for shipwrecks not documented in the historical record to be located within the study area, including Aboriginal, Macassan, and early colonial watercraft.

Any shipwreck within the study area that dates prior to 1947 – whether located or not – is automatically protected under the *UCH Act 2018*.

Table 5: Potential shipwrecks within the study area. [85]

Name	Type	Year lost	Wreck event	General location
Ark	Timber pearling lugger	1897	Wrecked in 1897 cyclone	Darwin Harbour
Astraea	Timber barque	1886	Disappeared on voyage	Between Darwin and Queensland.
Bear Sing	Timber sailing vessel	1886	Wrecked in a strong gale	Darwin Harbour
Black Jack	Timber pearling lugger	1897	Wrecked in 1897 cyclone	Darwin Harbour
Charity	Timber lugger	1897	Disappeared on voyage	Between Darwin and WA

[84] *Op. Cit.* **Cosmos Archaeology, 2012**:11.
[85] All data obtained from the Australian Underwater Cultural Heritage Database (AUCHD)

Name	Type	Year lost	Wreck event	General location
Darwin Harbour Unidentified Chinese Junk 1	Timber junk	1897	Wrecked in 1897 cyclone	Darwin Harbour
Darwin Harbour Unidentified Lugger 1	Timber lugger	1939	Destroyed by fire after stove explosion	Darwin Harbour
Darwin Harbour Unidentified Lugger 2	Timber lugger	1910	Scuttled	Darwin Harbour
Dawn	Timber ketch; 51 tons	1893	Broken up	Darwin Harbour
Eileen	Timber ketch; 13 tons	1939	Foundered	Near Charles Point, Beagle Gulf
Good Intent	Timber ketch	1892	Foundered	Between Darwin and Charles Point, Darwin Harbour – Beagle Gulf
Gertrude	Timber pearling lugger	1897	Wrecked in 1897 cyclone	In shoal water on Middle Point, Darwin Harbour
Gunyana	Timber motor vessel sloop	1974	Disappeared in Cyclone Tracy	Darwin Harbour – Beagle Gulf
HMAS *Hankow*	Composite clipper ship, coal hulk, 1249 tons, 223 m in length	1932	Scuttled with demolition charges	Outside entrance to Darwin Harbour / west of East Point
Harbour Tug	Tug	1942	Foundered	Beagle Gulf – Timor Sea
Hibernia	Timber ketch, 13 tons	1882	Foundered	Darwin Harbour, within the fairway to the anchorage
Jack	Timber pearling lugger	1897	Wrecked in 1897 cyclone	Darwin Harbour
Karalee	Timber lighter, 117 tons	1943	Foundered	Darwin Harbour
Lighter No. 2	Steel lighter, 86 tons	1943	Lost by enemy action	Near Darwin
Olga	Timber motor vessel launch	1926	Sunk after onboard chemical explosion	Ca. 48 km from Darwin, towards Bathurst Island, Beagle Gulf
Olive	Timber pearling lugger	1897	Wrecked in 1897 cyclone	South-west of Fort Hill, Darwin Harbour
Peron	Motor launch	1948	Disappeared	Near Darwin; Darwin Harbour – Beagle Gulf
Pinafore	Timber sailing vessel	1881	Wrecked in a gale	Darwin Harbour, ca. 4 km out of Fannie Bay
Revenge	Timber pearling lugger	1897	Wrecked in 1897 cyclone	Darwin Harbour
Roebuck	Timber pearling lugger	1897	Wrecked in 1897 cyclone	In mangroves, one mile south of Middle Point, Darwin Harbour
Scout	Timber pearling lugger	1897	Wrecked in 1897 cyclone	On eastern side of Middle Point, Darwin Harbour
Spray	Timber launch	1915	Wrecked in 1915 cyclone	Darwin Harbour
Triumph	Steel barge	1954	Foundered	Off Darwin, Darwin Harbour - Beagle Gulf
Zulieka	Timber sailing vessel	1897	Wrecked in 1897 cyclone	On a reef off Channel Island, Middle Arm, Darwin Harbour

4.4.2 *Aircraft wrecks*

There are twenty-five known but unlocated aircraft wrecks in Darwin Harbour and Beagle Gulf that could potentially occur within the study area based on historical accounts of the wreck event and general wreck location – see Table 6.

All of these wrecks are military combat aircraft, including eleven Imperial Japanese Navy (IJN) and Navy Air Force (IJNAF) aircraft, seven United States Army Air Force (USAAF) aircraft, six Royal Australian Air Force (RAAF) aircraft, and one Royal Air Force (RAF) aircraft. All but one of these aircraft – an RAAF fighter wrecked in 1961 – were lost during World War II.

Any of these World War II aircraft wrecks that are situated within Commonwealth waters (from waters 3 nm seaward of the territorial sea baseline) are automatically protected under the *UCH Act 2018.* All USAAF aircraft wrecks are also automatically protected under the US *Sunken Military Craft Act 2004.*

Table 6: Potential aircraft wrecks within the study area.

Aircraft type / number	Operator	Wreck event	Year Lost	General location
CAC Sabre A94-360 (military fighter); pilot Irvine	Royal Australian Air Force (RAAF) – 81 Wing	Failure of port wing caused catastrophic mid-air explosion.	1961	Darwin Harbour, near Talc Head
Curtiss P-40E Kittyhawk (military fighter); pilot Andrew	United States Army Air Force (USAAF) - 7th Squadron, 49th Pursuit Group	Damaged during dogfight with incoming IJNAF attack, forcing pilot to bail out and aircraft to crash into sea.	1942	West of Charles Point, Beagle Gulf
Curtiss P-40E Kittyhawk (military fighter); pilot Drake	USAAF - 7th Squadron, 49th Fighter Group	Damaged during dogfight with incoming IJNAF attack, forcing pilot to bail out and aircraft to crash into sea.	1942	Off West Point, Darwin Harbour
Curtiss P-40E Kittyhawk (military fighter); pilot Fish	USAAF - 8th Squadron, 49th Pursuit Group	Shot down by IJNAF A6M2 “Zero” fighters.	1942	Approximately 3 km S-SE of Swires Bluff, Darwin Harbour
Curtiss P-40E Kittyhawk (military fighter); pilot McComsey	USAAF - 9th Squadron, 49th Pursuit Group	Damaged during dogfight with incoming IJNAF attack, forcing pilot to bail out and aircraft to crash into sea.	1942	Off West Arm, southern side of Darwin Harbour
Curtiss P-40E Kittyhawk (military fighter); pilot Pell	USAAF - 33rd Pursuit Squadron	Damaged during dogfight with incoming IJNAF attack, forcing pilot to bail out and aircraft to crash into sea.	1942	Camerons Beach, Shoal Bay, Darwin Harbour
Curtiss P-40E Kittyhawk (military fighter); pilot Strauss	USAAF - 8th Squadron, 49th Pursuit Group	Shot down by IJNAF A6M2 “Zero” fighters.	1942	Approximately 2.7 km north-west of Emery Point, Fannie Bay, Darwin Harbour
Curtiss P-40E Kittyhawk (military fighter); pilot Wiecks	USAAF - 33rd Pursuit Squadron	Shot down by IJNAF A6M2 “Zero” fighters.	1942	Darwin Harbour; near harbour entrance
Kawanishi H6K4 "Mavis" (military bomber); pilot Mirau	Imperial Japanese Navy (IJN) - Toko Ku Southwest District Fleet	Shot down by USAAF 3rd Pursuit Squadron P-40 Kittyhawk.	1942	South / south-west of Melville Island, Beagle Gulf – Timor Sea
Lockheed Hudson A16-137 (ex 41-23207) (military bomber)	RAAF - No. 13 Squadron	Disappeared after departing Darwin for an attack mission on Kupang, Indonesia.	1942	Possibly Beagle Gulf - Timor Sea
Lockheed Hudson A16-170 (ex 41-23607) (military bomber)	RAAF - No. 13 Squadron	Disappeared after departing Darwin for an attack mission on Kupang, Indonesia.	1942	Possibly Beagle Gulf - Timor Sea
Mitsubishi A6M2 "Zero" (military fighter); pilot Murakami	Imperial Japanese Navy Air Force (IJNAF) - 3 Ku, 23rd Koku Sentai	Shot down by USAAF 7th Squadron, 49th Pursuit Group P-40 Kittyhawks. .	1942	ca. 32 km north-west of Darwin, Beagle Gulf
Mitsubishi A6M2 "Zero" (military fighter); pilot Tajiri (m/n 6540)	IJNAF - 202 Ku, 23rd Koku Sentai	Shot down by RAAF / RAF No. 54 Squadron Spitfire.	1943	Darwin Harbour; immediately south of West Point
Mitsubishi G4M1 "Betty" (military bomber); pilot Asahiro	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF P-40 Kittyhawks.	1942	Beagle Gulf
Mitsubishi G4M1 "Betty" (military bomber); pilot Fujiwara	IJNAF – 753 Ku, 23rd Koku Sentai	Shot down by RAAF 457 Squadron Spitfires.	1943	West / north-west of Charles Point, Cox Peninsula, Beagle Gulf
Mitsubishi G4M1 "Betty" (military bomber); pilot Inada	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF 49th Pursuit Group P-40 Kittyhawks and / or 14 HAA anti-aircraft battery Darwin.	1942	In sea north-west of Darwin, Beagle Gulf.

Aircraft type / number	Operator	Wreck event	Year Lost	General location
Mitsubishi G4M1 "Betty" (military bomber); pilot Kato	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF 49th Pursuit Group.	1942	North-west of Darwin; Beagle Gulf - Timor Sea
Mitsubishi G4M1 "Betty" (military bomber); pilot Kirino	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF 49th Pursuit Group.	1942	North-west of Darwin; Beagle Gulf - Timor Sea
Mitsubishi G4M1 'Betty" (military bomber); pilot Ozaki	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF 49th Pursuit Group.	1942	North-west of Darwin; Beagle Gulf - Timor Sea
Mitsubishi G4M1 "Betty" (military bomber); pilot Tomohara	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF 49th Pursuit Group.	1942	North-west of Darwin; Beagle Gulf - Timor Sea
Mitsubishi G4M1 "Betty" (military bomber); pilot Unohara	IJNAF - Takao Ku, 23rd Koku Sentai	Shot down by USAAF 49th Pursuit Group.	1942	North-west of Darwin; Beagle Gulf - Timor Sea
Supermarine Spitfire A58-6 (ex AR563) (military fighter)	RAAF - No. 452 Squadron	Engine failure during formation practice flight caused pilot to force land in intertidal mangroves.	1943	Middle Arm, Darwin Harbour
Supermarine Spitfire A58-34 (ex-BR525) (military fighter)	RAAF - No. 452 Squadron	Damaged during dogfight with incoming IJNAF attack, forcing pilot to bail out and aircraft to crash into sea.	1943	Approximately 48 km north-west of Darwin, Beagle Gulf.
Supermarine Spitfire A58-86 (ex-BS221) (military fighter)	Royal Air Force (RAF) - No. 54 Squadron	Engine failure during flight to intercept incoming IJNAF attack forced pilot to bail out and aircraft crashed into sea.	1943	Approximately 48 km north-west of Darwin, Beagle Gulf.
Supermarine Spitfire A58-89 (ex-BS225) (military fighter)	RAAF - No. 452 Squadron	Damaged during dogfight with incoming IJNAF attack, forcing pilot to bail out and aircraft to crash into sea.	1943	North-west of Darwin, Beagle Gulf - Timor Sea

4.4.3 *Maritime infrastructure*

The study area passes through some historical anchorages within Darwin Harbour, including a late 19th to mid-20th century quarantine anchorage, and 1930s to 1940s naval anchorages. It is possible that permanent moorings were established in some areas of these anchorages, and that remnants of such moorings, most likely large clump anchors or concrete mooring blocks and associated chains, remain on the seabed.

4.4.4 *Sea dumping*

Previous maritime archaeological investigations have found substantial evidence of sea dumping of World War II era military material within Darwin Harbour: including aircraft parts, armament and ammunition, automotive parts and accessories, camp furniture and equipment, power and electrical equipment, fuel storage containers, and manual tools. Much of this material has been found in piles or clusters across the seabed, suggesting discrete dumping events from a barge or similar vessel. It was concluded that this material most likely represents post-war disposal of surplus and / or unserviceable military equipment.[86]

There is a potential for similar evidence of post-World War II sea dumping of military material to occur within the study area.

4.4.5 *UXO*

*** This section looks at UXO only from a heritage perspective. It is not intended to provide UXO specialist advice or to constitute a detailed UXO risk assessment.*

[86] **Cosmos Archaeology Pty Ltd. 2014.** INPEX Ichthys LNG Project, Nearshore Development – Dredging, East Arm, Darwin Harbour, Northern Territory – Relocation of Heritage Objects and Removal of Debris. Report prepared for Tek Ventures Pty Ltd.

There is a potential for various types of UXO – namely World War II era UXO – to occur within the study area, including:

- Crashed Allied and Japanese military aircraft ordnance payloads;
- Japanese air-delivered munitions;
- Japanese sea-delivered munitions;
- Allied artillery munitions from coastal defences and anti-aircraft bases, and;
- Sea dumping of surplus military ammunition.

The Department of Defence maintains a record of sites confirmed as, or reasonably suspected of, being affected by UXO.[87] These records show that various areas of Darwin Harbour and Beagle Gulf have historically been used for military training – see Figure 35. The study area passes through the location of a former air to air weapons range; however, Defence records do not confirm whether this area was used for live firing, and UXO or explosive ordnance fragments have not been recovered from the area.

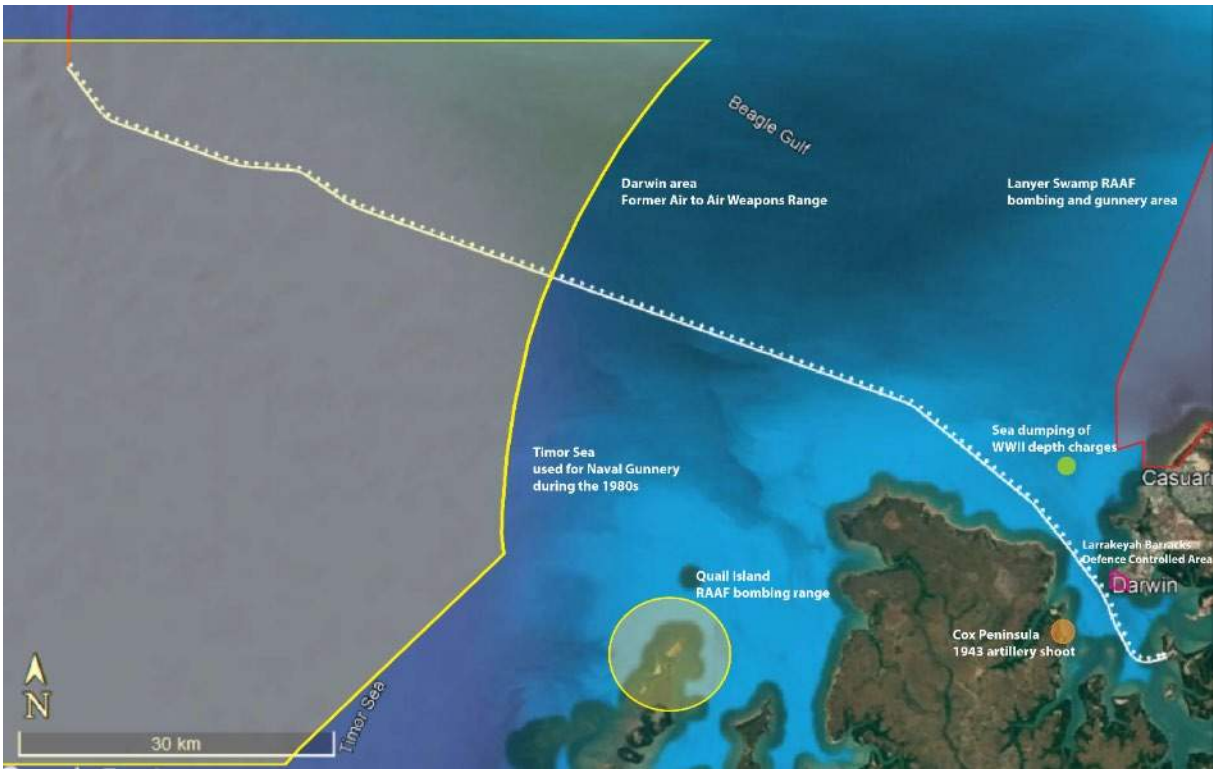

Figure 35: Areas where UXO may occur based on Department of Defence records.[88]

[87] **Australian Government Department of Defence. 2022.** Defence UXO Mapping Application. whereisuxo.org.au
[88] **Australian Government Department of Defence. 2022**.

5 PREDICTED CONDITION OF MARITIME ARCHAEOLOGICAL SITES

5.1 Introduction

The condition of any maritime archaeological resource is affected by environmental and cultural factors as well as the nature of the seabed.

With regards to the study area, the following factors will have the greatest impact on site formation processes:

- Type of event leading to presence on seabed;
- Soft marine sediments;
- Mechanical damage caused by waves;
- Salvage;
- Anchor and trawl drags;
- Chemical and biological degradation.

5.2 Site Environment

As discussed in Section 4.1, the seabed is primarily sandy and featureless along most of the Beagle Gulf portion of the proposed GEP route. From KP 0 to KP 100, the seabed appears to be primarily flat and almost featureless sand, crossed in several places by gullies. Around KP 105, where the GEP route enters Darwin Harbour, the flat sand gives way to rock outcrops and other hardgrounds. Between Larrakeyah and Mica Beach, the seabed becomes more gravelly and forms a thin cover over flat sandstone and phyllite pavements. The hardgrounds within Darwin Harbour are punctuated by isolated deposits of thick sediments, before giving way to sand and mudflats as the GEP approaches its terminus at Wickham Point.

5.3 Shipwrecks

The wrecking event is the first factor that influences site formation. Depending on the reasons or forces behind wrecking, the ship may be mostly complete or extensively broken up. A vessel rarely falls or sinks as a result of little or no damage; it is more likely that a vessel would run aground, cause damage to the hull, and then sink with part of the vessel intact and part damaged. Often the force of initial impact is sufficient to break the vessel and cause considerable damage. The vessel would then sink in large pieces, depending on the damage, or remain stuck until it is broken up by physical or human forces. Another reason for a wrecking event is fire which, depending on the extent, can cause a considerable amount of breaking up and scrambling of the ship material before it reaches the seabed.

It is reasonable to assume that a large majority of potential shipwrecks within the study area foundered or were forced ashore. In this scenario, the vessel's structural remains would remain highly intact, although if run ashore it may have been salvaged for key parts before discard and therefore would have less artefactual remains.

The seabed upon which a shipwreck lies has the greatest effect on site formation processes, in particular with wooden hulled vessels, with other factors also having contributory effects.

With regards to vessels coming to rest on a sandy seabed, the archaeological site will usually be formed in the following manner:

- Vessel comes to rest on the seabed.

- The wreck will settle into the seabed up to a certain depth, dependent on the resistance of the sediments and the weight of the vessel. It is a general rule, especially with iron hulled vessels, that wrecks sink into softer sediments up to their waterline.
- Parts of the vessel which protrude above the water may be salvaged for re-use. Non-perishable, accessible and high value parts of the vessel situated underwater may also be removed. It is a general rule that the deeper the water in which a vessel sinks and the more remote the location, the less likelihood of it being salvaged at the time of loss. Rapidly changing technology in recent times, however, has allowed salvage at greater depths.
- Biological processes will commence immediately on a timber wreck, attacking the exposed timbers and other organic elements of the wreck. This will lead to a weakening of the hull's integrity and eventually organic elements above the seabed will disappear.
- If it is in shallow water, wind generated waves would act upon the broader surfaces of a wreck thereby breaking down exposed components into sections. These sections will orientate themselves to prove the least resistance to the direction from which the waves are more commonly generated.
- Large waves will raise sediments into suspension, thereby resulting in cultural objects, including the hull of the wreck, sinking further into the marine sediments. The older the wreck the deeper it would be buried, unless a hard-alluvial substrate is present close to the surface of the seabed against which the wreck will rest.
- Cultural behaviour will have the effect of scrambling wreck sites and masking their presence. Dragging anchors, scallop dredgers and trawling will spread wreck material and may also result in the 'ploughing up' of buried cultural material.
- Salvaging will have a destructive effect on the hull and organic elements that have survived below the seabed, as well as by removing artefacts and creating a scatter of remaining material around the wreck site.

A wreck coming to rest on a rocky bottom would eventually collapse under its own weight as it would not be able to sink into the seabed. With such a collapse the integrity or coherence of the wreck begins to dissipate. Pockets of surviving structure and other artefacts can remain well preserved amongst boulders, gullies and depressions.

Assessing the condition or, more precisely, the structural integrity of the shipwrecks is of relevance because this can provide an indication of the nature and scale of the obstacle that could affect the pipeline installation process. Shipwreck condition also relates to its 'detectability'. A number of factors influence the condition of shipwrecks, the primary ones being the materials used in the construction of the vessel, the bottom type upon which the wreck rests, the depth of the wreck and its age.

With regards to detecting wreck sites, the two most common remote sensing techniques that are applied would be magnetometer and side scan sonar surveys. The side scan sonar would be more useful in detecting high- and low-profile wreck sites while the magnetometer is best employed in searching for sites with a high ferrous content which are partially buried or resting on a rocky bottom.

Generally speaking, the 'younger' the wreck is, and the deeper it sank in the water column, the better preserved it would be. Also, a wreck resting on a sandy bottom would be better preserved than if it was resting on a rocky bottom. In conjunction with these factors, the method and type of construction of the vessel is the most important variable when it comes to assessing the condition of a wreck.

Iron/Steel Hulled Wrecks

If resting on a sandy bottom it could be expected that the hull integrity of the wreck would be relatively intact. The hull along midships may have collapsed but the stern and bow sections may still be upright or heeled to one side. The engine components, if any, would be largely intact and *in situ*. Such vessels on a rocky bottom would be relatively disarticulated, though the components of the vessel would still be present. Iron/steel wrecks on either bottom type can be detected using a magnetometer. Locating such a wreck site on a rocky bottom with side scan sonar would be difficult but the opposite is true with such wrecks on a sandy seabed.

Wooden Hulled Wrecks with Engines

In most cases the hulls of such wrecks would have disappeared. In situations, however, where the wreck rests on a sandy bottom, sections of the hull may have been preserved under the sand. The engine components of such wrecks would be visible. A magnetometer can detect such wrecks on either bottom type. Such wrecks on a rocky bottom would be difficult to detect with side scan sonar but the opposite can be true with such wrecks on a sandy seabed. However, engine components can be partially or completely covered by sediments and would appear as scattered dumped debris or a linear mound.

Large Tonnage (> 100 ton) Wooden Hulled Wrecks (Sail)

In most cases the hulls of such wrecks would have disappeared. In situations, however, where the wreck rests on a sandy bottom, significant sections of the hull may have been preserved under the sand. There would be enough ferrous material present, such as anchors, chain and winches, for such wreck sites to be detected using a magnetometer. The identification of such wreck sites using side scan sonar would be difficult as it could appear as scattered dumped debris, unless the cargo was non-perishable, in which case a linear mound may be visible.

Small Tonnage (< 100 ton) Wooden Hulled Wrecks (Sail)

The same as for large tonnage vessels except that the size of the target and the amount of ferrous material present would be considerably less. It would be difficult to detect using a magnetometer and may be mistaken for dumped material debris from side scan sonar imaging.

5.4 Aircraft Wrecks

There are significant differences between the site formation of underwater aircraft wrecks and shipwrecks due to the vastly different construction, in terms of both shape and material used, as well as the depositional process, i.e., the wrecking event. These are two key determining factors that will influence site formation.[89] The wrecking event for aircraft is the first factor affecting site formation, and can take many forms, from deliberate scuttling on the water's surface and dumping of material to high impact crashes and slower, more controlled ditching events. Aircraft dumping was considered 'fairly commonplace' following WWII, and significant dump sites exist near Sydney and Greencape in NSW, along with sites near Brisbane, and Rottnest Island in WA.[90] Aircraft wrecked as a result of military combat may have sustained significant damage before crashing into the water. Aircraft sitting on the

[89] **Burgess, A., 2013**, *Underwater Aviation Archaeology: What is its Place and Value Within Archaeology, and in Particular Maritime Archaeology?*, Masters thesis, Faculty of Humanities, University of Southampton, United Kingdom.
[90] **Smith, T., 2004,** Plane Sailing: The archaeology of aircraft losses over water in NSW, Australia. *Bulletin of the Australasian Institute for Maritime Archaeology.* Vol. 28:113-124.

surface of the water may have also been attacked and sunk through military action.[91] The initial integrity of the aircraft hull depends largely on the wrecking incident, and is influenced by numerous factors, such as the speed and angle of impact upon entry.

Upon entering the water, the shape of the aircraft and the depth of the water column will determine how the aircraft comes to rest on the seafloor. Aircraft hulls and wings are typically made of lightweight material, such as aluminium or even wood and fabric, while machinery and components such as engines will weigh significantly more and contain more ferrous elements. This disparity in weight will cause some aircraft to invert on descent, coming to a rest on their back. Other aircraft, such as single engine WWII fighter planes built with engines at the front, will sink to the bottom nose first. As the aircraft sinks in the water column, it may break up further, with the loss of wings or tail sections being sometimes noted.[92] Once on the seafloor, the combination of increased weight and galvanic corrosion due to differing metals means that larger components, such as engines, may detach and fall away from the rest of the structure. The depth of the wreck has a significant role in its deterioration, as aircraft sunk in shallower waters are more at risk from wave surge and corrosion due to warmer water temperature and increased oxygen levels.[93]

The seafloor composition will determine the burial environment for a sunken aircraft which in turn will have a large impact on the survival and condition of the aircraft. Aircraft are generally lighter than ships and are therefore less likely to penetrate the seabed, and less of the hull may be buried. As with shipwrecks, it is assumed that aircraft that are quickly buried in an anaerobic, stable environment, deep underwater will be better preserved than those in shallow inshore environments, particularly those with hard seabed and heavy surf.[94]

The composition of alloys used in aircraft construction can have a significant impact on the rate of deterioration once an aircraft has sunk. Aluminium, the primary material used in aircraft construction, is highly reactive. When alloyed with metals like copper, its corrosion rate is accelerated. This leads to a phenomenon known as 'pitting,' where perforations appear as the aluminium corrodes.[95] Water with a higher acidity will cause more rapid deterioration.

Direct cultural impacts can also play a role in site formation, especially on sites located in areas of high boat traffic. Fishing nets have frequently become entangled with aircraft wrecks, resulting in damage and fragmentation.[96] Impacts and damage by anchors was frequently noted on PBY Catalina wrecks in Darwin Harbour, including some anchors that remained embedded in the aircraft.[97] Further damage can occur from propeller jet turbulence in shallow water. Due to the lightweight construction of aircraft, these anchor and fishing net collisions can easily move pieces of a sunken aircraft from one location to another, resulting in highly fragmented wreck sites.[98] Aircraft parts can be light enough that even recreational fishing line has been known to snag and disturb sites. Seafloor dredging has also been shown to have a significant negative impact on aircraft crash sites.[99] Other cultural impacts include salvaging, which can include initial salvaging efforts shortly after the wrecking event, as well as looting, illicit salvage, and souvenir taking. Sunken aircraft may become popular with recreational divers and can be damaged by careless visitors.

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[91] **Wilkinson, D., 2012,** Underwater aircraft sites in Australia: a summary of what has been learnt so far. *Bulletin of the Australasian Institute for Maritime Archaeology.* Vol. 36:31-35.
[92] **Wessex Archaeology, 2008,** *Aircraft Crash Sites at Sea: A Scoping Study,* Prepared for English Heritage.
[93] *Op. Cit.* **Smith, 2004.**
[94] *Op. Cit.* **Wessex Archaeology, 2008**.
[95] *Op. Cit.* **Burgess, 2013**.
[96] *Op. Cit.* **Smith, 2004.**
[97] **Cosmos Archaeology, 2016,** *INPEX Ichthys Project, Catalina Flying-Boat Monitoring 2012 to 2015,* Prepared for Tek Ventures Pty Ltd.
[98] *Op. Cit.* **Cosmos Archaeology, 2016**.
[99] *Op. Cit.* **Wessex Archaeology, 2008**.

Although the site formation processes for sunken aircraft display large variation between sites, a general flow of deposition can be summarized:

- An aircraft enters the water, either through a violent and high-impact uncontrolled crash, slower deliberate bailout, or through dumping/scuttling on the surface. Aircraft may have sustained damage prior to entering water, such as those suffering mid-air explosions and aircraft shot down in combat.
- As the aircraft sinks, its orientation and hull integrity will change depending on its construction. Wings and tail may separate, and heavier components may invert an aircraft.
    - It has been noted on Catalina wrecks that the tails and wings are very rarely found with the rest of the fuselage, indicating that they have potentially broken off and drifted away as the aircraft sunk.[100]
- The aircraft will settle on the sea bottom. Aircraft deposited on hard substrate may not be buried, while those settling on sandy, muddy, or silty bottoms may partially sink into the seafloor.
- In certain cases, salvaging operations may take place immediately, including the removal of high value components. In other cases, illicit salvaging, looting, treasure hunting, and souvenir taking can damage wrecks.
- Aircraft materials will begin to deteriorate over time, due to corrosion as well as natural and cultural external factors.
    - Corrosion will cause deterioration of metals, particularly aluminium, and may cause heavier ferrous components to detach.
    - Surf and surge can further disarticulate aircraft and spread material around a larger area.
    - Human activities such as dredging, fishing and recreational boating can further disperse sites by dragging fishing nets and anchors across sunken aircraft.

5.5 Sea dumping and UXO

Ordnance from WWII

Generally, ordnance resting on rocky seabeds in high energy environments will corrode and disintegrate at a more rapid rate while those in lower energy environments or completely buried will retain their integrity for much longer.[101] Such objects will appear as scattered low relief and highly reflective debris on the seabed.

Ballast mounds

Ballast mounds are usually composed of rock and occasionally of scrap iron. They will present as high relief and highly reflective on the seabed.

5.6 Maritime Infrastructure

Moorings

Moorings are selected for their durability and therefore remain in a solid condition, whether they be anchors or concrete blocks. They tend to become buried over time in sandy/silty seabeds. Associated chain can also become buried, with exposed sections eventually corroding to a point where they become brittle and break easily. The length of time required

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[100] *Op. Cit.* **Cosmos Archaeology, 2016**.
[101] **G-tek Australia, 2010:6.**

for chain to reach this state of deterioration depends very much on its thickness, but it can be expected that such material in Darwin Harbour will still retain some tensile strength.

Cable and nets

On a sandy/silty seabed, wire and netting can become partially buried. Similarly, to chain, exposed sections eventually corrode to a point where they become brittle and break easily, but the length of time required to reach this state of deterioration depends very much on the object's thickness. Given that these objects are around 70 years old, they can be expected to still retain tensile strength. They would appear as meandering low relief and highly reflective linear anomalies. The associated 'clumps' would appear as round or square low relief and highly reflective objects.

6 REVIEW OF GEOPHYSICAL SURVEY DATA

6.1 Introduction

Geophysical data was provided by Santos in the form of high-resolution geo-tiffs for side scan sonar (SSS) and multi-beam echosounder (MBES) survey data. Magnetometer data was provided as georeferenced feature points. Additionally, a detailed geophysical survey report was provided to supplement the raw data.[102] The proposed anchoring corridor for vessels installing the GEP is wider than the geophysical survey corridor conducted by Fugro. Therefore, an additional MBES dataset published by Geosciences Australia was consulted to cover this data gap.

Of relevance to this assessment in particular was the SSS. Additionally, MBES and magnetometer data was used as a second and third data source to support the selection of targets from SSS. SSS data was provided as geo-tiffs at 0.5m resolution which were imported into QGIS software and laid over basemaps. This provided highly accurate coordinates of seabed anomalies as well as their dimensions. The 0.5m resolution allowed for the selection of small, isolated anomalies due to the high resolution.

SSS and MBES data adequately covered the proposed pipeline route, with no discernible gaps in coverage. Magnetometer data, though useful in identifying cultural objects, was provided only as feature points, and raw data was not provided.

6.2 Geophysical survey data provided

6.2.1 *Side Scan Sonar survey*

SSS data was provided as 0.5m resolution black and white geo-tiffs covering the entirety of the proposed GEP route (see Figure 36 and Figure 37). Additionally, targets identified by FUGRO during geophysical survey reporting were provided. These were assessed against the available raw SSS and MBES data to assess their potential historical significance and cultural origin (see Table 7).

[102] **Fugro, 2022,** *Barossa Pipeline to Shore Project – Survey Results Report – Offshore Geophysical Survey – (Work Package 1) North Route 2*, provided for Santos Pty Ltd. (BAS-200 0629).

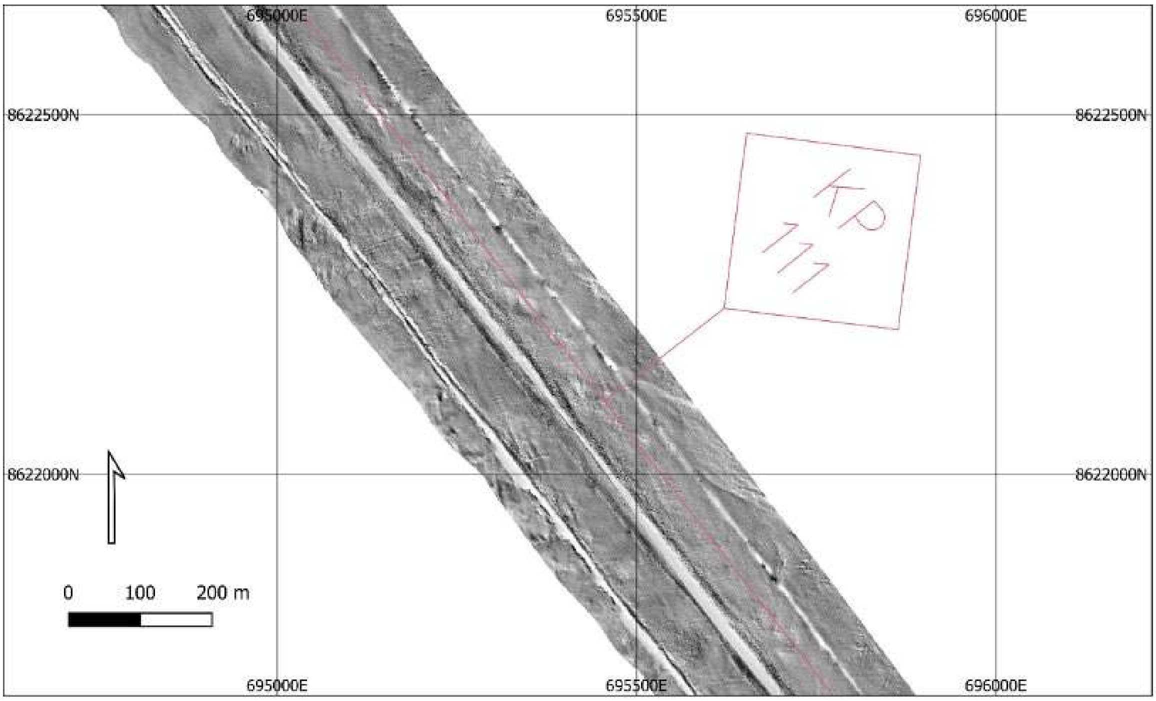


Figure 36: Detail example of SSS data at KP 111.

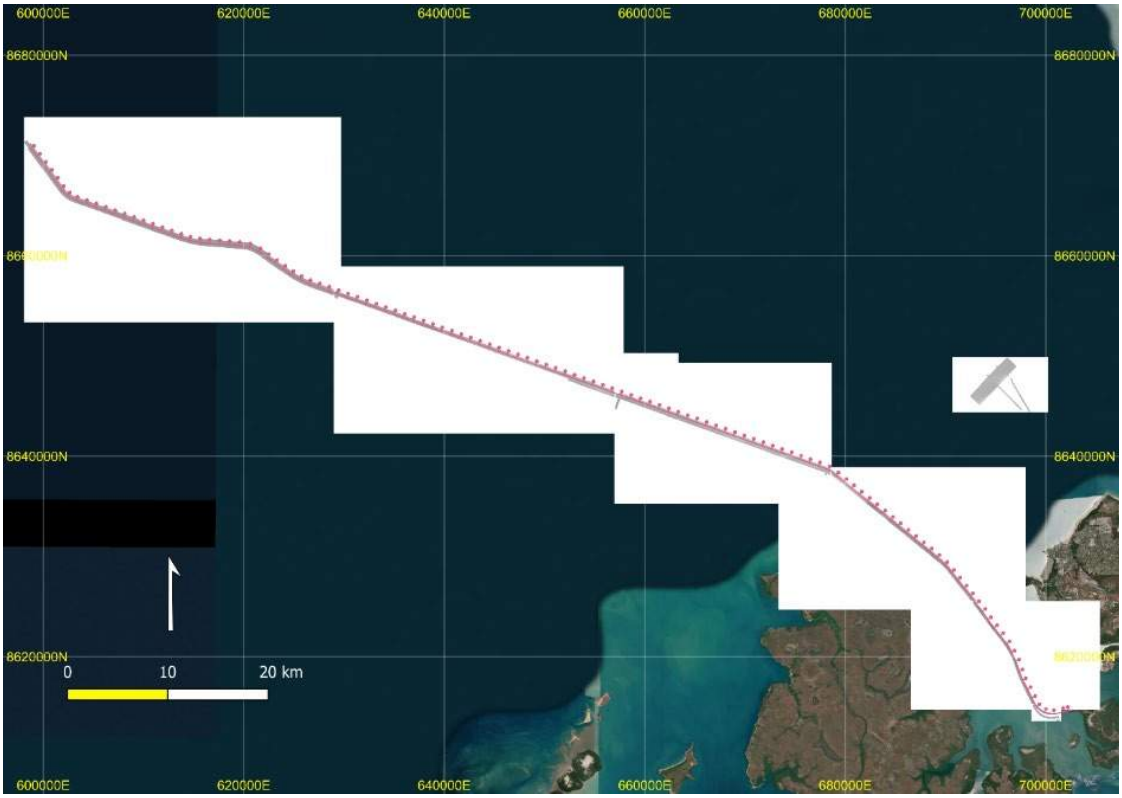


Figure 37: Overview of SSS data provided. Isolated survey location at upper right is proposed spoil dumping ground and has not been assessed as part of this study.

Table 7: SSS targets identified by FUGRO.

Contact ID	Easting	Northing	KP	Lateral Offset (m)	Target Length (m)	Target Width (m)	Target Height (m)	Comments
NCL_SC_001	700 423.74	8 614 259.84	120.575	14.2	2	0.6	0.5	Interpreted as possible debris
NCL_SC_002	698 297.94	8 616 489.78	117.323	-11.6	0.9	0.4	0.3	Interpreted as possible debris
NCL_SC_003	696 916.66	8 619 697.08	113.822	-18.7	1	0.9	0.5	Likely Cable Support
NCL_SC_004	696 907.83	8 619 708.85	113.807	-15.9	1	1	0.6	Likely Cable Support with indicated floating feature
NCL_SC_005	696 407.33	8 620 690.74	112.705	-0.2	5.4	4.8	2.2	Interpreted area of boulders
NCL_SC_006	696 419.44	8 620 731.18	112.674	-28.9	15.2	2.6	4.1	Interpreted area of boulders
NCL_SC_007	696 392.69	8 620 736.62	112.658	-7.3	37.9	4.8	4.1	Interpreted area of boulders
NCL_SC_008	695 229.68	8 622 439.49	110.594	-29.6	4.4	4.2	2.3	Interpreted as possible boulder
NCL_SC_009	695 133.04	8 622 512.87	110.476	1.6	19.4	9.8	2.2	Interpreted area of boulders
NCL_SC_010	694 982.00	8 622 822.59	110.139	-69.5	17.2	0.4	0.0	Interpreted as linear debris
NCL_SC_011	694 570.93	8 623 163.28	109.618	45.6	7.9	3	0.0	GEP Support
NCL_SC_012	694 554.56	8 623 338.56	109.47	-49.1	1.7	0.6	0.5	Interpreted as possible debris
NCL_SC_013	694 194.43	8 623 694.54	108.967	16.4	2.4	0.9	0.3	Interpreted as possible debris
NCL_SC_014	694 154.18	8 623 697.79	108.94	46.1	5.6	3.1	0.0	GEP Support
NCL_SC_015	694 149.50	8 623 705.26	108.931	45.2	4.8	3.1	0.0	GEP Support
NCL_SC_016	694 168.64	8 623 820.49	108.85	-39.5	3.5	1.6	0.3	Likely Cable Support
NCL_SC_017	693 408.43	8 624 885.18	107.544	-42.5	2.2	1.6	1.6	Likely Cable Support
NCL_SC_018	693 397.60	8 624 896.59	107.528	-41.6	3.7	1.5	1.6	Likely Cable Support
NCL_SC_019	693 392.07	8 624 908.88	107.515	-45.2	3.2	0.5	0.5	Likely Cable Support
NCL_SC_020	693 289.83	8 624 881.53	107.472	51.4	1.2	0.7	1.0	Likely Cable Support
NCL_SC_021	693 256.72	8 625 008.55	107.351	-0.7	1.2	0.7	0.3	Likely Cable Crossing
NCL_SC_022	693 204.05	8 625 169.57	107.192	-57.9	7.3	0.5	0.8	Likely rock outcrop
NCL_SC_023	693 194.32	8 625 167.23	107.188	-48.7	3.3	3	1.4	Likely Cable Support
NCL_SC_024	693 197.88	8 625 175.94	107.183	-56.9	1.6	1.2	0.6	Likely as possible boulder
NCL_SC_025	693 173.38	8 625 221.05	107.133	-65.2	2.4	1.2	0.6	Likely Cable Support
NCL_SC_026	693 033.94	8 625 246.57	107.027	29.2	2.2	1.1	2.1	Likely Cable Support
NCL_SC_027	692 377.30	8 626 358.51	105.749	-140.6	3.8	0.6	0.5	Interpreted as possible debris
NCL_SC_028	692 201.01	8 626 347.87	105.646	2.8	5.9	1.7	0.3	Interpreted as possible boulders
NCL_SC_029	692 113.89	8 626 472.65	105.494	-8.4	7.3	4.9	1.0	Interpreted as possible boulders
NCL_SC_030	692 203.88	8 626 576.45	105.471	-143.7	2.7	0.5	0.8	Interpreted possible depression
NCL_SC_031	691 780.61	8 626 909.95	104.945	-26	1.4	0.7	0.3	Interpreted as possible debris
NCL_SC_032	691 794.14	8 626 925.97	104.941	-46.6	5.9	3.9	0.7	Interpreted seabed depression
NCL_SC_033	691 531.47	8 627 231.14	104.538	-35.5	3.9	3	0.5	Interpreted as boulders area
NCL_SC_034	690 883.80	8 628 009.18	103.526	-18.2	2.4	2.2	1.8	Interpreted as possible boulders
NCL_SC_035	690 884.02	8 628 053.80	103.49	-45.7	5.4	3.4	0.5	Interpreted as possible debris
NCL_SC_036	690 874.11	8 628 054.11	103.484	-38.1	3.2	2.1	1.4	Interpreted as possible boulders
NCL_SC_037	690 850.08	8 628 066.18	103.46	-26.5	6.4	2.1	1.4	Interpreted as possible boulders

Contact ID	Easting	Northing	KP	Lateral Offset (m)	Target Length (m)	Target Width (m)	Target Height (m)	Comments
NCL_SC_038	690 694.00	8 628 289.49	103.188	-40.4	4.3	3.1	1.2	Interpreted as possible boulder
NCL_SC_039	690 654.94	8 628 293.38	103.161	-11.9	10.8	9.1	2.2	Interpreted as possible boulders
NCL_SC_040	690 656.57	8 628 303.24	103.154	-19.3	3.4	1.6	1.3	Interpreted as possible boulders
NCL_SC_041	690 751.17	8 628 441.21	103.103	-178.6	18.5	7.2	0.6	Unknown contact
NCL_SC_042	690 507.00	8 628 467.70	102.932	-2.1	4.7	3.3	1.5	Interpreted as possible boulder
NCL_SC_043	690 594.22	8 628 586.13	102.892	-143.7	5.6	1.6	1.1	Interpreted as possible item of debris
NCL_SC_044	690 589.91	8 628 584.83	102.891	-139.5	4	1.3	0.9	Interpreted as possible debris
NCL_SC_045	690 572.03	8 628 605.50	102.863	-138	5.2	1.7	0.9	Interpreted as possible debris
NCL_SC_046	690 576.71	8 628 624.49	102.851	-153.4	5	1.4	0.3	Interpreted as possible debris
NCL_SC_047	689 666.39	8 629 478.40	101.621	-47	22.8	0	0.0	Interpreted as possible linear debris
NCL_SC_048	689 718.75	8 629 576.50	101.595	-155	2.3	1.2	0.4	Interpreted as possible debris
NCL_SC_050	689 665.26	8 629 484.58	101.616	-50.9	1.9	1.6	1.5	Interpreted as possible debris
NCL_SC_049	681 875.94	8 635 783.35	91.6	-1.89	2.47	0.32	NA	Possible linear contact, Debris

6.2.2 *Multi-beam sonar*

Multi-beam bathymetry for the entire route was provided as high-resolution geo-tiffs with colouring and shading to designate elevation changes. MBES resolution was 0.5m.

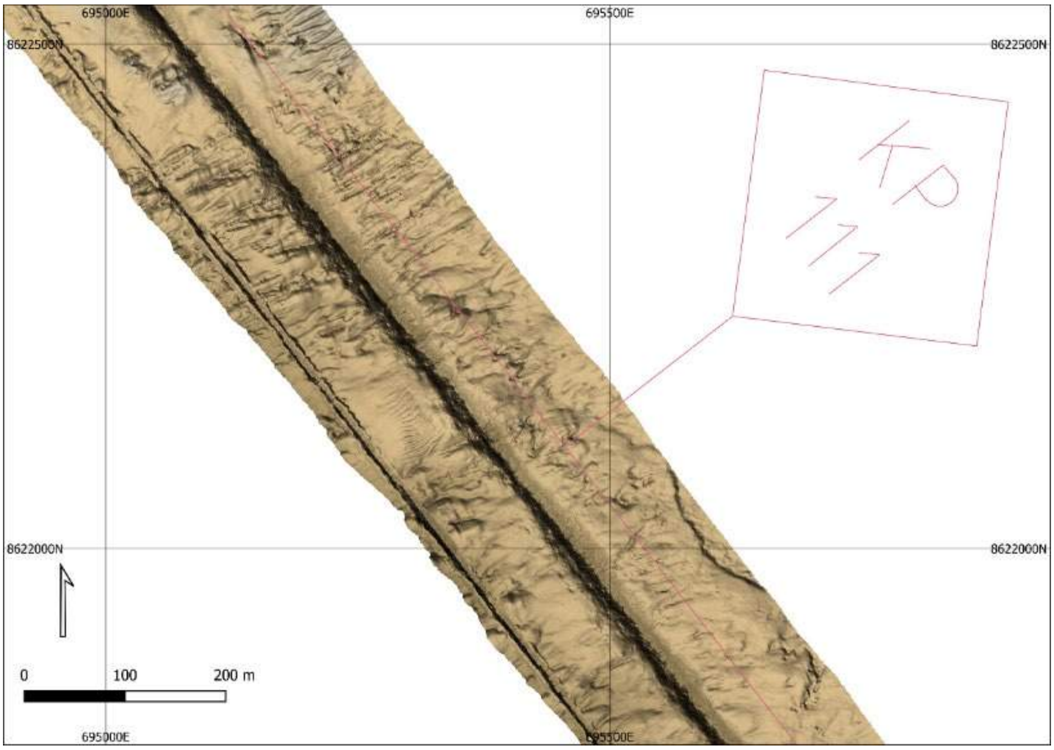


Figure 38: Example of MBES data provided at KP 111. Note INPEX GEP and Bayu-Undan pipeline clearly visible.

A second set of multi-beam data was provided 13 April 2022 as an XYZ data file. This second set of data was recorded by FUGRO in 2021 and is higher resolution (0.25m). The second MBES data set covers roughly the last third of the proposed pipeline route, from approximately KP 87 to the terminus.

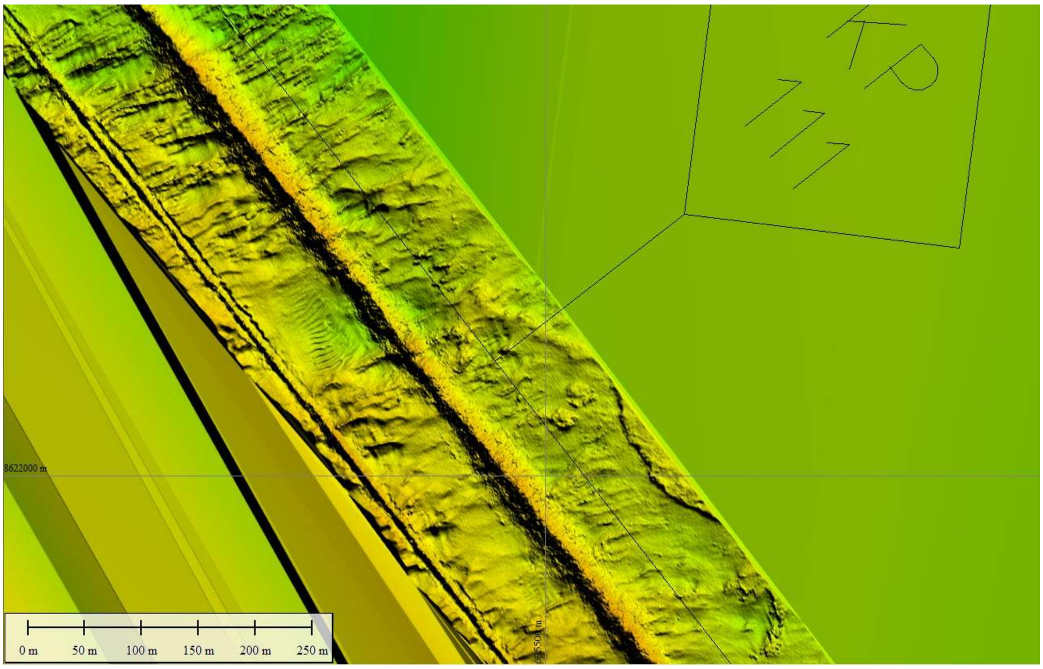


Figure 39: Example of 2022 MBES data with higher resolution (0.25m) in approximately the same location as previous figure.

The anchoring corridor for the proposed works, located between KP 91.5 and the terminus, is wider than the geophysical survey corridor. Therefore, public MBES data covering the entirety of Darwin Harbour was examined to identify underwater cultural heritage located in the area between the Fugro survey corridor and the anchoring corridor (see Figure 40 and Figure 41). This publicly available dataset is published by Geoscience Australia and consists of 1 m resolution gridded MBES data.[103]

[103] **Siwabessy, P.J.W., Smit, N., Nicholas, W.A., Nansen, R., Picard, K. 2020.** Data package – Darwin Harbour Habitat Mapping Program, Northern Territory. Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/127494.

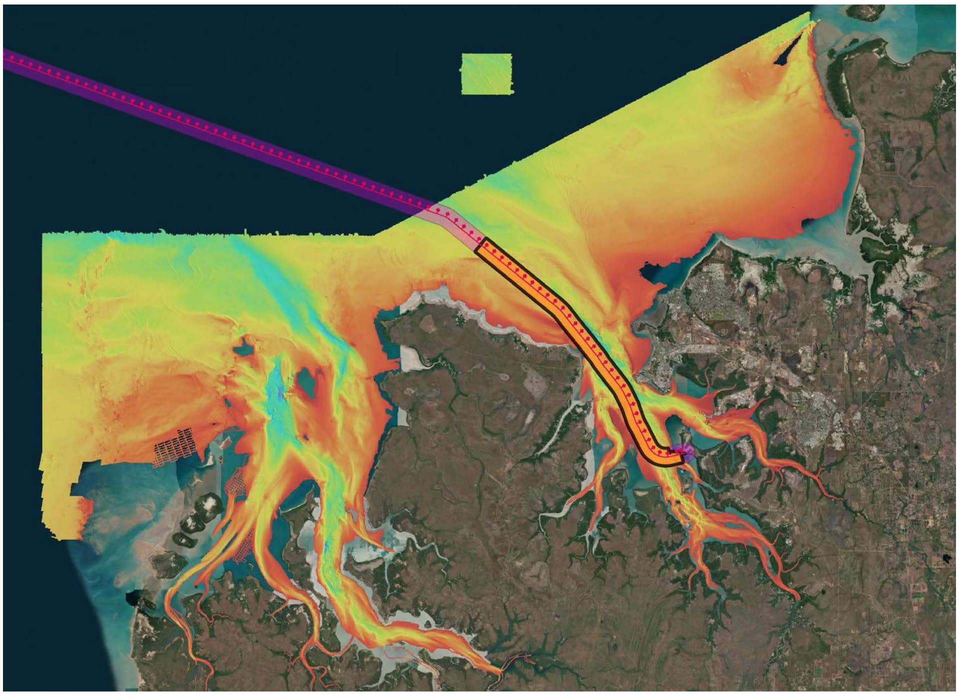


Figure 40: Overview of total coverage of public Darwin Harbour MBES data. Study area in purple, anchoring corridor in orange.

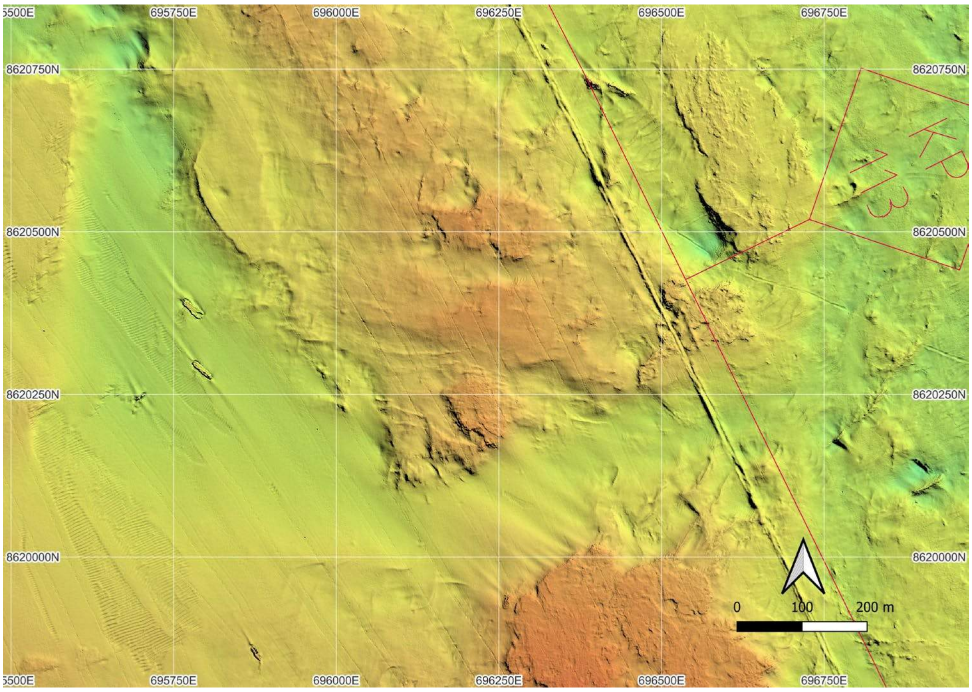


Figure 41: Detail of same dataset at KP 113, showing GEP route and several shipwrecks at left.

6.2.3 *Magnetometer*

Magnetometer data was collected from a single channel mag and provided as a shapefile of georeferenced points. Additionally, the same magnetic anomaly contacts were provided as part of a report delivered by FUGRO in April 2022 (see Table 8).[104]

Magnetometer data was collected using a SeaSpy magnetometer deployed behind the combined SSS/SBP system via an 11m long cable. Altitude of the magnetometer was approximately 1.5m lower than that of the SSS/SBP, and therefore achieved results at elevations less than ~10m above the seafloor.[105]

Due to the tow height and line spacing of the MAG survey, actual locations of magnetic contacts given are approximate and may not be located directly below survey lines. Their locations are proportional to the distance of the magnetic sensor to detected object. Therefore, actual magnetic contacts may be laterally offset to the magnetic survey lines.[106]

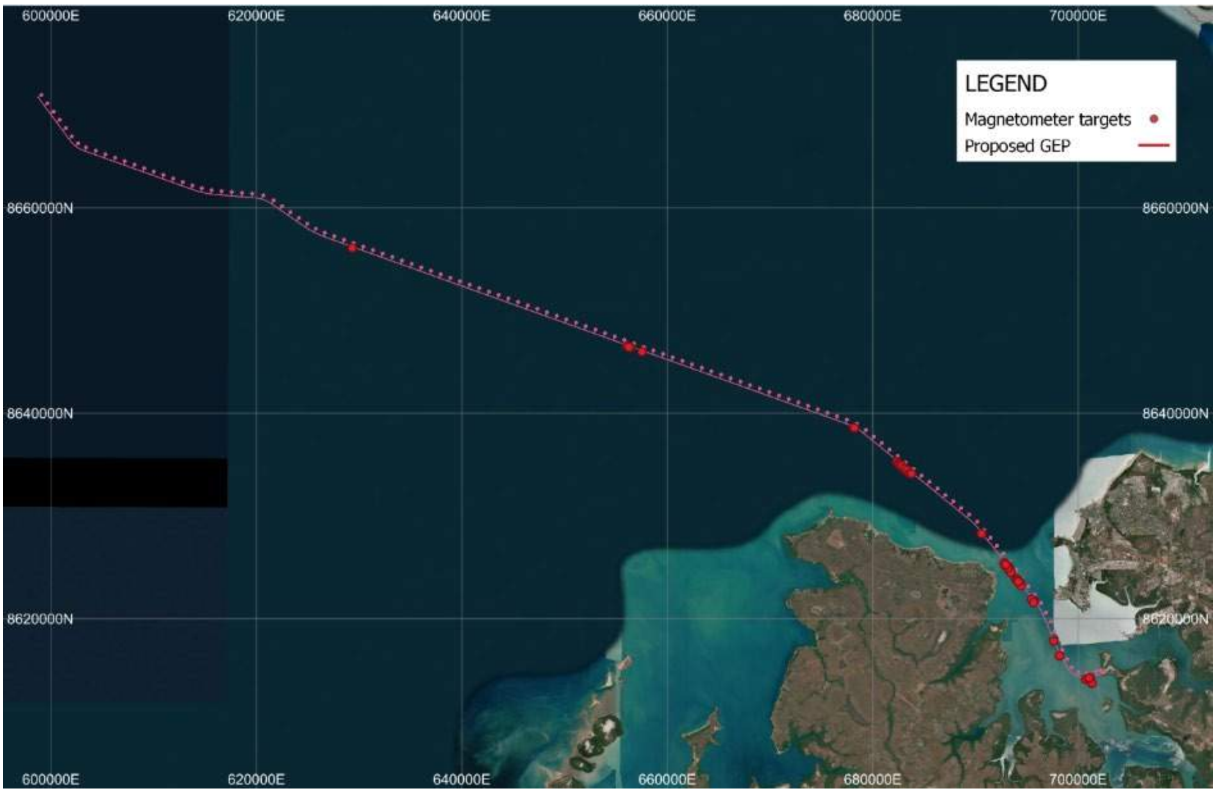


Figure 42: Locations of magnetometer targets provided by FUGRO survey.

Table 8: List of magnetometer strikes provided by FUGRO.

Contact ID	Easting	Northing	KP	Lateral Offset	Magnetic Intensity (nT)	Magnetic sensor altitude	Comments
MA_051	629 303.20	8 656 083.30	35.014	112.6	36.8	20	Bayu-Undan GEP
MA_038	682 530.80	8 635 126.40	92.524	93	225.7	13.5	Bayu-Undan GEP
MA_039	682 697.00	8 634 980.60	92.745	100.9	596.4	10.2	Bayu-Undan and Icthys GEPs
MA_040	682 824.80	8 634 880.90	92.907	97.3	168.3	15.2	Bayu-Undan GEP

[104] **FUGRO, 2022,** *Results Report – North Route 2 – Offshore Geophysical Survey (Work Package 1): Barossa Pipeline to Shore Project, Darwin,* report prepared for Santos NA Barossa Pty Ltd.
[105] *Op. Cit.* **FUGRO, 2022:**13.
[106] *Op. Cit.* **FUGRO, 2022:**14.

Contact ID	Easting	Northing	KP	Lateral Offset	Magnetic Intensity (nT)	Magnetic sensor altitude	Comments
MA_041	682 820.00	8 634 759.60	92.980	194.3	139.5	10.8	Icthys GEP
MA_042	683 109.80	8 634 510.30	93.362	204.3	47.1	16.2	Icthys GEP
MA_043	683 119.80	8 634 630.10	93.294	105.1	42.7	18.2	Bayu-Undan GEP
MA_044	683 371.80	8 634 440.50	93.609	92.7	182.1	12.3	Bayu-Undan GEP
MA_045	683 329.80	8 634 341.30	93.640	196.1	101.9	14	Ichthys GEP
MA_046	683 585.80	8 634 131.90	93.970	196.5	302.8	12	Ichthys GEP
MA_047	683 772.10	8 634 111.30	94.128	94.6	88.6	15	Bayu-Undan GEP
MA_048	656 411.80	8 646 395.20	63.802	96.3	22.4	6.2	Bayu-Undan GEP
MA_049	656 056.10	8 646 529.60	63.422	89.6	119.5	25.1	Bayu-Undan GEP
MA_050	656 258.10	8 646 432.00	63.645	113.4	31.7	16.3	Bayu-Undan GEP
MA_052	657 533.60	8 645 980.50	64.998	108.6	33.2	9.4	Bayu-Undan GEP
MA_053	678 201.60	8 638 571.20	86.966	94.3	16.3	25.7	Bayu-Undan GEP
MA_001	697 628.20	8 617 803.70	115.846	-35.3	13.3	14.2	Inferred Buried Debris
MA_002	693 037.60	8 625 230.40	107.042	36.3	33.6	19.4	Inferred Cable Infrastructure
MA_003	693 280.20	8 624 938.20	107.421	24	19.1	26.5	Inferred Cable
MA_004	694 088.70	8 623 805.80	108.816	34.2	23.8	29.2	Inferred Cable
MA_005	694 270.00	8 623 584.10	109.101	24.6	11.2	28.1	Inferred Cable
MA_006	694 340.30	8 623 487.70	109.22	28.3	53	27.7	Inferred Cable
MA_007	695 763.20	8 621 695.50	111.508	6.4	21.5	17.1	Inferred Buried Debris
MA_008	694 368.90	8 623 483.00	109.241	8.6	2.4	21.8	Inferred Cable
MA_009	694 288.70	8 623 586.70	109.11	8.2	10	22	Inferred Cable
MA_010	694 195.20	8 623 712.20	108.954	4.9	45.7	24.7	Inferred Cable
MA_011	693 259.90	8 625 000.50	107.36	1.8	10.1	19.6	Inferred Cable
MA_012	693 160.20	8 625 119.90	107.204	7.2	13.9	14.7	Inferred Buried Debris
MA_013	693 294.80	8 624 761.80	107.565	123.9	57.9	22	Inferred Buried Debris
MA_014	693 327.90	8 624 726.50	107.613	121.4	68.3	20.4	Inferred Buried Debris
MA_015	693 395.30	8 624 640.10	107.723	125.6	101.2	20.8	Inferred Buried Debris
MA_016	693 438.60	8 624 583.40	107.794	129.1	46.3	21.8	Inferred Buried Debris
MA_017	694 427.20	8 623 200.30	109.5	136.2	94.9	20.5	Inferred Cable
MA_018	694 230.10	8 623 485.50	109.154	116.6	33.1	21.9	Inferred Cable
MA_019	694 143.00	8 623 584.60	109.023	124.5	13.5	23.8	Inferred Cable
MA_020	694 041.00	8 623 720.90	108.857	122.3	19.2	23.6	Inferred Cable
MA_021	695 672.30	8 621 568.70	111.553	156	148.8	17.1	Inferred Buried Debris
MA_022	695 454.30	8 621 871.00	111.18	142.3	177.5	21.1	Inferred Buried Debris
MA_023	693 904.20	8 623 870.50	108.663	152.2	802.4	25.1	Inferred Buried Debris
MA_024	694 000.90	8 623 742.90	108.816	142.2	46.5	26.5	Inferred Cable
MA_025	693 425.00	8 624 481.80	107.863	205	137.4	10.1	Inferred Buried Debris
MA_026	693 264.60	8 624 703.70	107.59	184.4	66.8	18	Inferred Buried Debris
MA_027	692 796.90	8 625 441.70	106.727	96.7	936.1	18.6	Bayu-Undan GEP
MA_028	693 130.70	8 624 923.90	107.341	150.8	33.2	18.4	Inferred Cable
MA_029	694 058.20	8 623 721.40	108.864	108.1	30.9	27.2	Inferred Cable

Contact ID	Easting	Northing	KP	Lateral Offset	Magnetic Intensity (nT)	Magnetic sensor altitude	Comments
MA_030	694 165.40	8 623 591.30	109.031	102.7	6.6	25.8	Inferred Cable
MA_031	698 180.90	8 616 372.60	117.376	145.6	34.3	14.6	Inferred Buried Debris
MA_032	701 103.60	8 614 208.70	121.233	106.2	2.4	19.5	Bayu-Undan GEP
MA_033	700 725.60	8 614 092.30	120.866	172.1	16.4	14.5	Bayu-Undan GEP
MA_034	701 167.90	8 614 234.30	121.3	96.1	285.3	10.8	Bayu-Undan GEP
MA_035	701 039.40	8 614 186.30	121.169	115	330.6	16.4	Bayu-Undan GEP
MA_036	701 078.90	8 614 217.70	121.211	91.9	2.1	15.9	Bayu-Undan GEP
MA_037	701 335.50	8 613 704.20	121.335	650.9	32.1	18.3	Ichthys GEP
MA_054	692 947.20	8 625 244.60	106.975	98.9	58.7	5.3	Bayu-Undan GEP
MA_055	692 865.40	8 625 182.90	106.974	201.4	15.3	14.9	Ichthys GEP

6.3 Anomaly Identification

The following table shows the identified geophysical targets, arranged in their priority level for visual survey. The priority level is defined as:

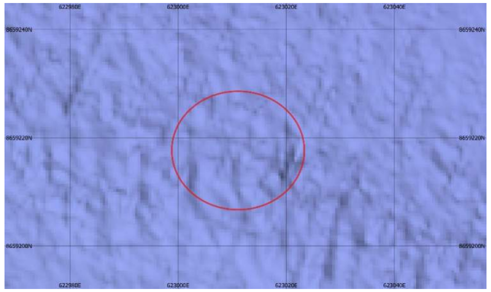
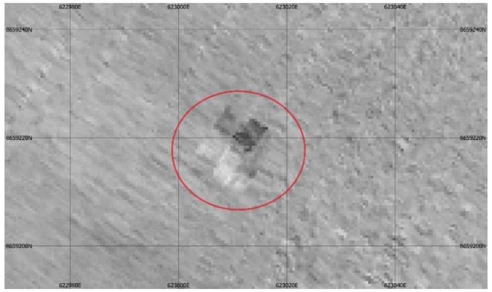
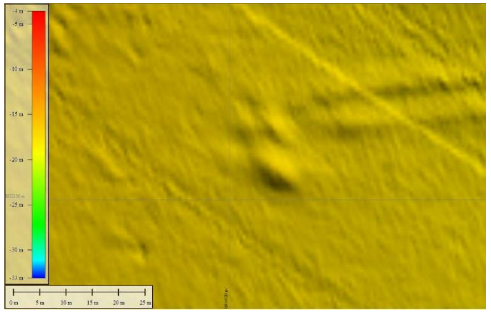
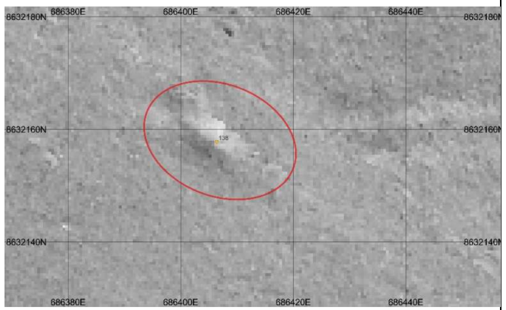
A = Primary – Identified as most likely cultural (unlikely but possibly natural), significance determined by dive survey or ROV

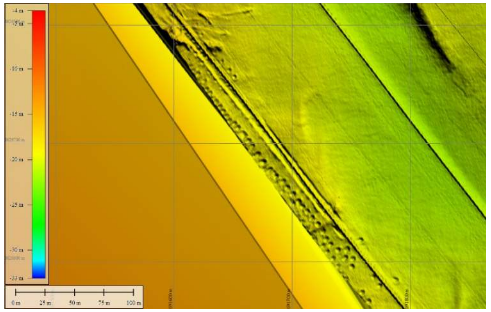
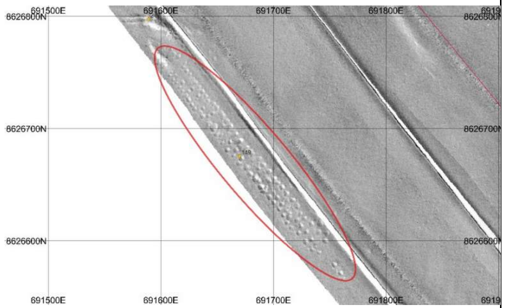
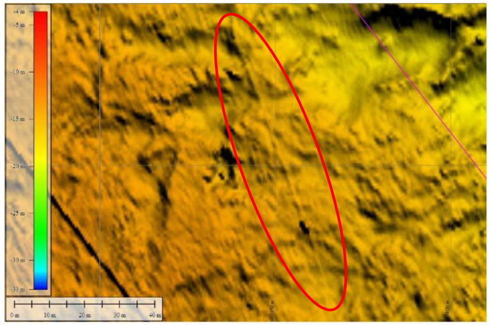
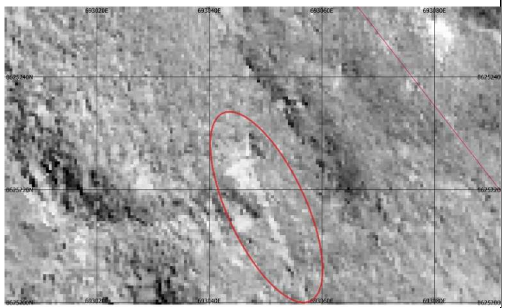
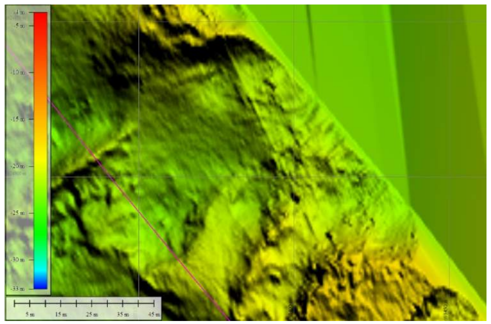
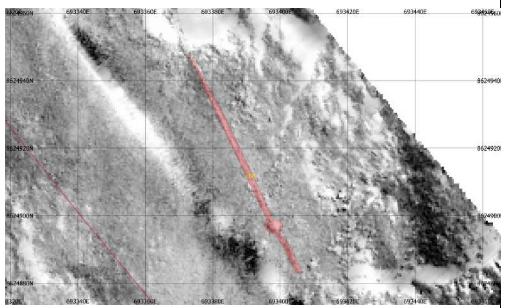
B = Secondary – Possibly cultural, possibly natural, significance determined by dive survey or ROV

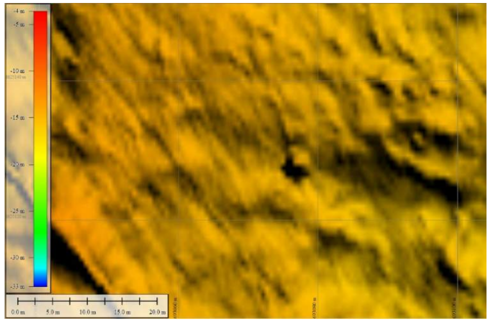
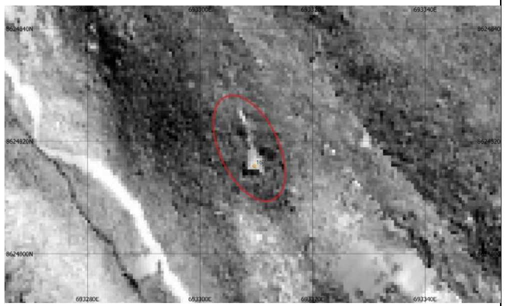
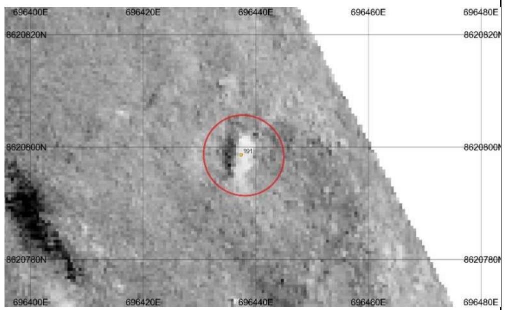
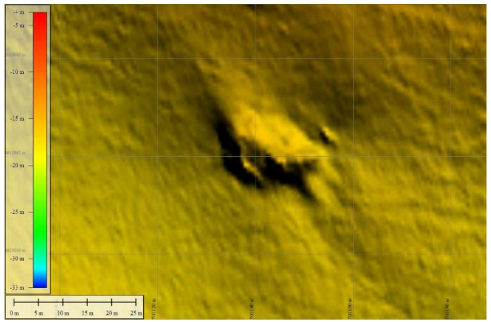
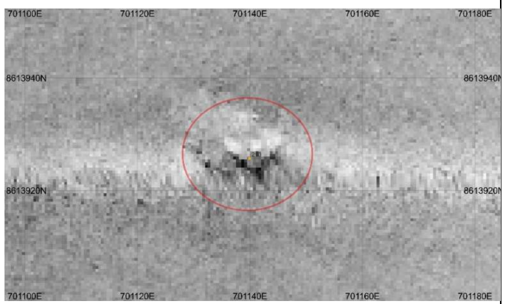
C = Low priority – Identified features determined to be not culturally significant

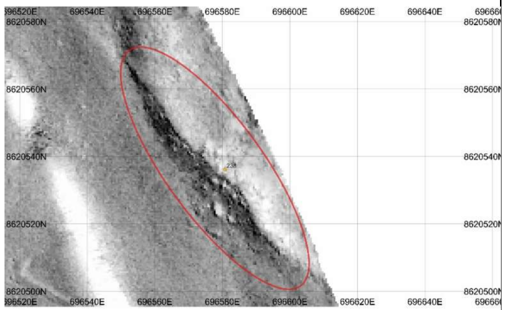
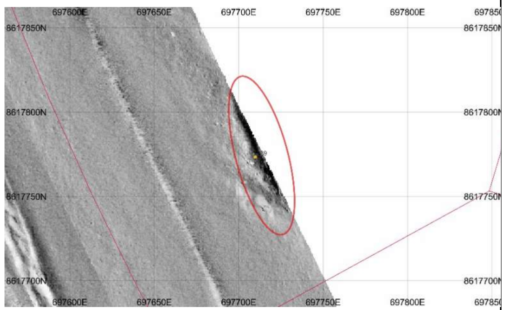
All images are oriented with north at the top. Where available, imagery from the 2022 MBES survey is used. Targets identified by CA are correlated with targets identified by FUGRO where appropriate. Targets surveyed during ROV surveys have IDs marked with *.

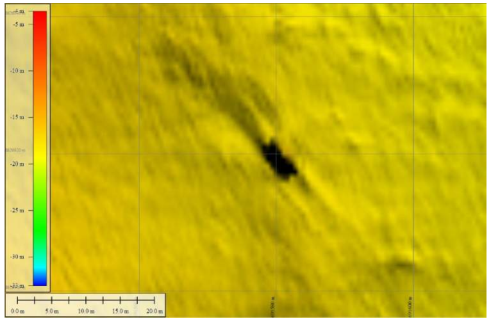
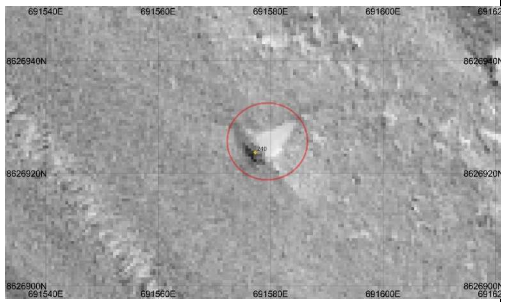
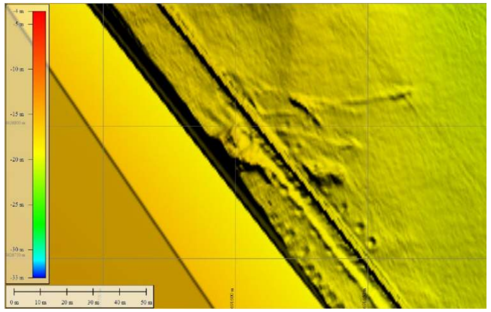
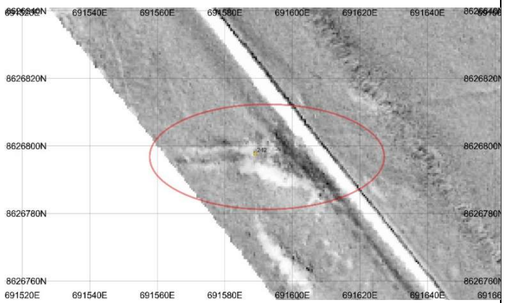
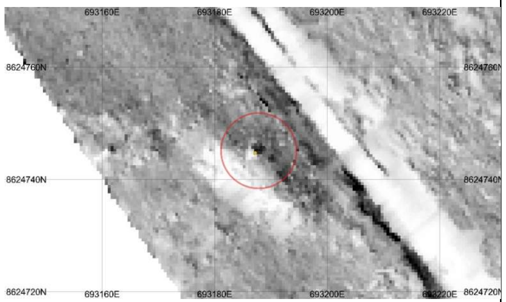
6.3.1 *Targets within survey corridor*

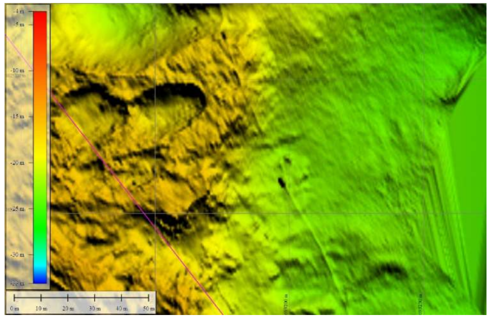
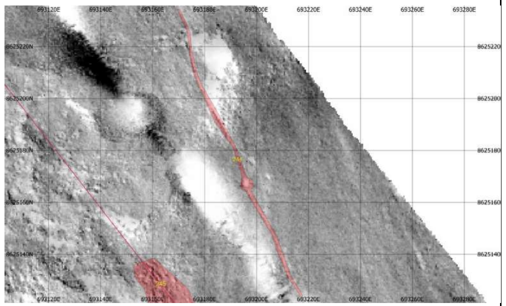
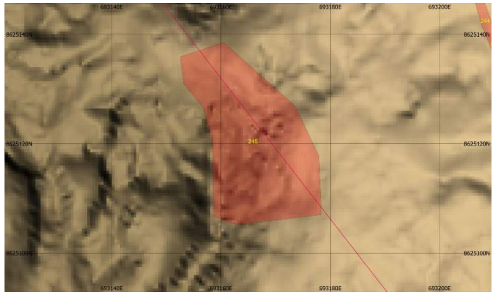
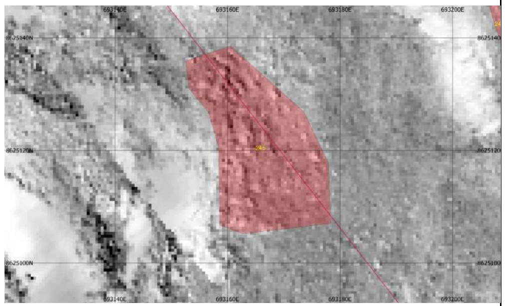
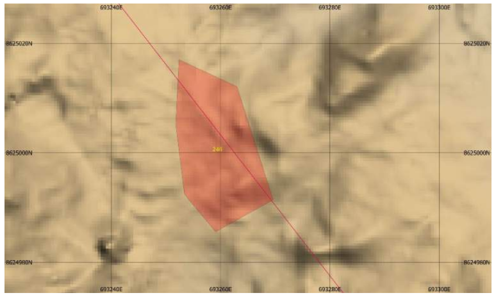
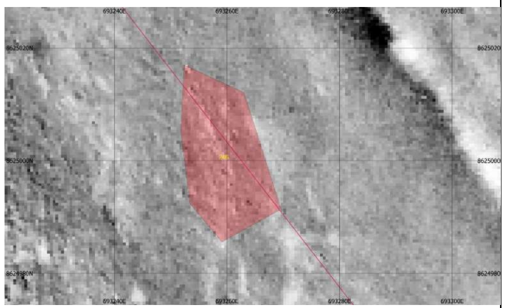
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	112	623 013.42	8 659 220.00			No	Single object of high relief. Possible debris related to I-124.	Length: 8m Width: 6m	46m	68m
A	138	686 407.37	8 632 159.33			No	Mound associated with anchor scars	Length: 13m Width: 16m	17m	59m

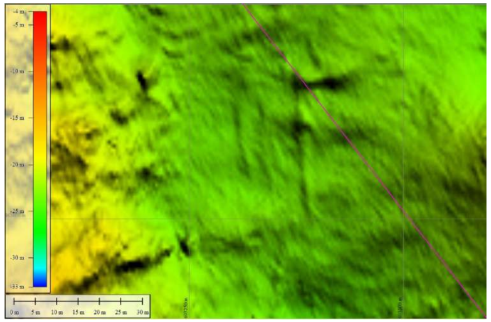
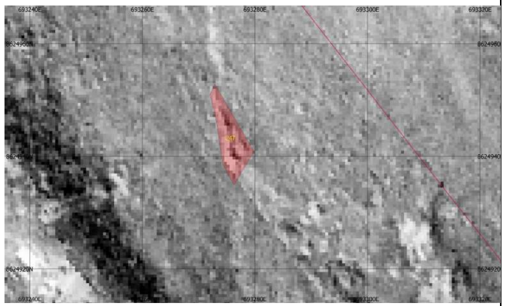
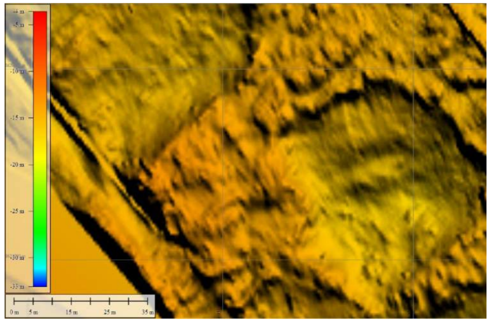
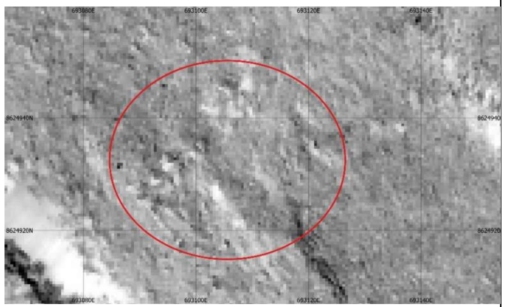
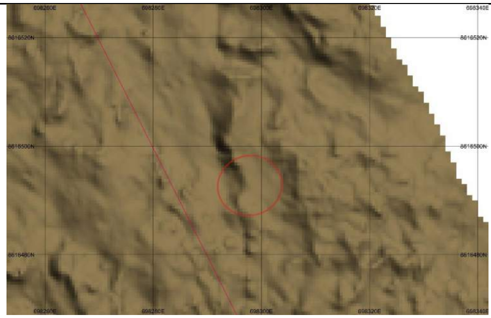
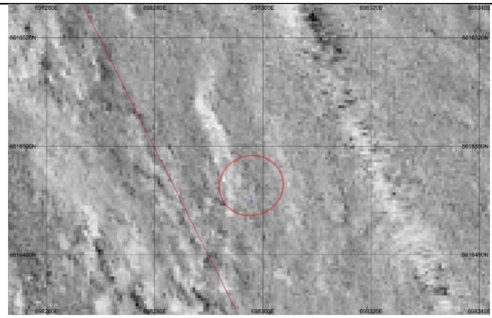
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	149	691 670.76	8 626 677.01			No	Unknown, may be related to pipeline or another cultural feature.	Total length: 258m Total Width: 19m Ind. Diameter: 5m	19m	200m
A	164*	693 038.56	8 625 231.53			Yes, MA_002	Possible 1879 subsea cable remains or anti-sub defences/ net. Likely connected to Target ID: 167 FUGRO ID: NCL_SC_026	Total length: 209m Width: 2m	16m	30m
A	166*	693 399.74	8 624 898.55			No	Series of high relief single objects with connecting line. Possible 1879 subsea cable remains or anti-sub defences. FUGRO ID: NCL_SC_017, 018, 019	Length: 73m Width: 5m	21m	41m

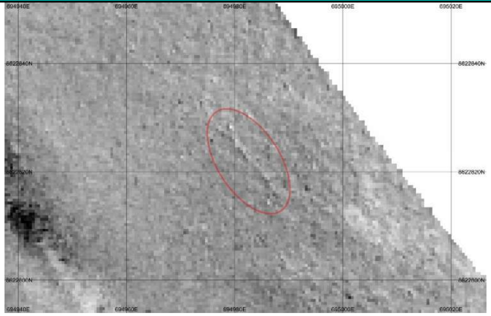
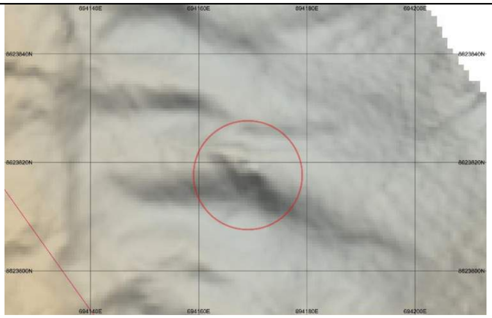
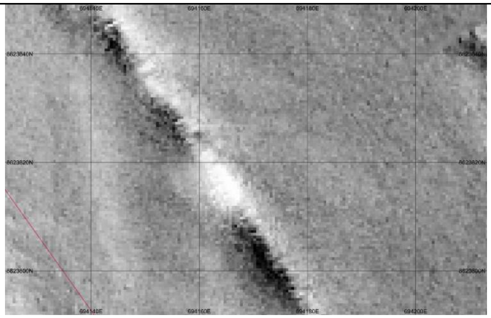
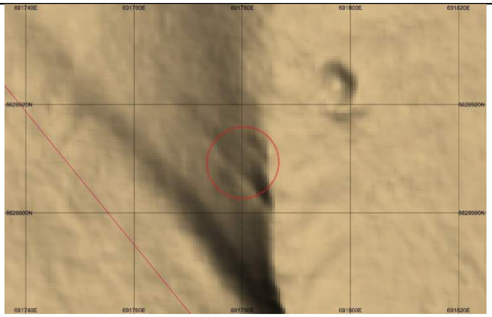
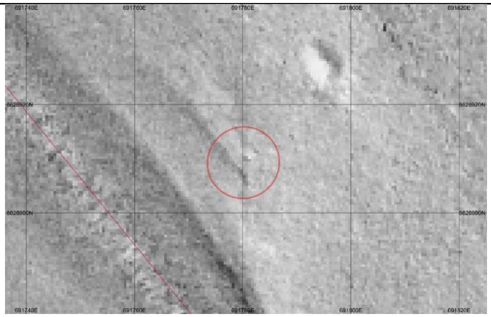
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	167*	693 085.69	8 625 121.75			No	Series of high relief single objects with connecting line. Possible 1879 subsea cable remains or anti-sub defences. Likely connected to Target ID: 164	Length: 3m Width: 3m	16m	76m
A	191	696 438.36	8 620 800.13	N/A		No	Single object of high relief. Possible small boat.	Length: 8m Width: 3m	19m	73m
A	210	701 140.90	8 613 958.61			No	Possible aircraft wreck or natural feature.	Length: 12m Width: 7m	17m	389m

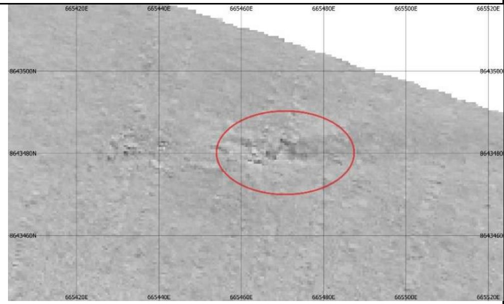
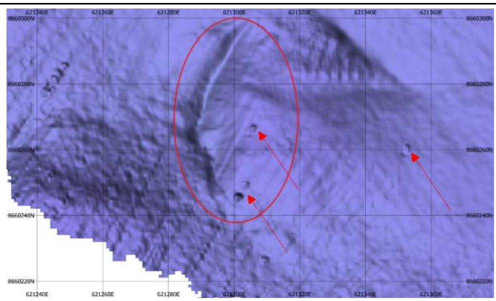
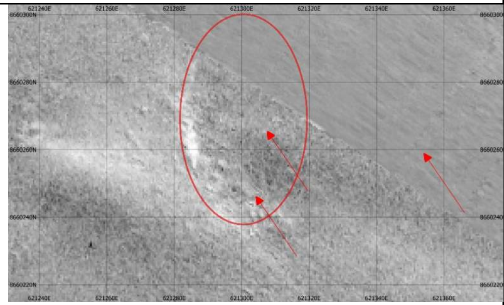
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	234	647 746.21	8 649 692.16			No	Single mound, indicating lone discarded object.	Length: 5m Width: 4m	43m	173m
A	238	696 581.70	8 620 537.67	N/A		No	Possible scattered debris.	Length: 70m Width: 10m	21m	78m
A	239	697 710.77	8 617 774.90	N/A		Yes, MA_001	USAT *Mauna Loa*	Length: 124.97m Width: 16.46m	19m	90m

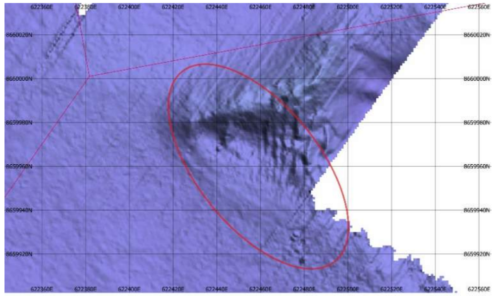
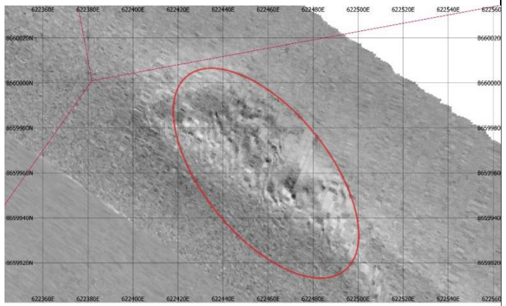
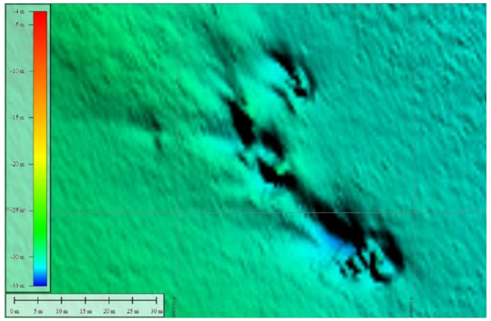
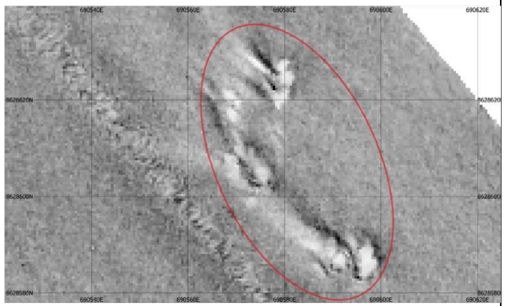
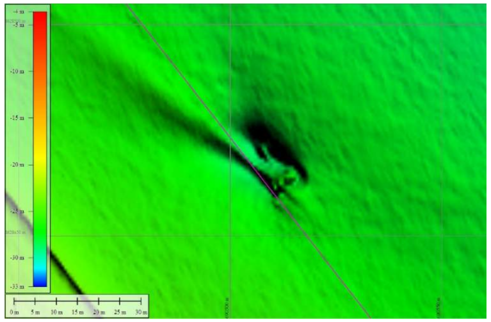
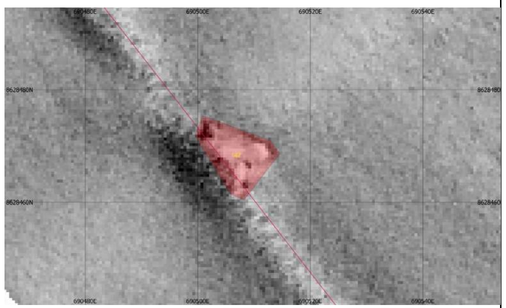
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	240	691 578.22	8 626 925.25			No	Possible mooring block for anti-submarine defences	Length: 4m Width: 2m	16m	122m
A	242	691 589.94	8 626 799.20			No	Steel wire rope and chain associated with anti-submarine defences. (boom net), UXO including mechanical fuses and fuse cones. (See Section 6.4)	Length: 23m Width: 13m	17m	186m
A	243	693 188.00	8 624 746.00	N/A		No	Possible mooring block related to anti-submarine defences.	Length: 2m Width: 2m	15m	216m

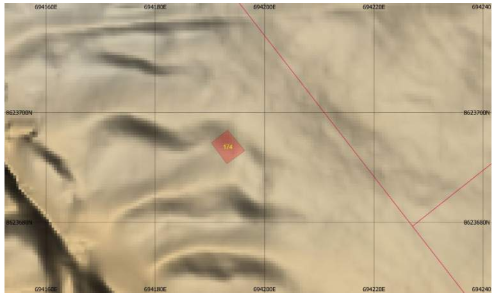
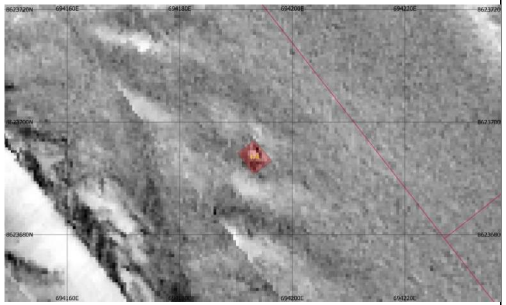
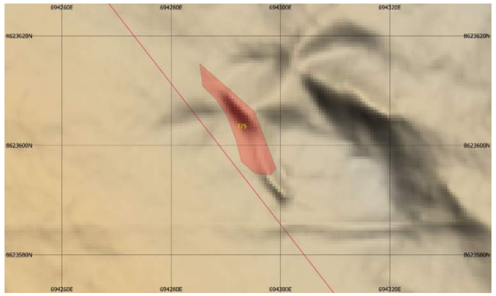
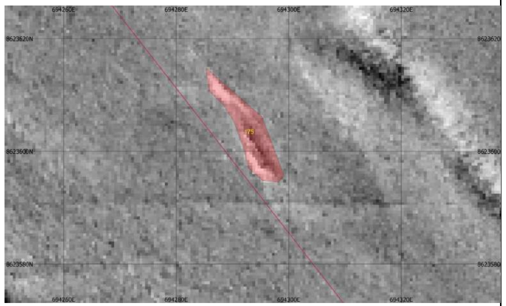
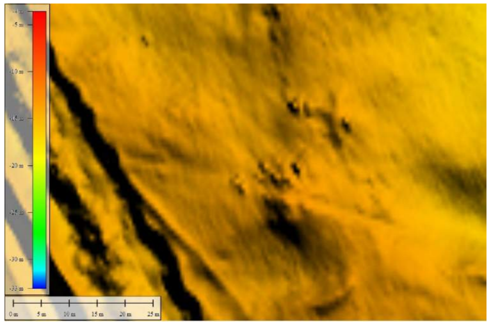
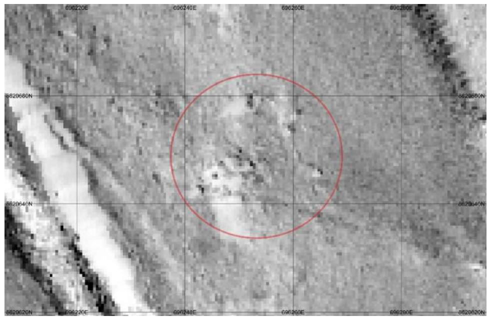
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	244*	693 196.00	8 625 167.00			No	Series of high relief single objects with connecting line. Possible 1879 subsea cable remains or anti-sub defences. FUGRO ID: NCL_SC_022, 023, 024, 025	Total Length: 120m Width: 5m (at arrow)	22m	50m
C	245*	693 161.00	8 625 121.00			Yes, MA_012	Rocks	Length: 38m Width: 22m	16m	0m
C	246*	693 260.86	8 625 002.53			Yes, MA_011	Boulders FUGRO ID: NCL_SC_021	Length: 31m Width: 15m	23m	0m

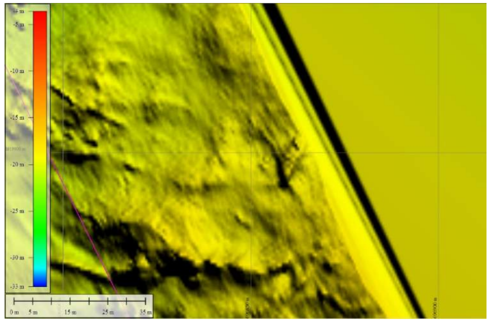
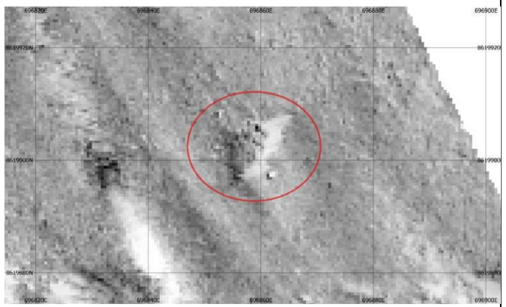
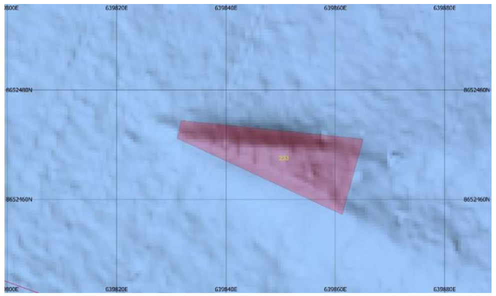
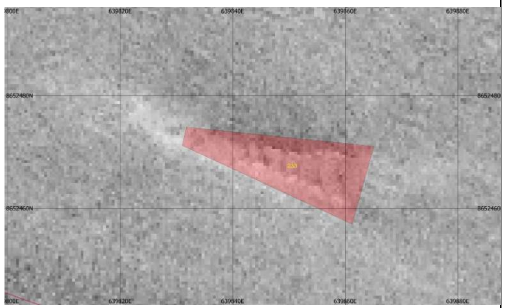
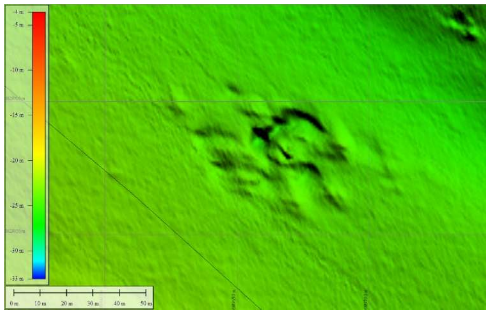
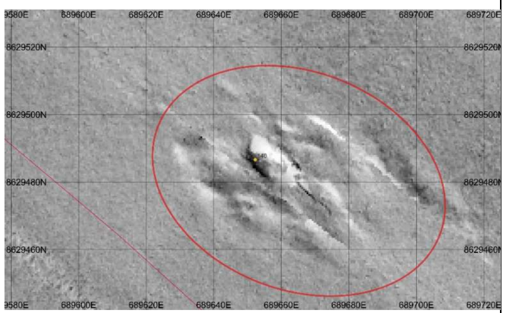
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	247*	693 281.16	8 624 939.53			Yes, MA_003	No cultural material found	Length: 18m Width: 6m	23m	23m
A	248	693 131.66	8 624 925.53			Yes, MA_028	Debris scatter, or possible anti-submarine net remains	Length: var. Width: var.	16m	150m
B	NCL_SC_002*	698 297.94	8 616 489.78			No	Single isolated object, possible debris or natural feature	Length: 1m Width: 0.4m	17m	11m

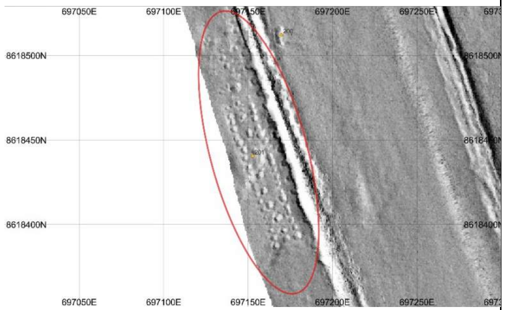
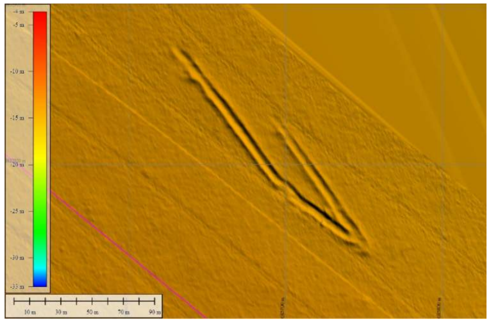
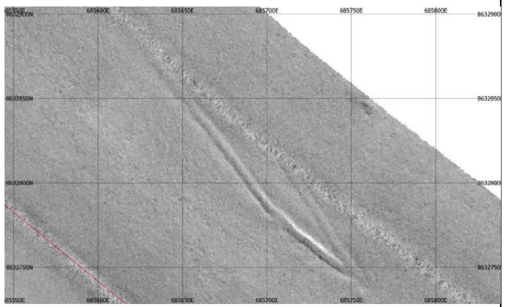
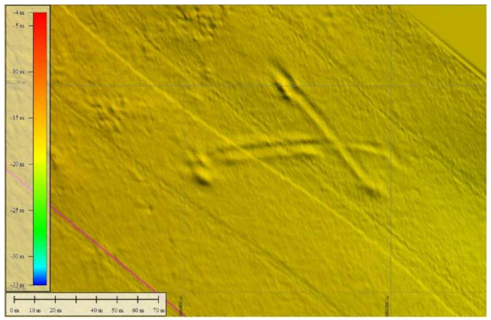
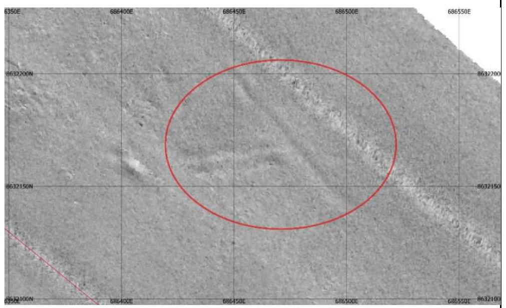
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
B	NCL_SC_010	694 982.00	8 622 822.59	N/A		No	Linear debris, likely cable remains.	Length: 17m Width: 0.5m	20m	70m
B	NCL_SC_016*	694 168.64	8 623 820.49			No	Possible cable support, or isolated non-ferrous object.	Length: 3.5m Width: 1.6m	24m	40m
B	NCL_SC_031*	691 780.61	8 626 909.95			No	Single isolated non-ferrous object, likely debris.	Length: 1.4m Width: 0.7m	16m	26m

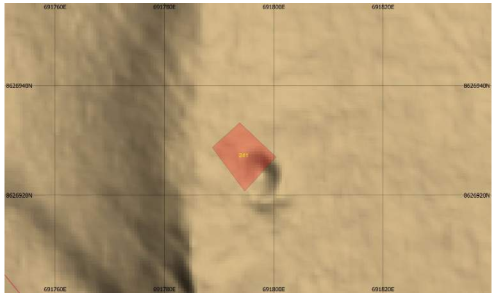
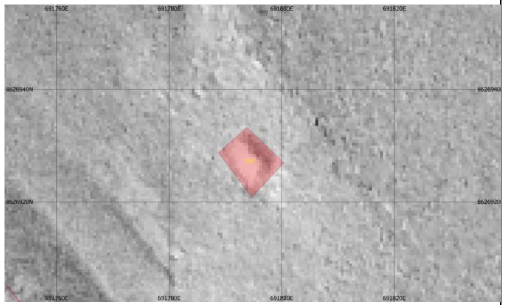
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
B	115	649 361.40	8 649 116.46			No	Shallow depressions with low relief object.	Length: 8m Width: 4m	44m	86m
B	130	665 465.07	8 643 481.67	N/A		No	Possible debris scatter.	Length: 18m Width: 8m	29m	208m
B	135	621 286.34	8 660 259.37			No	Likely natural feature, closest proximity target to I-124	Length: 62m Width: 58m	48m	143m

	Target ID	Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
B	136	622 455.26	8 659 969.89			No	Possible debris scatter or natural feature.	Length: 98m Width: 32m	49m	214m
B	141	690 574.96	8 628 606.67			No	Debris or rocks FUGRO ID: NCL_SC_043, 044, 045, 046	Length: 53m Width: 20m	30m	137m
C	142*	690 511.00	8 628 469.00			No	Boulders FUGRO ID: NCL_SC_042	Length: 15m Width: 12m	29m	0m

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
A	174*	694 194.43	8 623 696.01			Possibly associated with MA_010	Windlass or winch from vessel with rope FUGRO ID: NCL_SC_013	Length: 5m Width: 4m	24m	16m
C	175*	694 295.02	8 623 601.00			Possibly associated with MA_009	Natural ridge	Length: 24m Width: 5m	24m	2m
B	192	696 253.89	8 620 643.48			No	Possible debris	Length: 24m Width: 22m	14m	147m

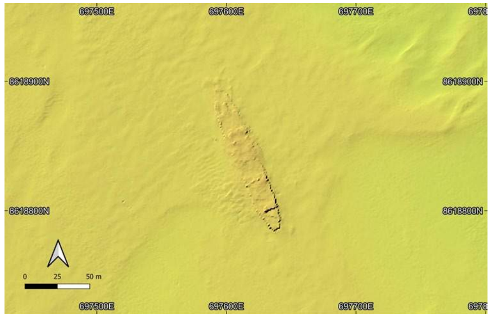
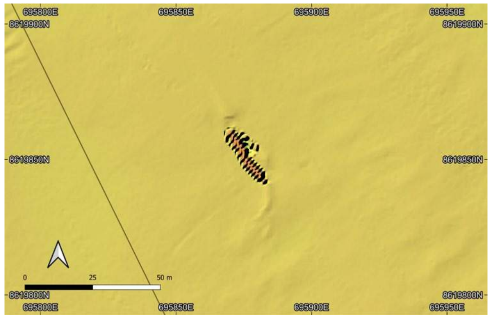
	Target ID	Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
B	196	696 859.94	8 619 902.39			No	Debris or rocks	Length: 9m Width: 6m	19m	53m
B	233*	639 844.98	8 652 470.81			No	Triangular depression, Likely natural feature.	Length: 39m Width: 8m	41m	34m
C	140	689 653.25	8 629 488.15			No	Darwin Harbour Lateral Buoy 5 mooring FUGRO ID: NCL_SC_047, 050	Length: 89m Width: 42m	24m	28m

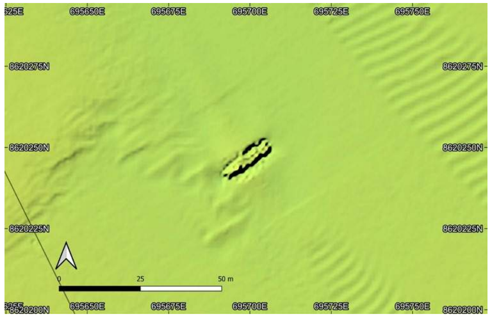
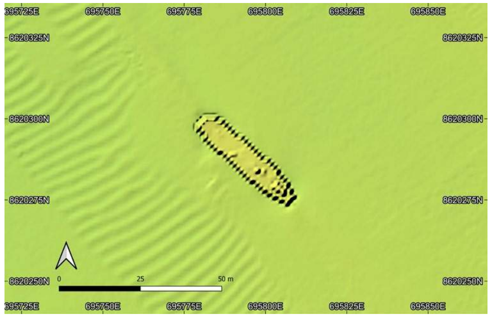
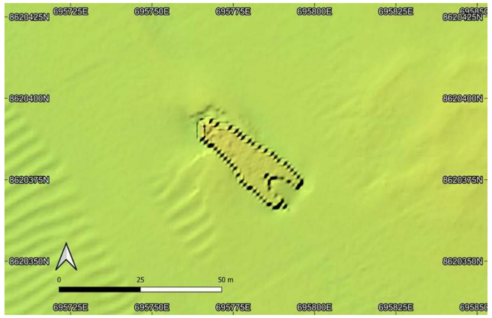
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
C	201	697 153.77	8 618 442.04	N/A		No	Spud marks from BU pipeline construction	Total length: 129m Total Width: 19m Ind. Diameter: 4m	16m	188m
C	235	685 698.53	8 632 788.44			No	Anchor drag	Length: 170m Width: 6m	14m	95m
C	236	686 460.34	8 632 164.86			No	Anchor drag	Length: 89m Width: 7m	18m	72m

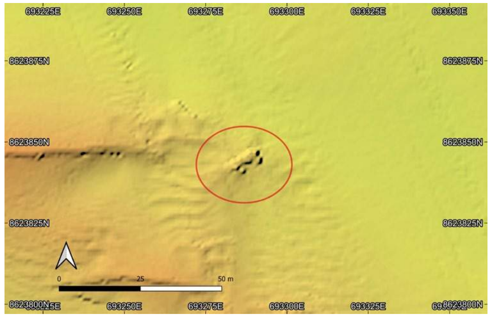
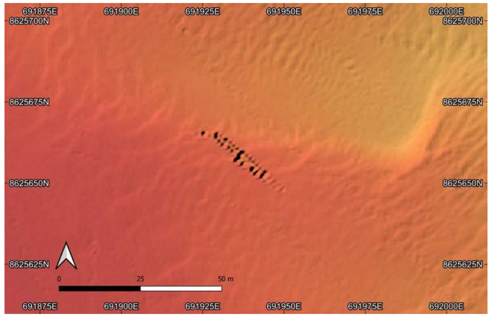
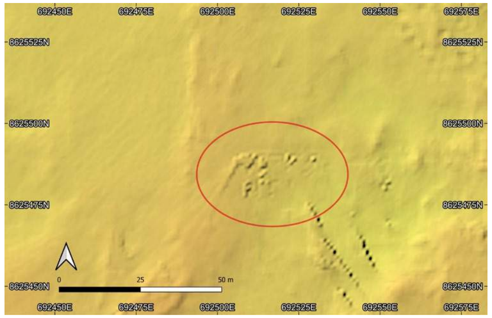
	Target ID	Datum: GDA94 CRS: UTM Zone 52S		Image MB	Image SSS	Mag Target	Interpretation	Dimensions	Depth	Distance from pipeline
		Easting	Northing							
C	241*	691 796.25	8 626 930.15			No	Depression on seabed, possibly cultural, anchor drag. FUGRO ID: NCL_SC_032	Length: 9m Width: 8m	20m	46m

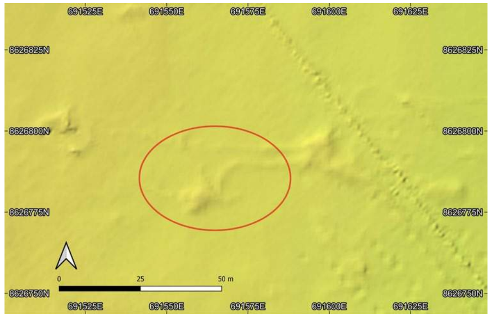
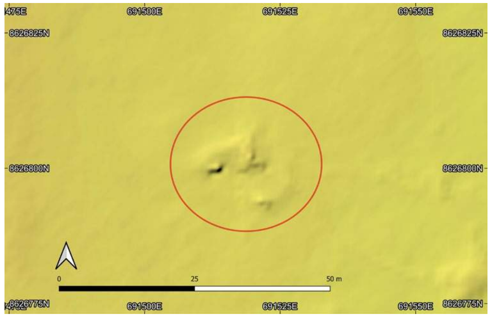
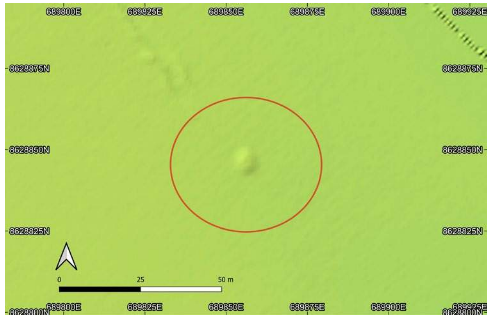
6.3.2 *Targets within anchoring corridor*

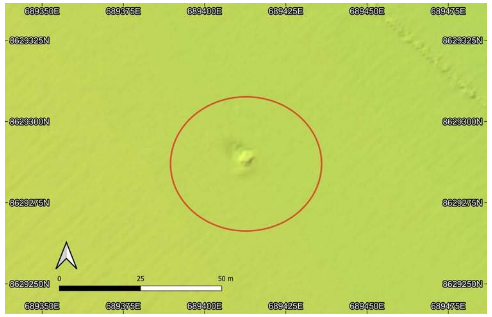
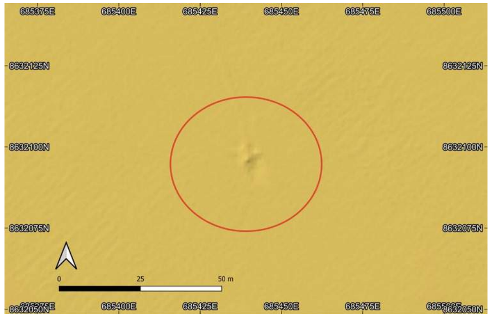
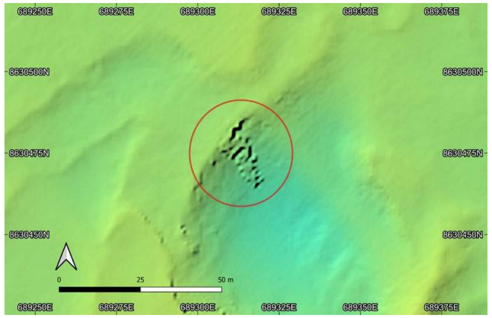
Table 9: Targets within anchoring corridor identified from Darwin Harbour public MBES data.

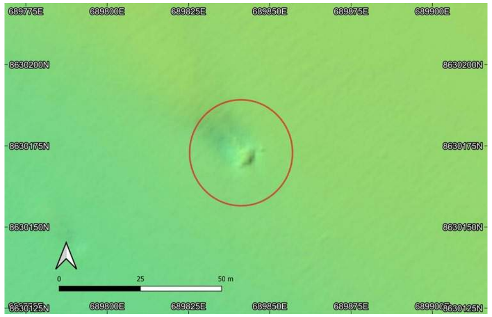
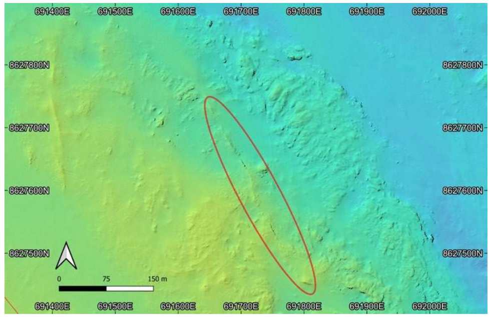
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	500	697,615.17	8,618,840.23		USAT Meigs	121.00	20.00	3.30	20	369
A	501	695,875.84	8,619,850.01		Medkhanun 3	25.00	8.00	7.00	19	847

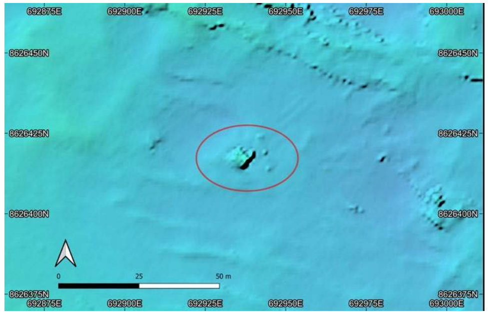
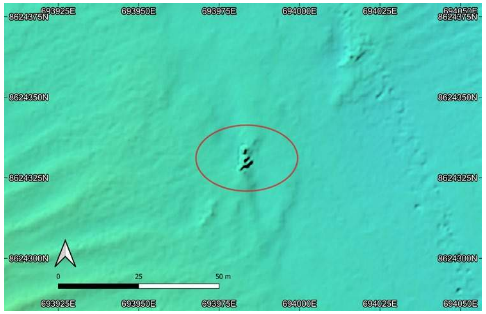
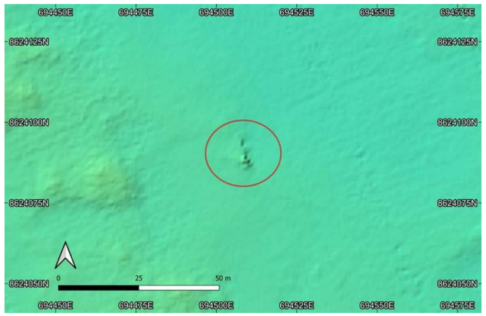
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	502	695,698.81	8,620,246.53		Ham Luong	18.00	5.00	3.00	25	832
A	503	695,794.02	8,620,287.72		Song Saigon	40.00	10.00	5.00	24	728
A	504	695,778.93	8,620,381.31		John Holland Barge	38.00	15.00	5.00	25	700

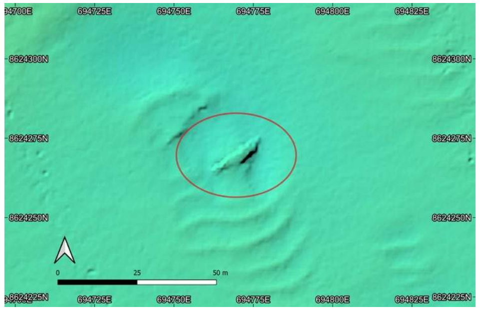
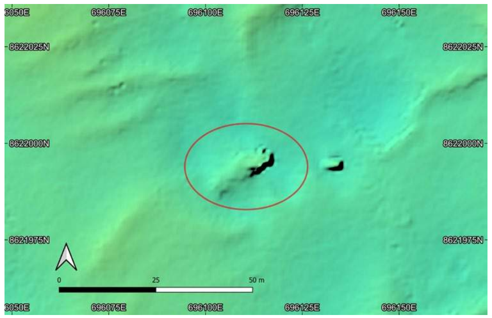
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	505	693,287.42	8,623,844.84		Mandorah Queen	12.00	5.00	2.00	20	683
A	506	691,938.35	8,625,657.51		NR Diemen	29.00	5.00	0.00	8	642
A	573	692,508.78	8,625,489.01		Debris	26.00	15.00	0.50	17	295

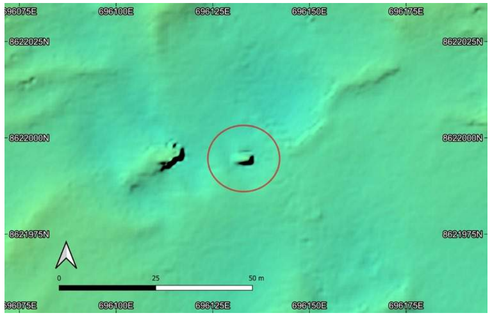
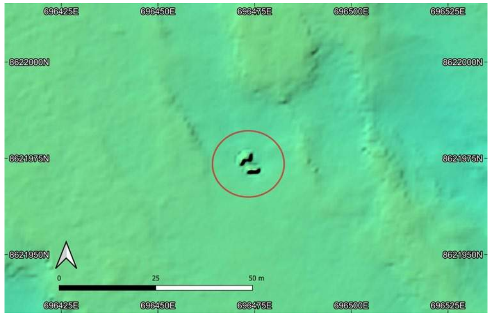
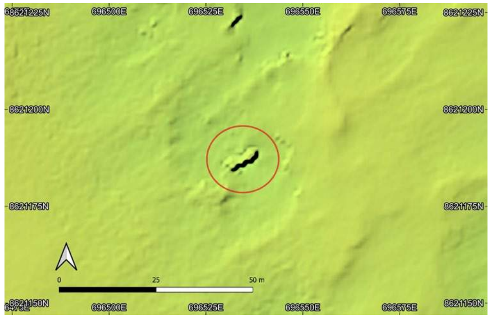
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	574	691,574.41	8,626,791.47		WWII anti-sub boom net	41.00	21.00	1.00	21	209
A	575	691,518.71	8,626,801.77		Debris	10.00	6.00	0.75	20	245
B	576	689,856.12	8,628,847.08		Mound	7.00	6.50	0.40	25	268

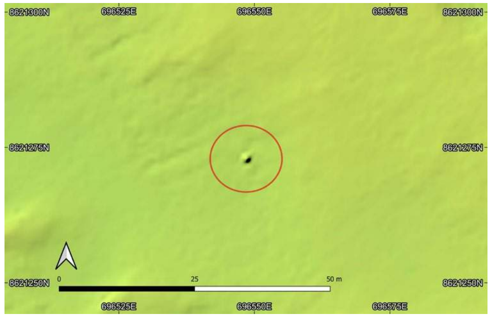
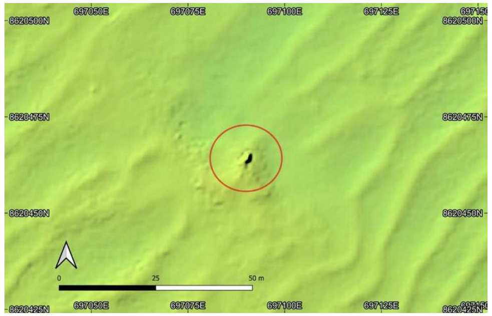
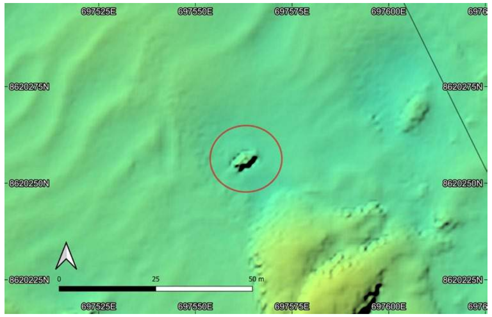
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
B	577	689,412.76	8,629,288.62		Isolated object	4.00	4.50	0.50	24	263
B	578	685,439.11	8,632,096.37		Mound associated with trawl scar	8.00	4.50	0.40	17	603
A	579	689,314.84	8,630,473.13		Debris	20.00	9.00	1.30	31	592

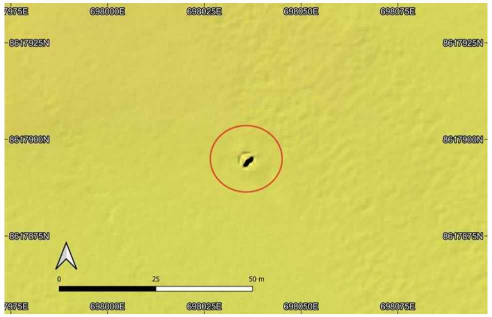
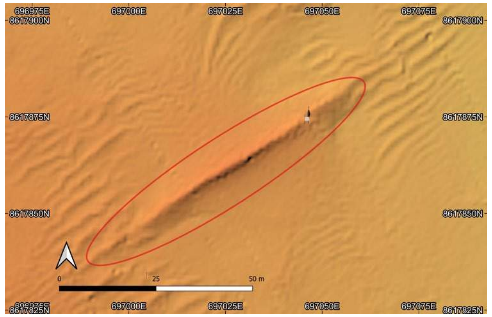
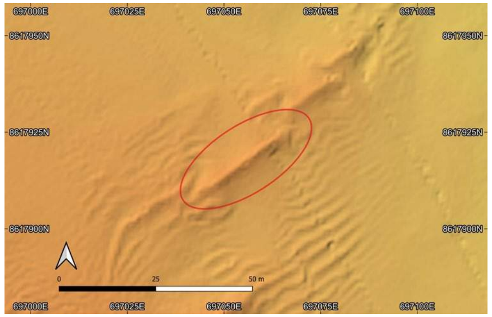
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
B	580	689,842.70	8,630,171.05		Mound	5.00	4.00	1.50	30	691
A	581	691,692.88	8,627,659.36		Possible cable	312.00	2.50	1.40	31	431
A	583	692,918.80	8,626,550.93		Linear debris	11.00	2.00	1.50	39	682

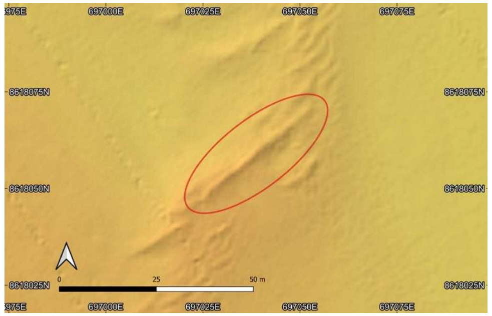
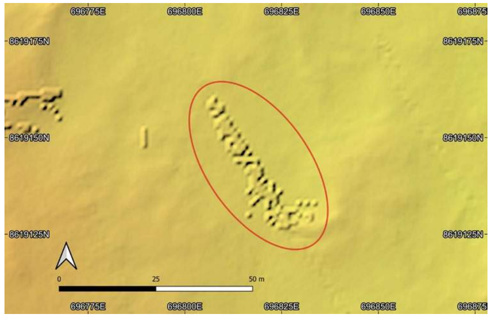
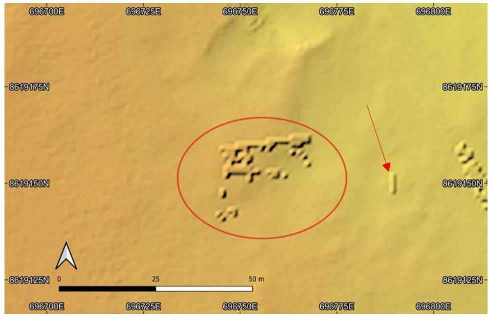
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	584	692,936.90	8,626,417.56		Debris or boulder	7.00	6.00	3.50	39	613
A	588	693,982.49	8,624,331.38		Debris	8.00	4.00	2.50	35	165
A	585	694,508.35	8,624,088.70		Debris	9.00	3.00	0.50	32	472

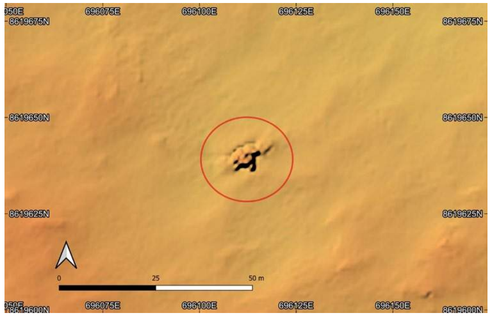
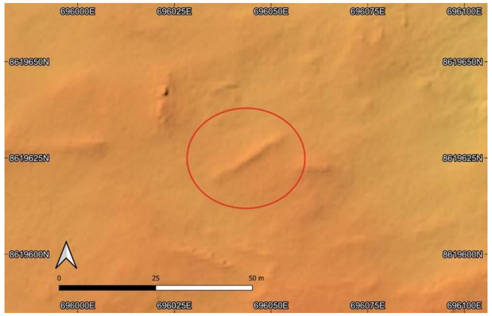
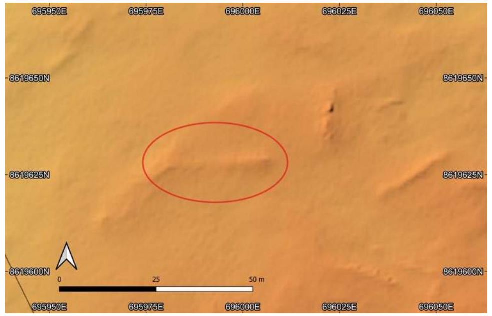
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
B	586	694,770.88	8,624,269.65		Possible small boat or natural feature	17.00	4.00	1.25	35	791
A	587	695,753.15	8,623,106.77		Mooring block	3.00	2.50	0.80	33	852
A	589	696,110.51	8,621,995.74		Debris	17.00	7.00	2.50	33	452

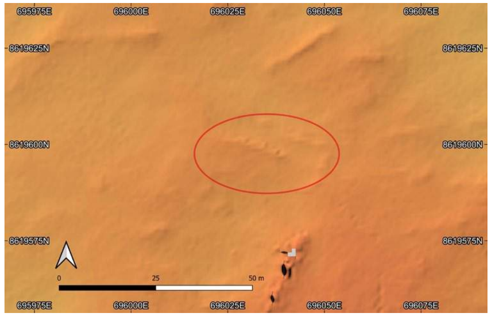
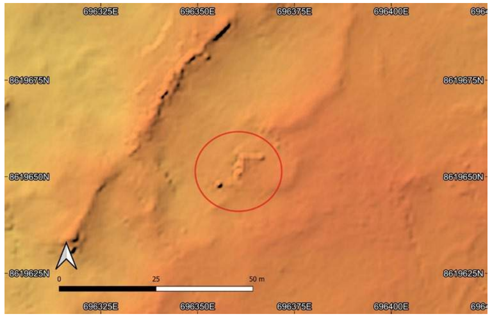
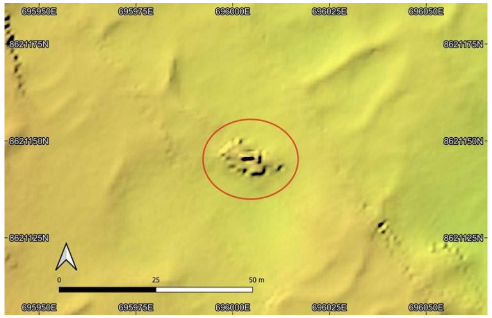
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	590	696,133.59	8,621,994.69		Debris	4.50	2.50	2.00	33	470
A	591	696,472.78	8,621,975.02		Debris	6.40	6.20	1.50	32	727
A	592	696,535.45	8,621,187.11		Debris	8.50	2.70	1.30	25	345

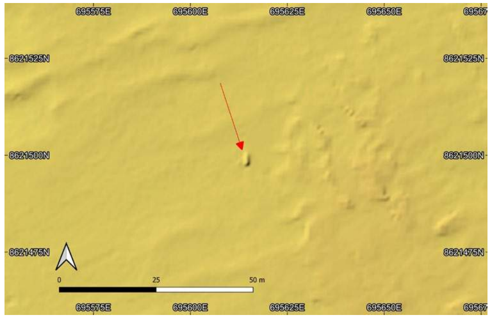
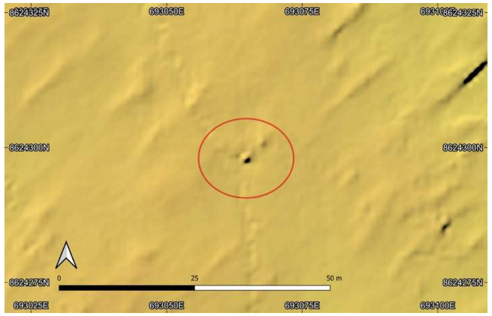
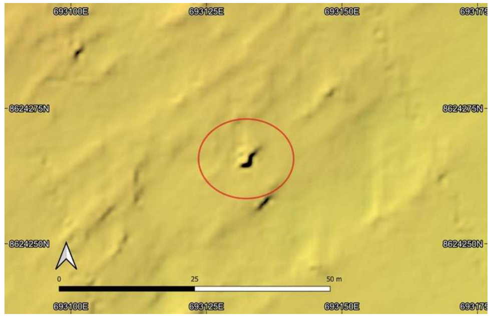
Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	593	696,548.46	8,621,272.90		Mooring block	1.40	1.40	0.75	25	399
A	594	697,090.00	8,620,464.24		Debris	3.50	3.00	1.75	25	513
A	595	697,563.09	8,620,256.32		Debris	6.50	4.20	1.75	32	845

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	597	698,035.82	8,617,894.98		Debris	3.00	3.00	2.00	20	443
B	598	697,030.36	8,617,864.23		Linear feature	59.00	2.00	0.75	12	504
B	599	697,055.70	8,617,918.12		Linear feature	24.00	2.00	0.75	13	462

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
B	600	697,036.34	8,618,057.64		Linear feature	33.00	2.00	1.00	16	434
A	601	696,815.85	8,619,144.52		Debris	40.00	8.00	0.50	19	286
A	602	696,751.52	8,619,156.36		Debris	24.00	11.00	0.75	16	343

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
A	603	696,112.03	8,619,639.40		Debris	8.00	6.60	3.00	14	729
B	604	696,043.52	8,619,624.92		Linear feature, log	18.70	2.40	1.00	13	797
B	605	696,000.91	8,619,629.09		Linear feature, log	15.80	2.40	0.50	13	833

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
B	606	696,032.94	8,619,598.74		Linear feature, log	13.00	2.40	0.75	13	818
B	607	696,362.60	8,619,654.65		Debris	7.00	6.50	1.00	12	497
A	609	696,003.49	8,621,145.27		Debris	16.00	7.50	3.00	21	132

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Image MB	Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing			Length	Width	Height		
B	610	695,614.51	8,621,498.95		Isolated object	3.30	1.50	0.60	18	244
A	611	693,064.64	8,624,298.00		Mooring block	1.70	1.70	0.50	17	599
A	612	693,132.32	8,624,265.69		Debris	3.00	2.50	0.90	18	568

6.3.3 *WWII anti-submarine net moorings*

Targets located between KP 107 and 108 have been identified as the remains of World War II anti-submarine net moorings. Targets listed in Table 10 omit geophysical survey images, as well as target dimensions, because all targets are highly uniform in size and shape.

Table 10: Location of potential WWII anti-submarine boom net moorings, identified from Fugro survey data and Darwin Harbour public MBES data.

ID		Datum: GDA94 CRM: UTM Zone 52S		Distance from GEP (m)
		Easting	Northing	
A	620	692,571.44	8,624,809.47	663
A	621	692,539.74	8,624,860.74	656
A	622	692,523.80	8,624,892.44	649
A	623	692,599.70	8,624,754.58	674
A	624	692,709.75	8,624,594.89	685
A	625	692,769.99	8,624,467.63	716
A	626	692,749.61	8,624,525.87	696
A	627	692,726.33	8,624,548.70	700
A	628	692,147.90	8,624,971.06	898
A	629	692,431.95	8,624,717.81	829
A	630	692,412.02	8,624,771.61	812
A	631	692,453.33	8,624,625.24	869
A	632	692,922.97	8,624,532.76	556
A	633	692,914.46	8,624,593.08	525
A	634	692,897.79	8,624,648.33	504
A	635	692,876.05	8,624,702.14	488
A	636	692,763.55	8,624,903.58	453
A	637	692,729.14	8,624,950.23	452
A	638	692,816.54	8,624,826.14	459
A	639	693,066.90	8,624,638.82	377
A	640	693,040.27	8,624,691.00	365
A	641	693,020.88	8,624,746.07	347
A	642	692,944.62	8,625,014.99	242
A	643	692,919.53	8,625,081.20	221
A	644	692,908.66	8,625,150.86	187
A	645	692,905.94	8,625,190.98	164
A	646	693,039.04	8,625,225.45	38
A	647	693,058.79	8,625,182.69	49
A	648	693,076.54	8,625,127.44	69

ID		Datum: GDA94 CRM: UTM Zone 52S		Distance from GEP (m)
		Easting	Northing	
A	649	693,093.03	8,625,071.10	90
A	650	693,205.80	8,624,728.36	213
A	651	693,234.87	8,624,680.26	222
A	652	693,144.21	8,624,841.13	191
A	653	693,182.07	8,624,784.25	196
A	654	693,311.23	8,624,817.58	75
A	655	693,293.93	8,624,874.10	53
A	656	693,197.83	8,625,161.77	48
A	657	693,162.23	8,625,272.64	88
A	658	693,173.46	8,625,217.02	63
A	659	693,400.45	8,624,893.93	42
A	660	693,420.92	8,624,841.76	24
A	661	693,376.72	8,624,944.02	56
A	662	693,282.43	8,625,202.62	140
A	663	693,307.79	8,625,145.38	125
A	664	693,254.26	8,625,282.33	167
A	665	693,362.50	8,625,014.22	88
A	666	693,460.95	8,625,089.13	211
A	667	693,555.33	8,624,959.96	203
A	668	693,650.62	8,624,848.92	204
A	669	693,506.97	8,624,814.32	72
A	670	693,465.48	8,624,923.37	111
A	671	693,643.69	8,624,929.98	251
A	672	693,469.78	8,625,242.93	313
A	673	693,711.60	8,625,070.97	394
A	674	694,135.50	8,625,135.19	759
A	675	694,161.68	8,625,283.10	875
A	676	694,183.69	8,625,228.03	856
A	677	694,250.36	8,625,094.43	821
A	678	693,923.28	8,625,184.46	629
A	679	693,952.90	8,625,141.07	624
A	680	693,970.93	8,625,083.92	601
A	681	693,751.64	8,625,475.17	678
A	682	693,775.01	8,625,422.23	664

ID		Datum: GDA94 CRM: UTM Zone 52S		Distance from GEP (m)
		Easting	Northing	
A	683	693,794.64	8,625,355.29	638
A	684	693,902.95	8,625,554.38	846
A	685	694,101.63	8,625,224.18	791
A	686	693,979.35	8,625,516.11	883
A	687	693,951.72	8,625,500.98	852
A	688	693,595.12	8,625,397.09	506
A	689	693,625.83	8,625,262.22	448
A	690	693,861.92	8,624,914.00	408
A	691	694,235.64	8,625,020.33	763
A	692	694,004.85	8,624,910.74	515
A	693	693,790.27	8,625,076.31	458
A	694	692,680.70	8,625,066.80	418
A	695	692,486.05	8,624,972.60	630
A	696	692,274.19	8,624,850.32	872
A	697	692,370.93	8,624,932.20	746
A	698	692,376.54	8,624,652.46	913
A	699	693,479.77	8,625,162.13	271
A	700	693,373.52	8,625,219.83	223
A	701	692,476.81	8,624,552.19	895
A	702	692,545.01	8,624,451.33	903
A	703	692,536.68	8,624,530.67	861
A	704	692,512.14	8,624,583.21	848
A	705	692,731.65	8,624,460.66	750
A	706	693,612.40	8,625,501.30	584
A	707	693,639.40	8,625,450.30	414
A	708	693,667.30	8,625,396.10	435
A	709	693,801.20	8,625,027.90	562
A	710	693,812.30	8,624,981.60	576

6.4 Summary of Fugro Geophysical Survey Data Review

In total, 39 potentially cultural anomalies were identified from a review of the Fugro geophysical data, including three magnetic anomalies with no sonar or multibeam presence (see Figure 43). Of these 39, 21 were classed as category A, 15 as category B, and 3 as category C, with the three magnetic anomalies unranked. The distribution of targets increases with the approach into Darwin Harbour, with the highest concentration between KP 101 and KP 116 (see Figure 43).

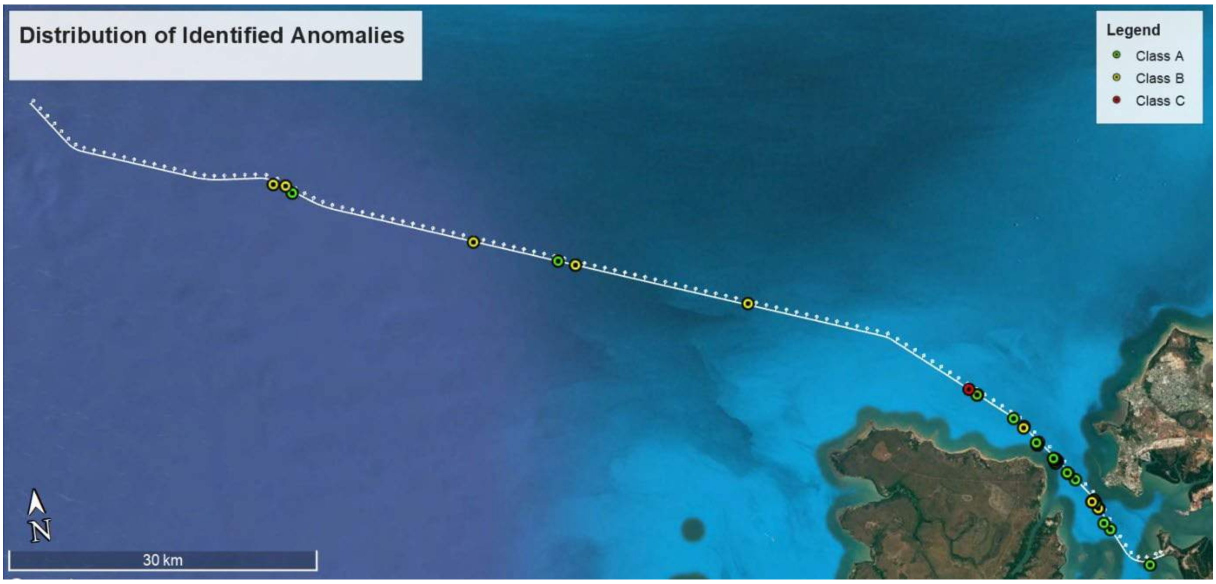


Figure 43: Overview of identified geophysical survey anomalies, colour coded by category type.

Figure 44: Identified geophysical anomalies within Darwin Harbour and approach, approx. KP 93 to 122 (terminus).

6.4.1 *Clusters of geophysical anomalies*

This section reviews five clusters of potential cultural heritage anomalies, and include mostly Class A anomalies, associated Class B anomalies, and associated magnetometer strikes.

6.4.1.1 Cluster 1: KP 25 – 28 (anomalies near I-124)

A cluster of targets was identified between KP 22-28 in the section of the proposed pipeline route that curves around the protected zone of the wreck of the Japanese submarine I-124 (see Figure 45). While the location of the wreck is well documented, and no evidence of I-124 was identified from the geophysical survey, the existence of geophysical anomalies in the area indicates a small likelihood that cultural material associated with the wreck may be present in the area. Of the three identified anomalies between KP 25 and 28, two are ranked in category B, and one is ranked category A. The category B targets cannot be positively identified as cultural or natural based on the available geophysical data. The single category A target, anomaly 112, appears to be a single object of relatively high relief, measuring approximately 8m by 6m. It is located over 2.5 km from the centre of the I-124 protected zone, indicating a very remote chance that it is associated with the Japanese submarine.

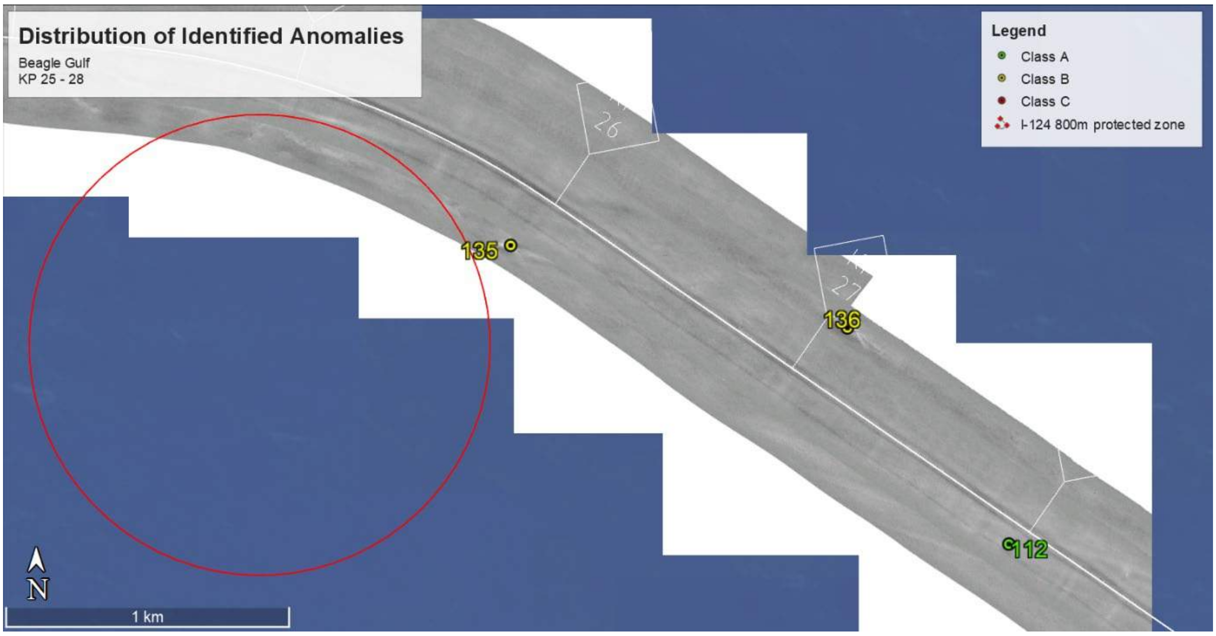


Figure 45: Cluster of geophysical survey anomalies between KP 25 and KP 28. 800m protection zone for I-124 indicated by red circle.

6.4.1.2 Cluster 2: KP 104 – 106 (anti-submarine defences/indicator loop remains)

A second cluster of targets was located between KP 104 and 106. Four geophysical anomalies were identified by SSS and MBES at KP105, three were categorised as A and one as category B.

Previous surveys by CA identified the remains of anti-submarine netting and mechanical time fuses and fuse cones located at 691614 m E and 8626792 m N (see Figure 48 and Figure 49). These remains, labelled Contact 2 in the CA report, are located within the immediate vicinity of anomaly 242, approximately 25m away at a bearing of 286 degrees:

> *Contact 2 consists of a large collection of steel wire rope and chain associated with the WWII anti-submarine boom net* [Figure 48]. *Also located were the remains of at least 4 boom net float buoys and what appear to be supporting frames for the boom net. On the south eastern side of the site is a collection of UXO consisting of mechanical time fuses and fuse cones* [Figure 49]. *These fuses and cones are most likely from artillery shells. A total of 15 fuses were identified but it is likely that more are buried beneath the sediment. The fuses and use cones were most likely stored together in a box but this has deteriorated and spilt the fuses and cones onto the sea floor. Contact 2 covers an area of approximately 25 metres by 30 metres.*[107]

This survey also identified the remains of an underwater telephone cable at 692023 m E and 8626266 m N, designated Contact 3 in the same report:

> *Contact 3 consists of two lengths of underwater telephone cable. There are two parallel sections of cable that run for 30m in approximately an east west orientation* [Figure 51]. *The two cables are set 300 mm apart. The western end of the cable has been cut while the eastern end disappears into the sea floor sediment and is most likely still in situ. The cable is approximately 25 mm across and consists of a six core copper wire encased in black rubber that is then encased in grey rubber. The outside is bound in canvas with steel wire armour* [Figure 52]. *Approximately 5 metres south west of the in situ cables is a jumbled collection of broken telephone cable that appears to have been dumped in a pile.*[108]

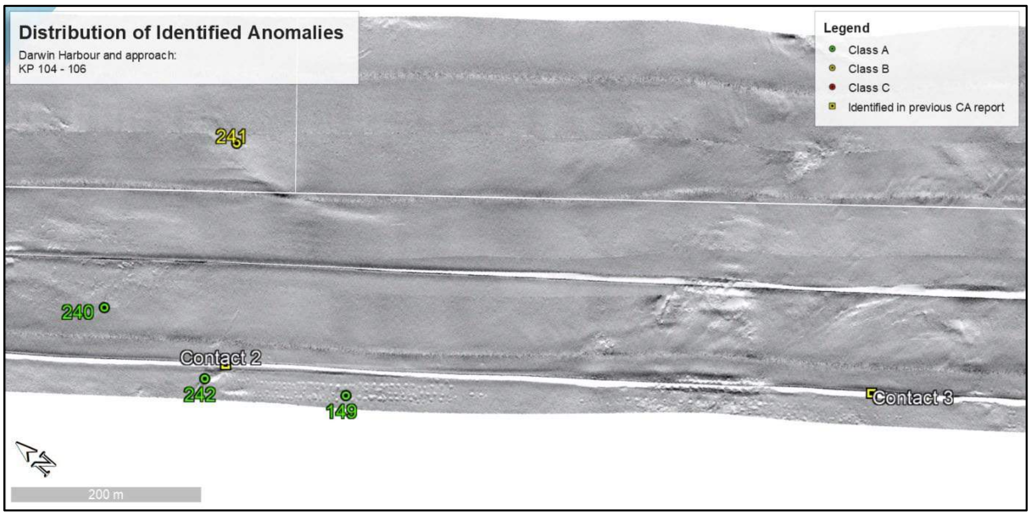


Figure 46: Cluster of geophysical anomalies from KP 104 – 106. Contact 2, associated with anti-submarine netting, and Contact 3 is indicated by yellow square.

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[107] **Cosmos Archaeology, 2012,** Ichthys Project Darwin Harbour, East Arm Gas Export Pipeline: Assessment of Heritage Impact of 7 side scan targets, report prepared for Tek Ventures Pty Ltd, p.11.

[108] *Op. Cit.* **CA, 2012:**12.

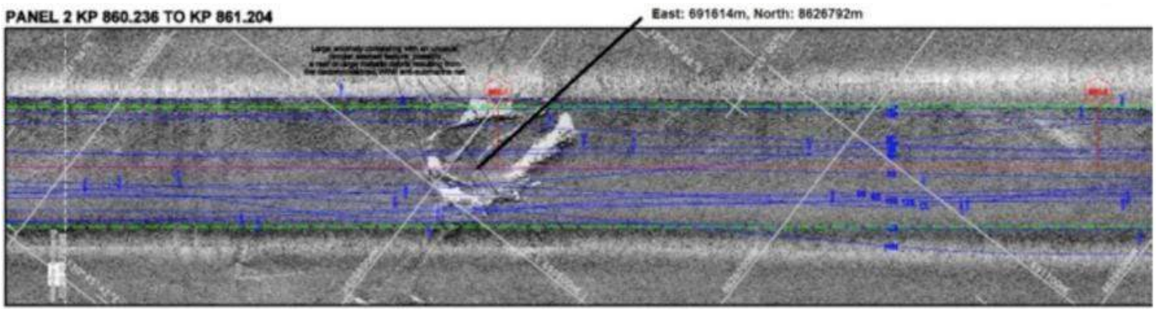

Figure 47: SSS image of Contact 2, taken during 2012 geophysical surveys for INPEX GEP. (Source: CA 2012).

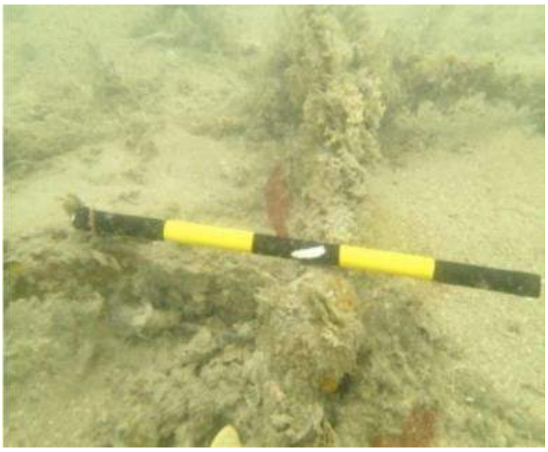

Figure 48: Remains of anti-submarine netting recorded at contact 2. (Source: CA 2012).

Figure 49: Collection of mechanical time fuses and fuse cones located at Contact 2. (Source: CA 2012).

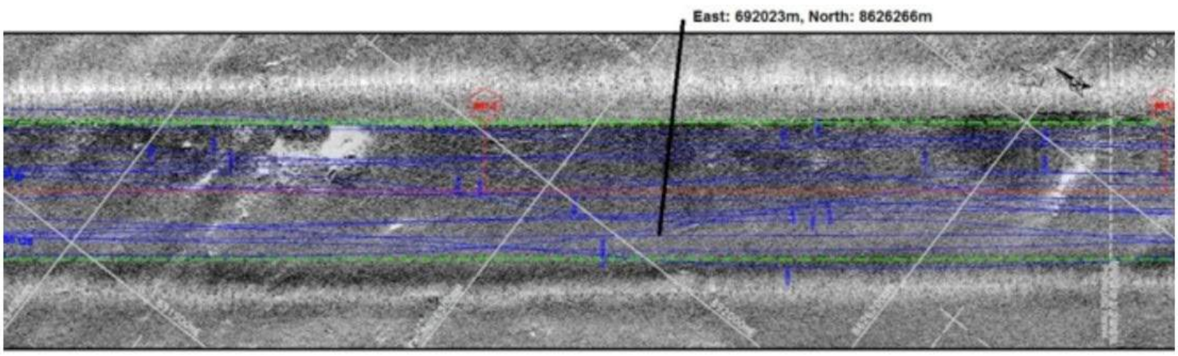

Figure 50: SSS image of Contact 3, taken during 2012 geophysical surveys for INPEX GEP. (Source: CA 2012).

Figure 51: Image of the two parallel lies of communication cable laying on sea floor. (Source: CA 2012).

Figure 52: Cross section of broken communication cable. (Source: CA 2012).

It appears from comparison of the SSS data from 2012 and 2018, that Contact 2 and Anomaly 242 are the same object, however new surveys show the INPEX GEP directly crossing the location (see Figure 47 and Figure 53). Adjacent to 242 is a series of small circular depressions, regularly spaced in several rows and uniform in size, 3-4m in diameter (Anomaly 149). The identity of these depressions is unknown, they may be related to either the anti-submarine defences or to the laying of the INPEX pipeline (see review of Anomaly 210 below). Despite the known location of ferrous material at Contact 2, no magnetometer strike was reported in the vicinity. Anomaly 240 is a high relief object rectangular in shape, potentially a mooring block related to the anti-submarine defences.

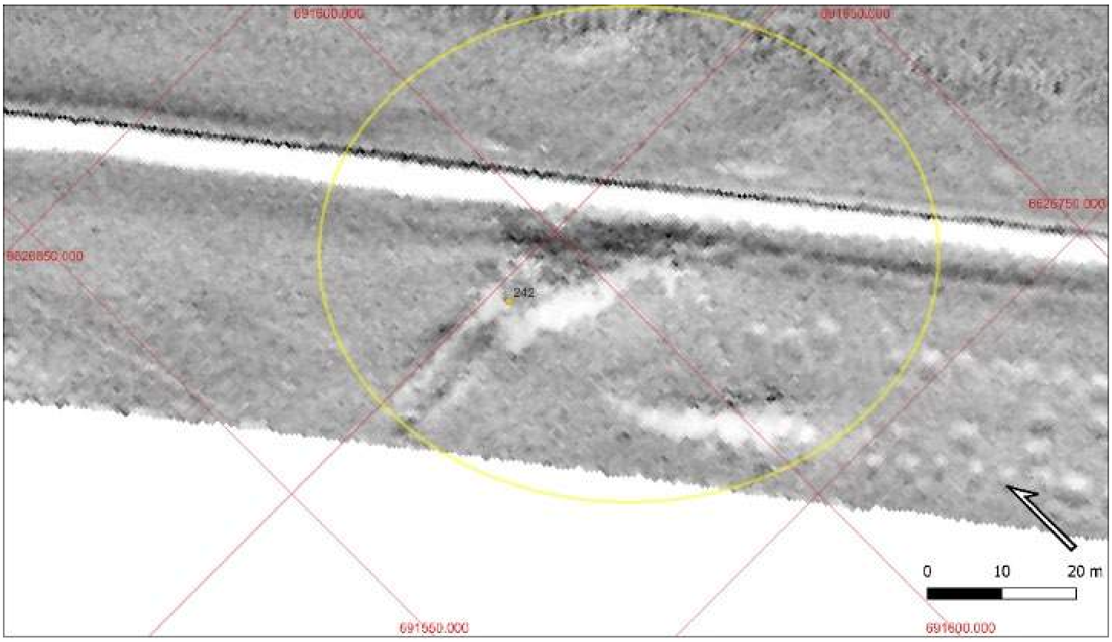

Figure 53: Anomaly 242 (circled in yellow). Note INPEX GEP crossing the target. Note circular depressions in lower right, designated Anomaly 149.

6.4.1.3 Cluster 3: KP 107-108 (anti-submarine boom net moorings)

Of particular interest is a cluster of targets located between KP 107 and 108 at a point directly between Mandorah and Dudley point at the entrance of Darwin Harbour (see Figure 54). A total of nine targets were identified within this 1km section of the proposed pipeline route, with five of those also registering as magnetometer targets, indicating the presence of ferrous materials. It was believed initially that some of these were related to WWII anti-submarine nets, identified by historical sources (see Section 4.3.3) and during CA investigations related to the INPEX project.[109] This conclusion was confirmed by ROV surveys conducted in June 2022 (see Section 7 and Annex A for summary of these surveys).

ROV surveys were conducted along three transects and identified a total of 11 moorings, including 10 large concrete clump weights and one ship's anchor (Target 164), repurposed as a mooring. These moorings were connected by heavy gauge chain and spaced roughly 60m apart. Three "trots", lines of mooring weights connected by chain, were identified within the geophysical survey corridor, and were visually inspected during ROV surveys.

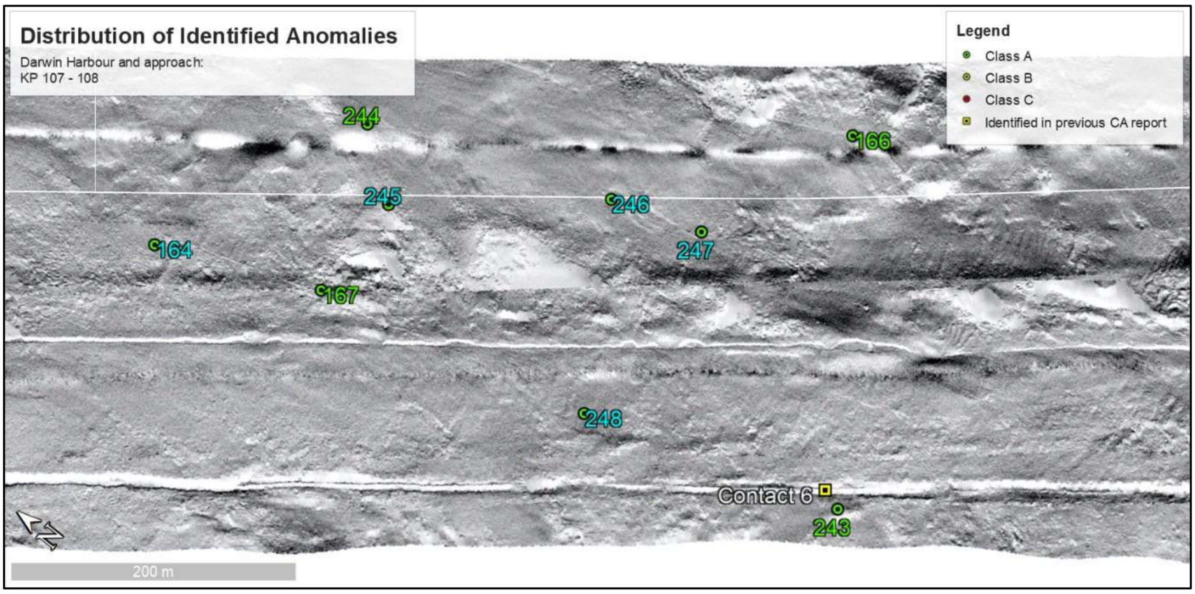

Figure 54: Identified geophysical survey anomalies between KP 107 and 108, overlaid on SSS data. Targets with blue labels are also magnetometer strikes. Contact 6 identified with yellow square.

Target 243 is approximately in the close vicinity of a mooring block (Contact 6) surveyed by CA in 2012. Contact 6, located at 693193 m E and 8624761 m N, was determined to be a structure related to an anti-submarine boom net installed during WWII (see Figure 55-56):

> *Contact 6 is a section of the mooring system for the WWII anti-submarine boom net. On the southern end of the site is a large concrete mooring block approximately 1.6 metres long, 1.4 metres wide and 0.8 metres high* [Figure 56]. *The block is sitting proud of the sea floor and there is some minor scouring around the base. On the north and the south sides of the mooring block are two large iron loops approximately 200mm from the bottom. Connected to these loops are stud link chains (350mm long, 230mm wide and 70mm across) leading off on a north and south axis* [Figure 57]. *The northern side of the chain extends for approximately 5 metres before disappearing into the sea floor. The southern side of the chain extends for approximately 7 metres before disappearing into the sediment. Although there would have originally been chain and wire rope that*

[109] *Op. Cit.* **Cosmos Archaeology, 2012**:14.

connected this mooring system to the anti-submarine net there is no indication of the chains or net left in this area. [110]

The high presence of ferrous material in this location, not associated with the existing pipelines, and sonar contacts supports the theory that most, if not all, of these targets are cultural in origin. Anomaly 245 presents as a magnetometer strike in an area of extensive rocky material. Lines seen on sonar running NW to SE are possibly remains of undersea cables installed during the 1870s (see Section 4.3.3). Note similarity in SSS image of Contact 6 (Figure 55) and Anomaly 166 (Figure 58). These two targets are approximately 250 m apart in a straight line between Mandorah and Dudley's Point.

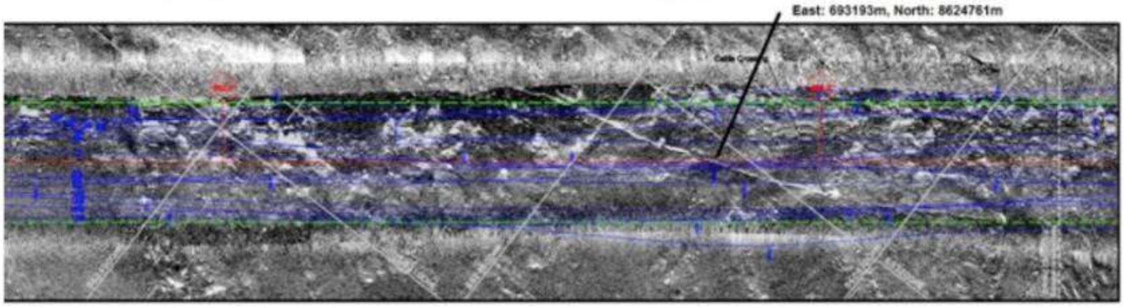

Figure 55: SSS image of Contact 6 taken during 2012 geophysical survey. Location 693193 m E and 8624761 m N.

Figure 56: Concrete mooring block for anti-submarine net. (Source: CA 2012).

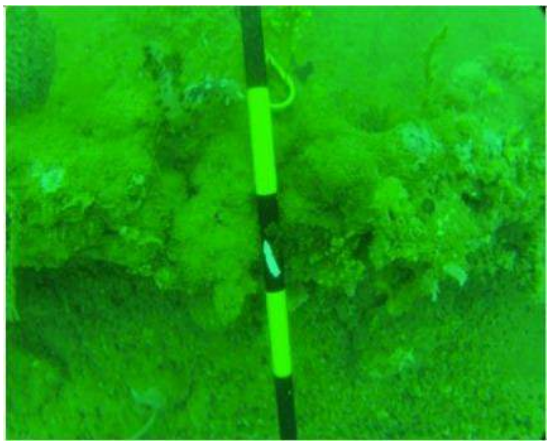

Figure 57: Detail of chain for anti-submarine netting. (Source: CA 2012).

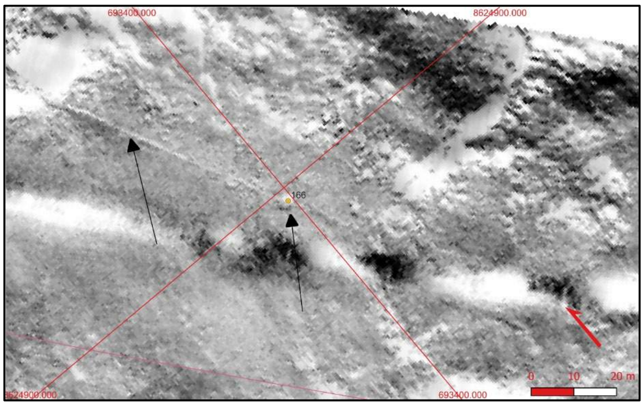

Figure 58: Geophysical anomaly 166. Black arrows pointing to mooring block and chain. DOF Subsea 2018.

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[110] Op. Cit., Cosmos Archaeology, 2012, p.14.

6.4.1.4 Cluster 4: KP 108 – 110 (magnetic anomalies)

Centred at KP 109 is a cluster of magnetometer targets potentially unrelated to the existing Bayu-Undan and INPEX GEPs. Although only two geophysical anomalies were identified by review of SSS and MBES, there are an additional 10 magnetometer strikes located at least 20m away from the existing pipelines. Faint lines seen on the seabed indicate that these magnetometer strikes are possibly the remains of undersea cables, anti-submarine defences, or debris associated with the pipelines (Figure 59). Anomaly 174 was designated class A and listed as potentially associated with a magnetometer strike. ROV survey was conducted on Target 174, and identified the target as a possible winch, windlass or ship's bollard with rope still coiled around the object (see Section 7.2).

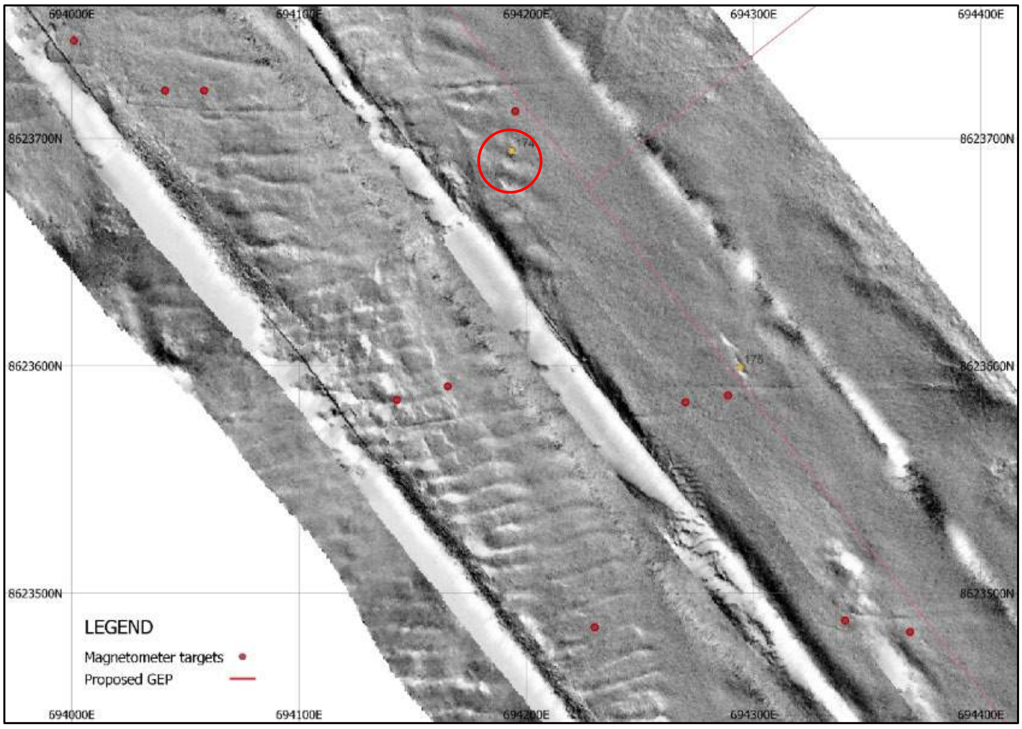

Figure 59: Location of magnetometer strikes and geophysical survey anomalies around KP 109. Note linear features along magnetometer targets. Anomaly 174 circled in red.

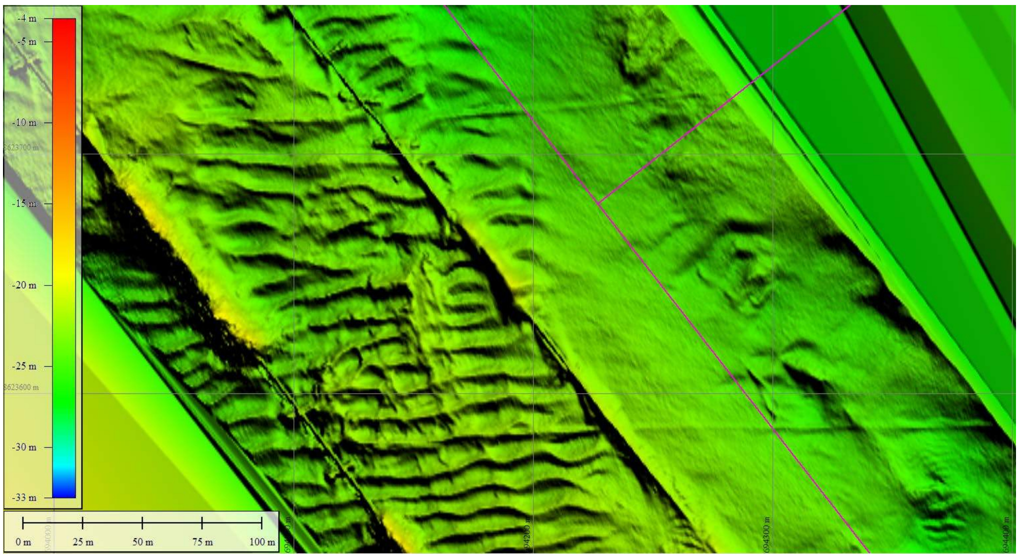

Figure 60: High resolution MBES data of same area, showing linear features near KP 109.

6.4.1.5 Cluster 5: KP 112 – 114 (debris scatters)

Around KP 113, between KP 112 and 114, is a cluster of six geophysical survey anomalies. Three are classed as category A and three are classed as category B, and no magnetometer strikes were recorded in the vicinity. One anomaly, 191, presents as a single high relief object approximately 8m in length and roughly the shape of a small boat. The remaining four targets appear to be either debris scatters or natural features.

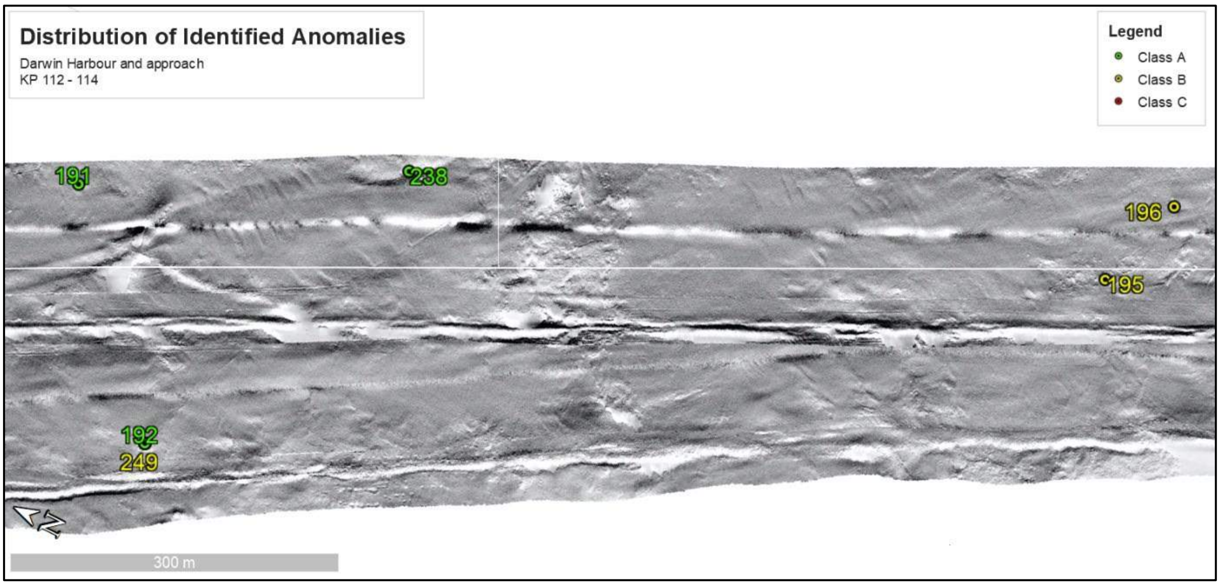

Figure 61: Cluster of geophysical survey anomalies between KP 112 and KP 114.

6.4.2 *Isolated Class A anomalies*

Anomaly 234: KP 54 – 55 (single mound, low relief)

Anomaly 234 appears to be, from SSS, a small mound of low relief, approximately 5m x 4m. It is in the general area of the known location of the 1871 subsea cable and may be related. Anomaly 234 is approximately 173m from the centreline of the proposed GEP route.

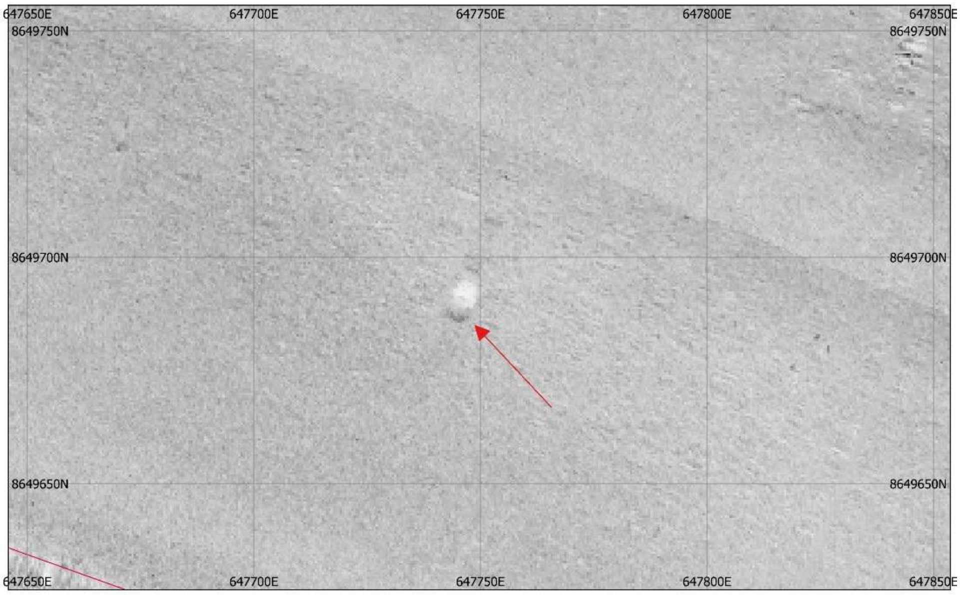

Figure 62: SSS view of anomaly 234.

Anomaly 138: KP 97 – 98 (mound in proximity to anchor scars)

Anomaly 138 appears on SSS to be a relatively large mound, measuring 13m by 16m, and is in close proximity to a pair of gouges on the seabed, crossing in an "X" pattern, identified as C Class anomaly 236. It is believed that these gouges are likely anchor scars. Both gouges are approximately 75m long and 6m wide.

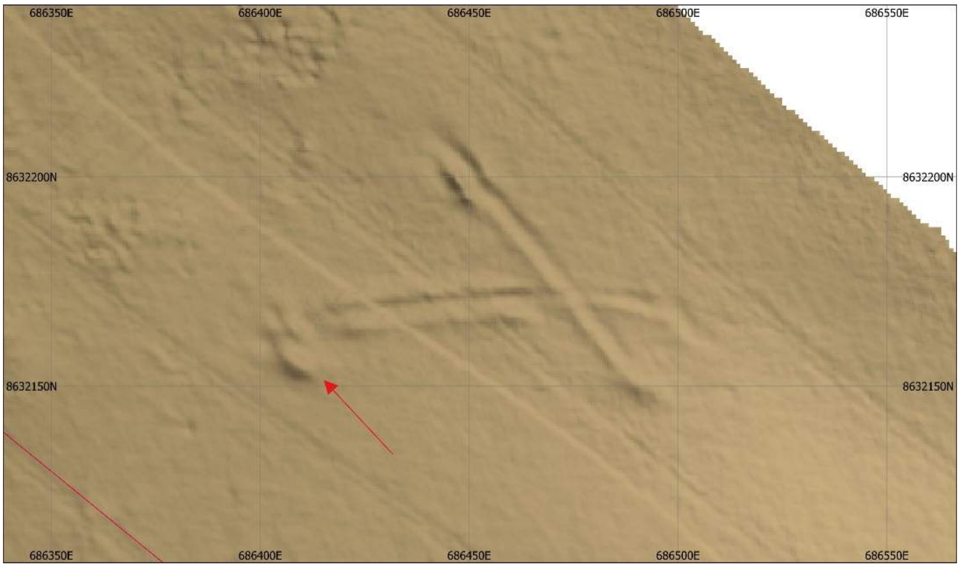

Figure 63: MBES image of Anomaly 138 with associated seabed gouges in X pattern. Anomaly 138 marked by red arrow.

Anomaly 239: KP 115 – 116 (USAT Mauna Loa)

Anomaly 239 is located at approximately KP 116 and is identified as the wreck site of USAT *Mauna Loa. Mauna Loa* was a steel hulled US military cargo ship, measuring 410 feet in length, 54 feet in depth, and 5,436 tons. The vessel was sunk by Japanese aircraft during a raid on Darwin on February 19, 1942, resulting in five casualties (see Section 4.3.1, Figure 19, and Figure 21).[111] Although the upper portions of the wreck were removed during salvage operations between 1959 and 1960, the lower portion of the wreck, and its cargo, is largely intact. Cargo remains include motorbikes, ammunition, gun carriers, and trucks.[112] The wreck is well known and protected under the *UCHA 2018, Northern Territory Heritage Act 2011,* and may be protected by the *SMCA 2004* (USA).

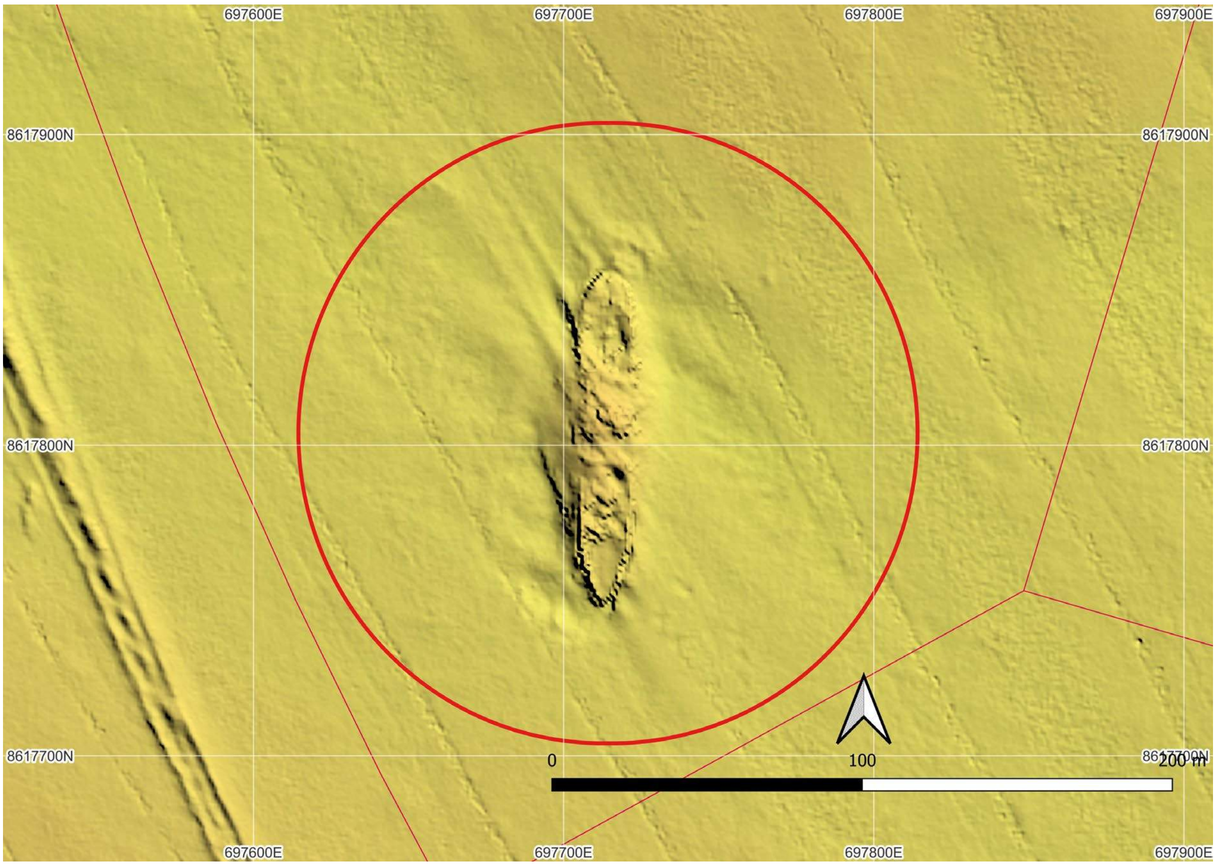

Figure 64: MBES image of anomaly 239, the USAT Mauna Loa. Statutory protection zone represented by red circle.

[111] **AUCHD,** shipwreck ID: 3503.
[112] **AUCHD,** shipwreck ID: 3503.

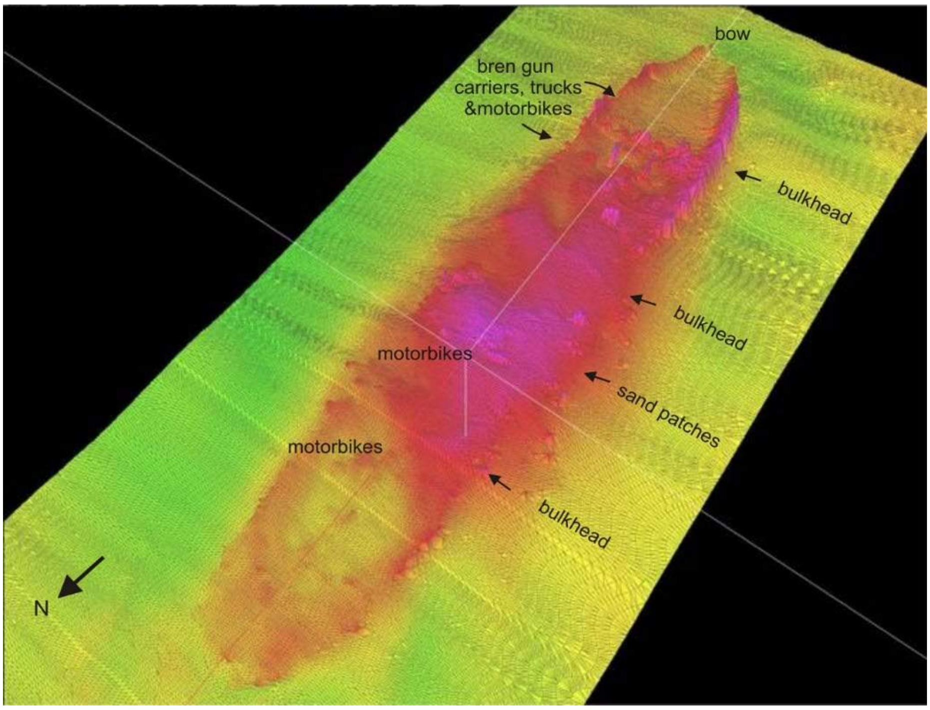

Figure 65: 2012 multi-beam sonar image of USAT Mauna Loa.[113]

Anomaly 210: KP 121 – 122 (unidentified debris)

Anomaly 210 is located between KP 121 and 122, approximately 360 m south of the proposed GEP route. The debris is unidentified, and due to the lack of comprehensive magnetometer data, it is unknown whether any ferrous material is present at the site. The shape of the debris bears a passing resemblance to known aircraft wrecks in the area, including five Consolidated Catalinas wrecked on the opposite side of Wickham Point, East Arm, Darwin (see Figure 67 and Figure 68). The size of the debris is approximately 12m by 7m - closer to the size of military fighter aircraft known to have operated over Darwin during World War II, such as RAAF Supermarine Spitfires (9m long fuselage and 11m wingspan), USAAF Curtiss P-40E Kittyhawks (9.6m long fuselage and 11.4m wingspan) and IJNAF Mitsubishi A6M2 “Zeros” (9m long fuselage and 12m wingspan). There are eight as yet unlocated World War II fighter aircraft wrecks that could potentially be situated within the study area – including six USAAF Kittyhawks, one RAAF Spitfire, and one IJNAF Zero (see Section 4.4.2).

[113] **AUCHD,** shipwreck ID: 3503.

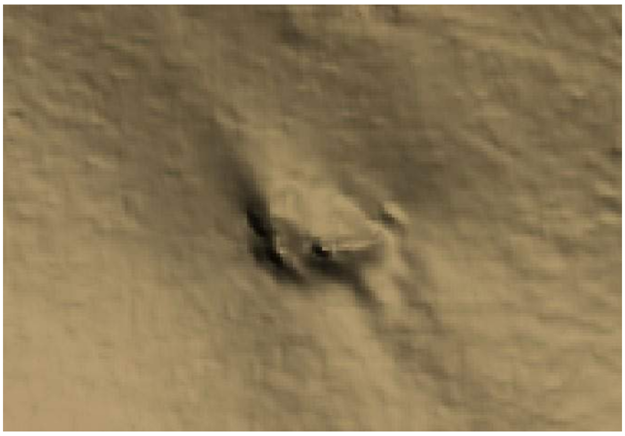

Figure 66: Anomaly 210, unidentified debris.

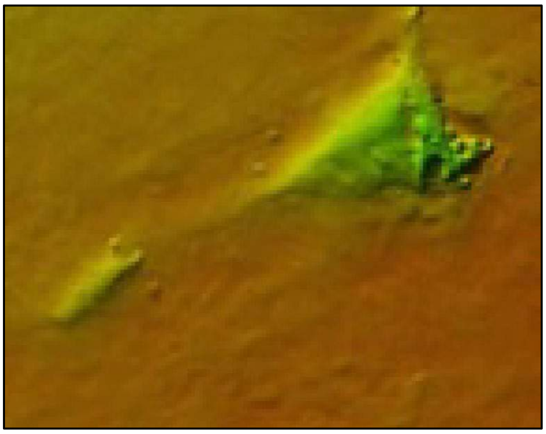

Figure 67: High resolution SSS image of Catalina 3, wrecked at East Arm.[114]

6.4.3 *Isolated Class B & C anomalies*

- *Anomaly 233: KP 46 – 47 (triangular depression)* - Anomaly 233 is a large triangular depression measuring roughly 39m by 8m. It was not identified as a magnetometer target and is likely a natural feature.
- *Anomaly 115: KP 56 – 57 (parallel depressions)* – Anomaly 115 is an isolated set of rectangular depressions measuring approximately 8m by 4m and may represent an area of debris or a natural feature.
- *Anomaly 130: KP 73 – 74 (possible debris field)* – Anomaly 130 is an area of numerous small, low-lying objects across a field approximately 18m by 8m. This likely represents a debris field, possibly of discarded objects, or an area of loose rocky seabed, which is incongruous with the surrounding flat sandy seabed. MBES and magnetometer survey did not cover Anomaly 130.
- *Anomaly 140: KP 101 – 102 (navigational buoy mooring)* – Anomaly 140 was determined to be in the same location as navigational buoy 5, used as a guide for the Port of Darwin shipping lane. Images seen on SSS and MBES are most likely the mooring and mooring line for Buoy 5.
- *Anomaly 141: KP 102 – 103 (possible field of large debris)* – Anomaly 141 is an area of several large, high-profile ridges across a total area measuring 53m by 20m, with each individual portion measuring 6 – 12m across. Objects are likely natural rocks, as similar features become more frequent following KP 113, or are cultural in origin, possibly indicating a dump site.
- *Anomaly 142: KP 102 – 103 (possible debris)* – Anomaly 142 is located approximately 150m southwest of Anomaly 141 and lays on the proposed GEP route. 142 appears similar to 141 on MBES, and on SSS appears as several relatively high-profile objects in a field roughly 13m by 8m.
- *Anomaly 235: KP 96 – 97 (anchor drag)* – Anomaly 235 is an anchor drag, vaguely U-shaped and measuring 244m in total length and 5m in width.

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[114] **AUCHD,** Aircraft Id: 8072.

6.4.4 Isolated Magnetic Anomalies

Three isolated magnetic anomalies were detected during magnetometer surveys. One is located beyond 50m from the proposed GEP route, one located approximately 35 m from the route, and one is located 6.4 m from the proposed route. These anomalies are inferred to be buried ferrous debris. Thus, these targets may represent buried cultural items.

- *MA_001: KP 115.846* – inferred buried debris, 13.3 nT magnetic intensity, 35.3m from GEP route. This magnetic anomaly was initially thought to possibly be associated with USAT *Mauna Loa,* because it is located approximately 65m from the wreck site. MA_001 was inspected during ROV survey and confirmed to be the remains of a buoy mooring.
- *MA_007: KP 111.508* – inferred buried debris, 21.5 nT magnetic intensity, 6.4m from GEP route. MA_007 was inspected during ROV survey. An unidentified metal structure was seen at the location of MA_007 and was assessed as cultural in origin. This structure may represent wreckage remains or discarded debris.
- *MA_031: KP 117.376* – inferred buried debris, 34.3 nT magnetic intensity, 145.6m from GEP route.

7 ROV SURVEY

7.1 Conduct of field survey

As part of environmental and heritage impact assessments, a geophysical survey was conducted, including multi-beam bathymetry (MBES), side scan sonar (SSS), and magnetometer surveys, to identify locations of potential cultural material (see Section 6). Review of the available geophysical survey data identified forty targets of possible cultural origin (see Section 6.3). Sixteen of these targets were located within 50m of the proposed GEP route and were shortlisted for visual survey to potentially confirm their identity and significance (Figure 69). In addition to these individual targets, three transects were planned solely for heritage purposes in the location of known WWII anti-submarine netting (Figure 70). The sixteen chosen targets were inspected over the course of three days between 6-8 June 2022.

Figure 68: Location of ROV survey shortlisted targets. All targets located between KP 102 and KP 118.

Figure 69: Location of ROV survey heritage transects between KP 107 and KP 108.

The objectives of this ROV survey were to:

> *Visually inspect targets identified through geophysical data for their potential cultural heritage significance and recommend measures to reduce impacts to their cultural heritage values.*

The underwater heritage survey was conducted with the use of an ROV, operated by crew from FUGRO under the direction of the maritime archaeologist. The features believed to be the anti-submarine net mooring trots were surveyed along transects following the features in a linear pattern. Isolated targets were targeted by dropping a clump weight with a buoy attached on the target coordinates while the vessel was moving, and then following the buoy line to the seabed with the ROV once the vessel was anchored. Once on the bottom, the ROV was manoeuvred in cross shaped search patterns, 10m out in each cardinal direction, using the clump weight as a reference point.

The ROV was battery powered and controlled remotely by the pilot from inside the survey vessel cabin. Because the ROV was not equipped with transponders or any location fixing devices, the exact location of the ROV had to be estimated based on identifiable features on the seabed that could be compared to MBES data, course headings, and position relative to the survey vessel.

7.2 Summary of ROV survey findings

In total, 21 ROV dives were attempted to locate and identify potential cultural objects identified in the marine geophysical survey. Of these 21 dives, 3 were aborted due to poor conditions or issues with the ROV. Despite these failed attempts, ROV surveys were conducted on all 16 targets shortlisted for ROV survey.

Remains of historic maritime infrastructure were identified during the ROV surveys (Figure 71). The remains of WWII anti-submarine boom net moorings were clearly identified by the three heritage transects.

Figure 70: ROV survey shortlisted target locations overlaid on map of known historic maritime infrastructure in Darwin Harbour.

Heritage Transects 1, 2, and 3 identified the remains of WWII anti-submarine net moorings near the entrance to Darwin Harbour. It was concluded based on these surveys that the northern and southern mooring trots (Transects 2 and 3) did not cross the proposed GEP route (Figure 72). It was noted that the northern end of the trot surveyed by Transect 2 was anchored with a potentially historical ships anchor.

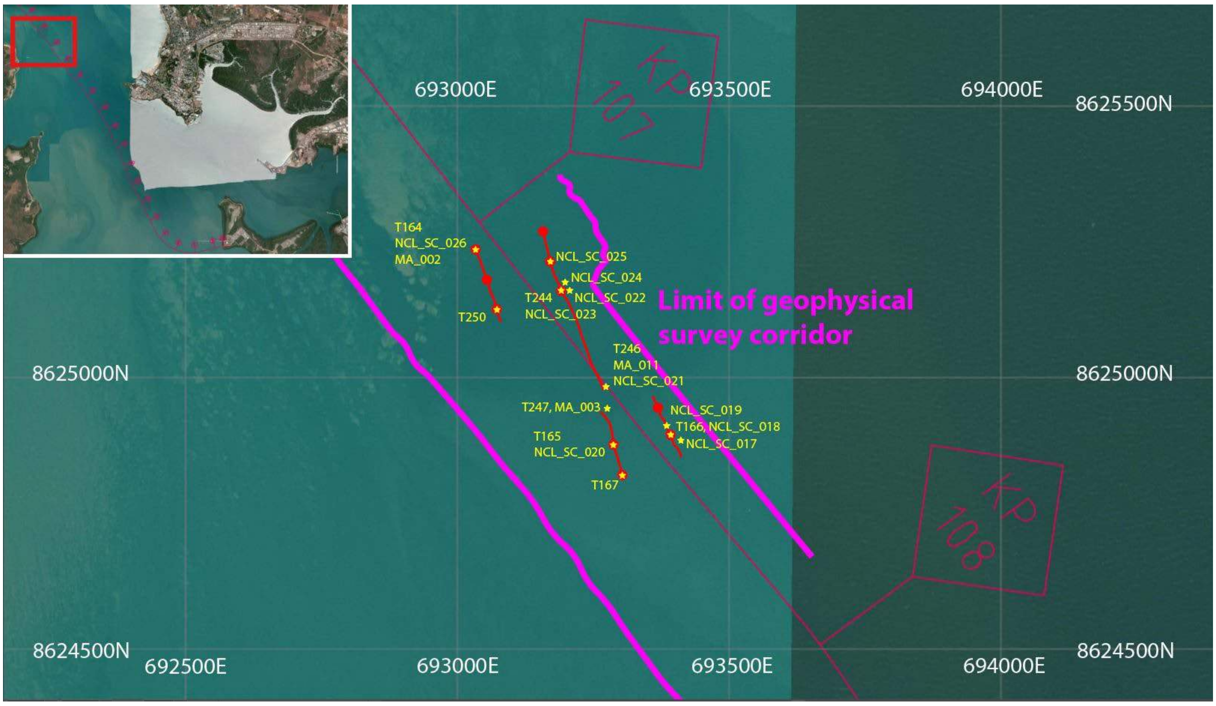
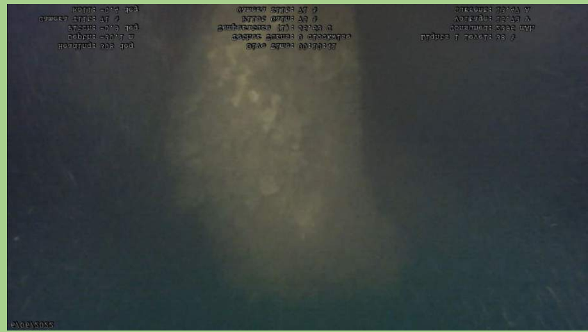
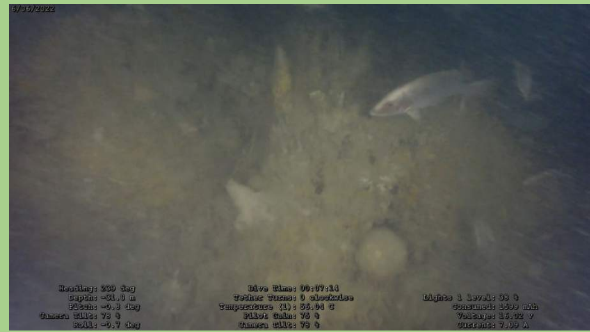
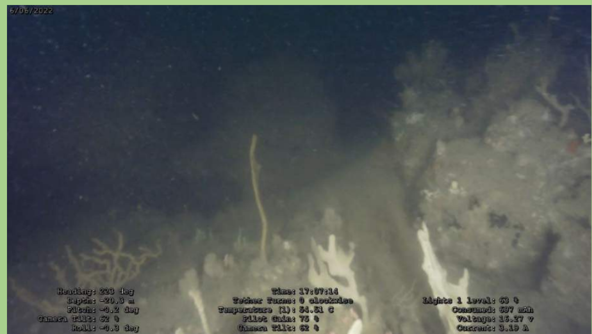
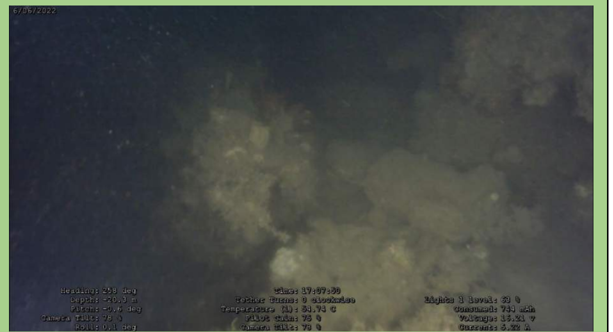
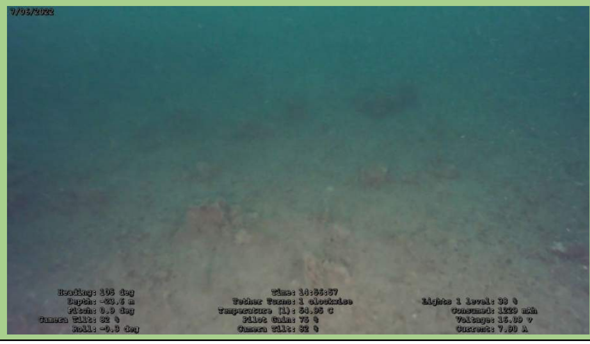


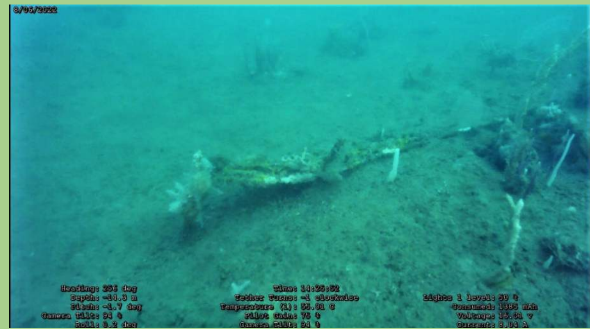
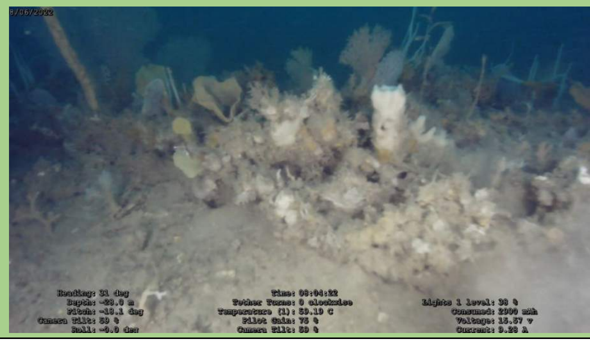
Figure 71: Location of anti-submarine net trots identified during ROV surveys. Circles represent mooring blocks/anchors, lines indicate chains in between blocks, stars represent geophysical survey anomalies, with IDs.

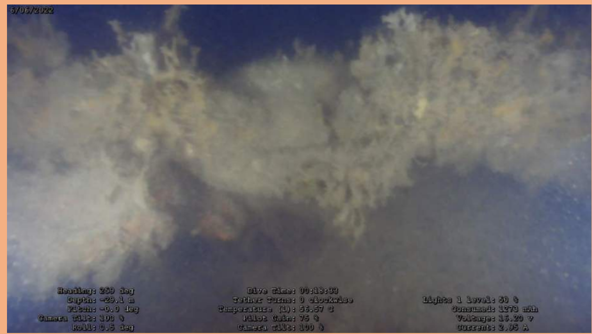
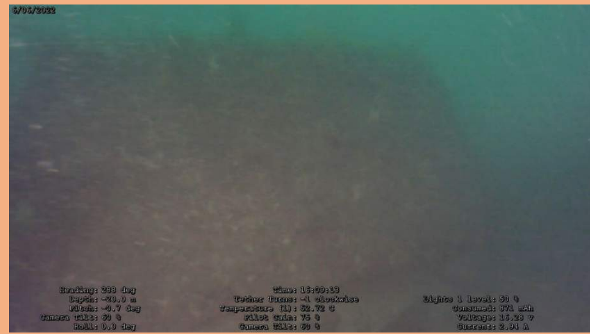
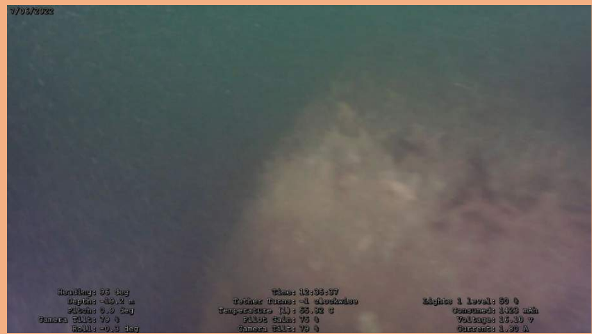
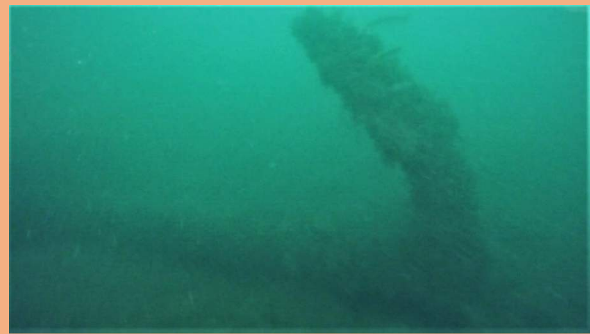
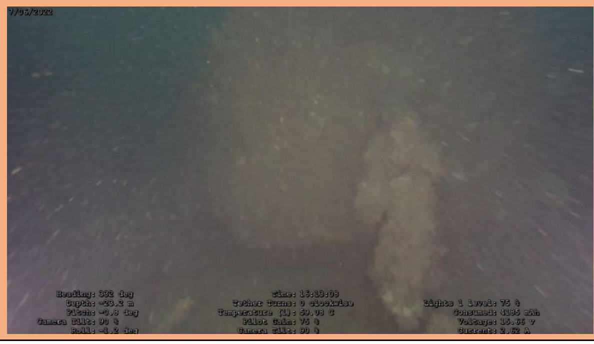
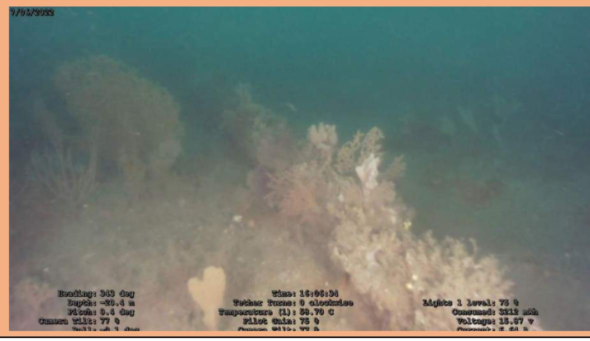
ROV survey of the middle trot (Transect 1) identified mooring chains that did cross the proposed GEP route. However, it was also seen that a gap exists between sections of the chain, southeast of the location of Target 246, which was not located.

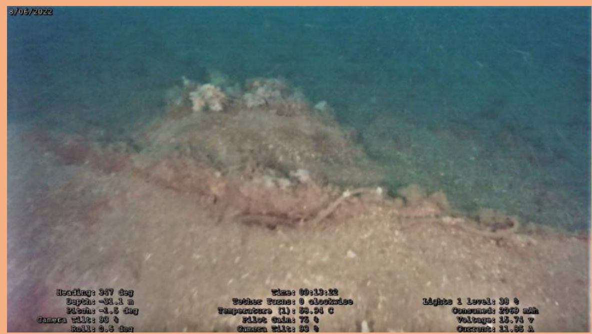
Individual dives on 10 isolated heritage targets identified 6 instances of natural features, not considered to be cultural in origin. The remaining four are conclusively cultural. All three heritage transects identified cultural remains. Table 11 summarizes the results of the survey of these features. The full summary of the ROV survey is attached to this report as Annex A.

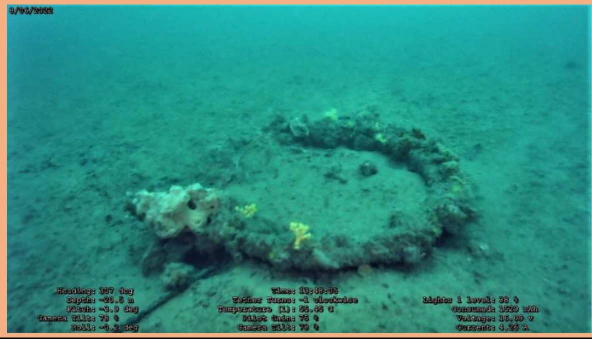
Table 11: ROV survey target identification

Target ID	Likely identification	Cultural/Natural	Image 1	Image 2
142	Boulders	Natural		
245	Rock rubble	Natural		
241	Shallow depression	Natural		

Target ID	Likely identification	Cultural/Natural	Image 1	Image 2
NCL_SC_002	Rock ridge	Natural		
NCL_SC_031	Sand ripples	Natural		
175	Narrow rock/coral ridge	Natural		

Target ID	Likely identification	Cultural/Natural	Image 1	Image 2
Heritage Transect 1 (incl. Targets MA_003, 011; Targets NCL_SC_020, 021, 022, 023, 024, 025; Targets 165, 167, 244, 246, 247)	Anti-submarine net mooring trot	Cultural		
Heritage Transect 2 (incl. Targets MA_002; Target NCL_SC_026; Targets 164 and 260)	Anti-submarine net mooring trot, with ship's anchor as northernmost mooring	Cultural		
Heritage Transect 3 (incl. Targets NCL_SC_017, 018, 019; Target 166)	Anti-submarine net mooring trot	Cultural		

Target ID	Likely identification	Cultural/Natural	Image 1	Image 2
174	Possibly winch, windlass, or ship's bollard	Cultural		
NCL_SC_016	Telegraph or other cable	Cultural		
MA_007	Metal structure, possible wreckage	Cultural		

Target ID	Likely identification	Cultural/Natural	Image 1	Image 2
MA_001	Buoy mooring and cable	Cultural		

7.3 Interpretation of survey results

7.3.1 *Anti-submarine net mooring trots (Heritage Transects 1, 2, and 3)*

In response to the threat of a Japanese invasion, a network of anti-submarine infrastructure was constructed around Darwin Harbour. This included the construction of a 6 km-long anti-submarine boom net, between Dudley Point and West Point (see sections 4.2.6, 4.3.3). Indicator loops and sonar systems were also put in place at the entrance to Darwin Harbour to detect any ships moving near the boom gates.

The submarine boom net was anchored to the seabed with 5- and 8-ton concrete clumps. A total of 265 clumps were used for the boom, which were arranged in groups of eight. Each group of eight clumps was called a "trot" and each trot was laid out 195 ft (~60m) apart, perpendicular to the axis of the submarine net. The clumps were connected by 2" chain.

ROV surveys visually identified the locations of nine mooring clumps, and one ship's anchor repurposed as a mooring clump, representing three separate trots. The locations of the three trots located during the ROV survey correspond roughly to trots 16, 17, and 18 shown on historic charts (see Figure 73).

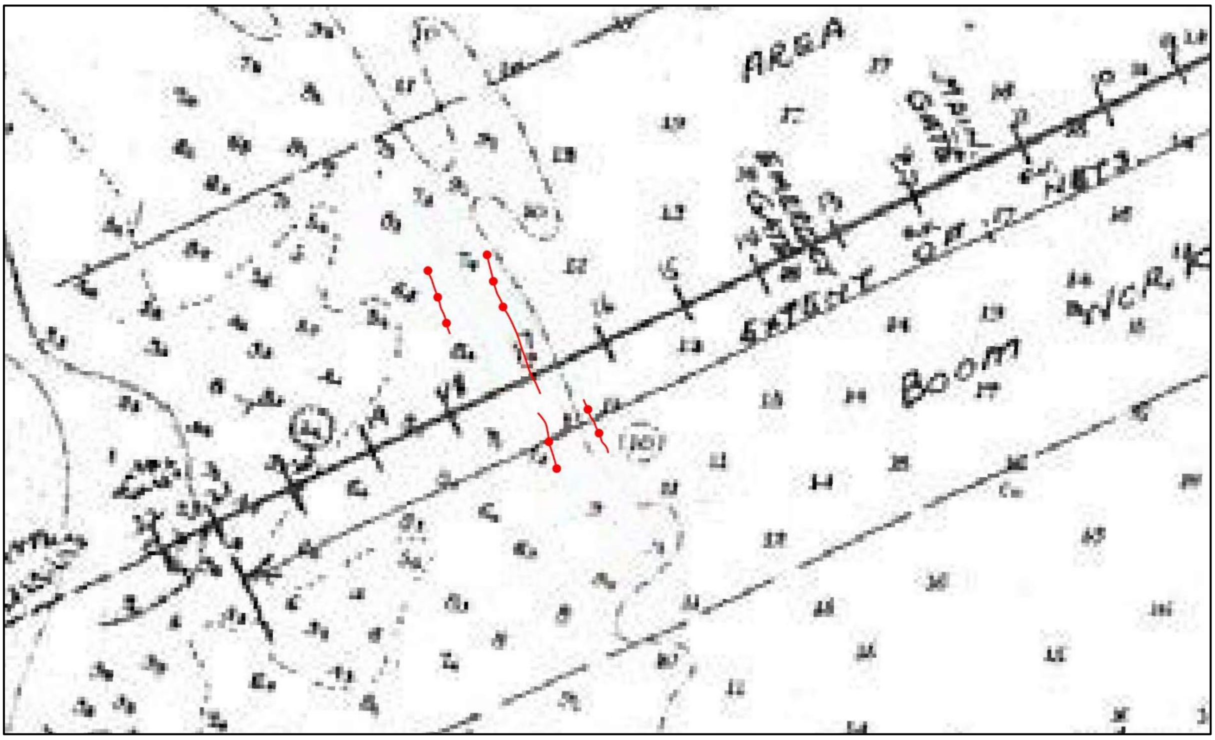


Figure 72: Historic chart of WWII anti-submarine boom net mooring trots overlaid with location of clump weights and chain identified by ROV (in red).

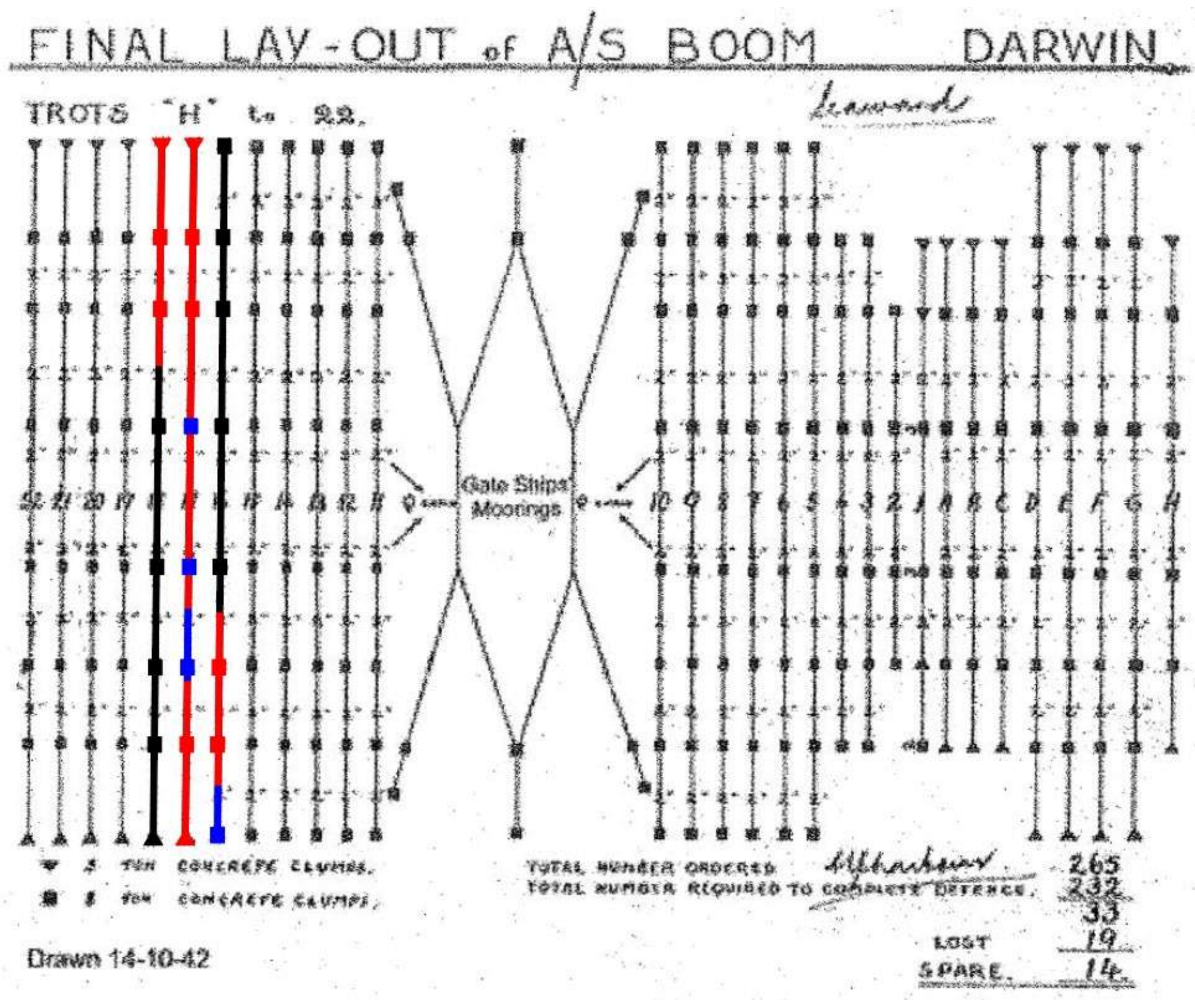


Figure 73: Schematic of anti-submarine net trots, with surveyed net trots highlighted. Clump weights shown by rectangles and triangles and chain shown by lines. Red represents features identified during ROV survey, blue represents features that were missing, and black represents features that were omitted from the survey.

Heritage Transect 1 (Trot 17)

Heritage transect 1 corresponds with the location of trot 17, and is the central trot of the three surveyed. Five mooring clumps were identified along this trot, two on the southern end, including the southernmost clump, and three on the northern end, including the northernmost clump. The location of the other three mooring clumps is unknown. The entire length of the trot is approximately 482m.

The chain ran continuously between the Clump 8 (northernmost) to around the location of where the Clump 4 should have been. At this location, there was a break in the chain, with an array of metal chain branching in multiple directions. The nature of this structure is unknown; however, it is clearly connected to the chain and the northern clump weights. Likewise, the chain from Clump 1 (southernmost) was observed to run from Clump 1 to Clump 2 unbroken before disappearing near the location where Clump 3 should have been. There appears to be a gap between the southern section of the mooring trot and the northern section of approximately 20-30m where no chain or clumps were observed. Between Clumps 5 and 6, a large kink was seen in the chain, indicating that it had perhaps been dragged out of position by an anchor or trawler.

Four of the five clumps observed appeared to be the 8-ton trapezoidal concrete weights shown in Figure 30 in section 4.3.3. Clump 2 appeared on video as a twin set of concrete blocks.

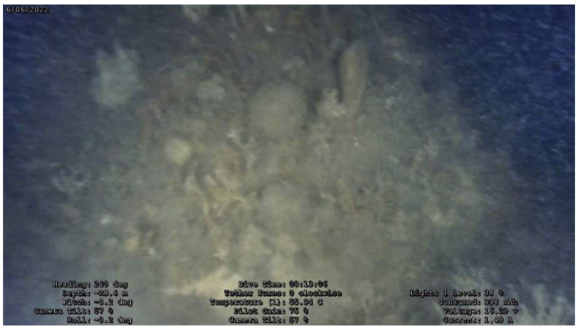


Figure 74: Clump 1 (aka geophysical target 167).

Figure 75: Trot 17, Clump 2 (aka geophysical anomaly NCL_SC_020).

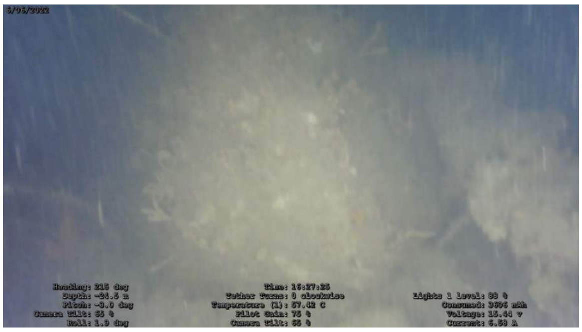


Figure 76: Trot 17, Clump 6 (aka geophysical anomaly 244).

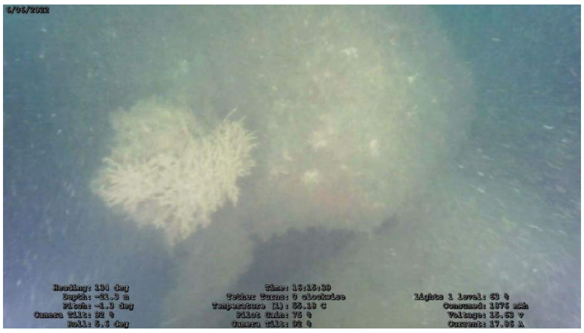


Figure 77: Trot 17, Clump 7 (aka geophysical anomaly NCL_SC_022).

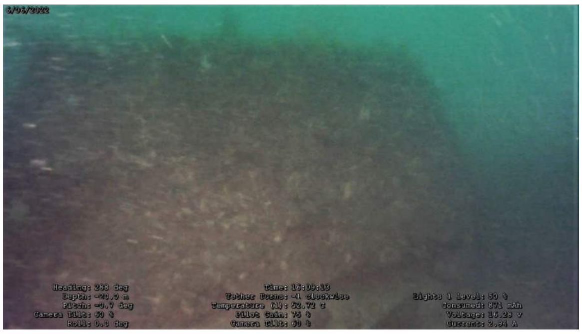


Figure 78: Trot 17, Clump 8 (not identified during geophysical survey).

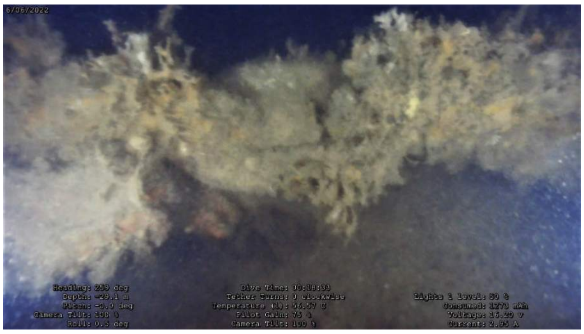


Figure 79: Detail of chain between Clumps 1 and 2.

Heritage Transect 2 (Trot 18)

Heritage Transect 2 corresponds roughly with the location of Trot 18 and is the western trot of the three surveyed. Three mooring clumps were observed by ROV survey comprising most of the northern half of the trot (Clumps 6, 7, and 8). Several of the southern clumps are clearly visible on geophysical survey data. Trot 18 is bisected by the Bayu-Undan GEP, with Clump 5 almost abutting the pipeline as seen on MBES and SSS data. The southern sections of Trot 18 were not surveyed, as their proximity to the existing GEP and their distance from the proposed GEP indicated they are unlikely to be impacted by the proposed works.

The chain ran continuously from Clump 6 to Clump 8, with no breaks or kinks. Clumps 6 and 7 were observed to be the same trapezoidal concrete weights identified in Trot 17, with the same gauge chain connecting them. Clump 8 was unique however, as it consisted of a large ship's anchor that had apparently been repurposed as a mooring for the anti-submarine net. The anchor appeared to be an admiralty pattern style, with a long narrow shank and curving arms with triangular flukes. The anchor laid perpendicular to the seabed, with one arm buried and one arm standing proud from the seafloor. A large rectangular stock was observed, with what appeared to be metal bands wrapped around the sides, indicating that the stock is possibly (but very unlikely) of wooden construction. However, it was impossible to determine from ROV footage precisely what material was used for the stock due to the extensive marine growth covering it. The crown of the anchor was connected to the trot chain with a large D-shackle.

The ROV's depth gauge was used to measure the length of the visible arm by taking a depth reading at the top of the fluke and another at the seabed. The arm measured approximately 1.9m in length, while measurements taken from SSS data indicate that the total length of the shank is approximately 4m.

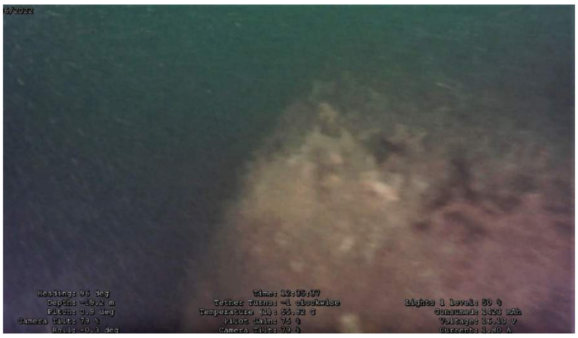


Figure 80: Trot 18, Clump 6.

Figure 81: Trot 18, Clump 7.

Figure 82: Trot 18, Clump 8, repurposed ship's anchor. Photo shows anchor arm and fluke.

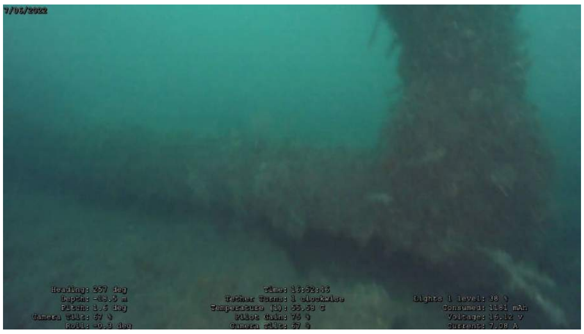


Figure 83: Trot 18, Clump 8, repurposed ship's anchor. Photo shows anchor throat and shank.

Figure 84: Trot 18, Clump 8, repurposed ship's anchor. Photo shows anchor stock and shank.

Figure 85: Trot 18, Clump 8, repurposed ship's anchor. Detail of stock and shackle connecting anchor to mooring trot chain.

Heritage Transect 3 (Trot 16)

Heritage Transect 3 corresponds roughly with the location of Trot 16 and is the eastern trot of the three surveyed. Two mooring clumps were observed by ROV survey, comprising a portion of the southern section of the trot (Clumps 2 and 3). The southernmost clump, Clump 1, was not observed on ROV survey or on geophysical survey data. The chain, running south from Clump 2, was observed to be severely kinked about 15m south of Clump 2 before ending abruptly. Further search of the area with ROV yielded no further evidence of the chain or Clump 1.

The chain ran continuously from Clump 2 to Clump 3 and extended north beyond Clump 3. It was decided to omit any survey of the northern section of the chain due to the distance from the proposed GEP route and the lack of geophysical survey data north of this location (see Figure 72 in section 7.2). Both clumps observed were 8-ton trapezoidal concrete weights.

Trot 16 had clearly been subjected to some disturbance, as the chain connecting Clumps 2 and 3 was heavily kinked and Clump 3 was observed to be upside down.

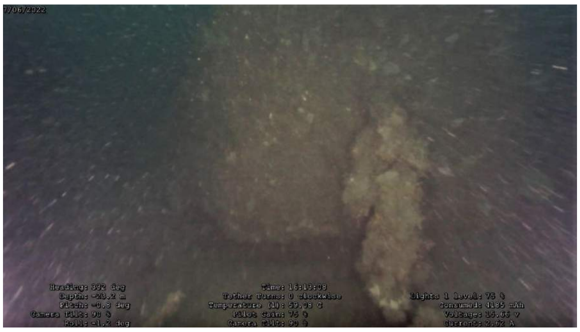


Figure 86: Trot 16, Clump 2 (aka geophysical anomaly 166).

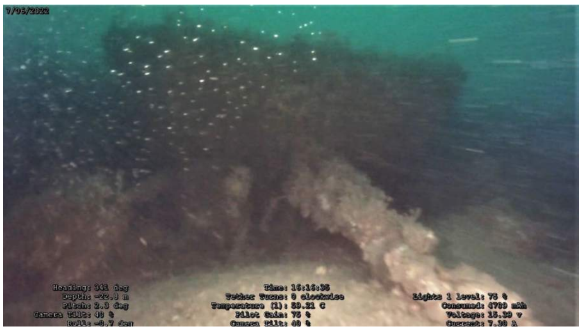


Figure 87: Trot 16, Clump 3. Note block appears to be flipped upside down.

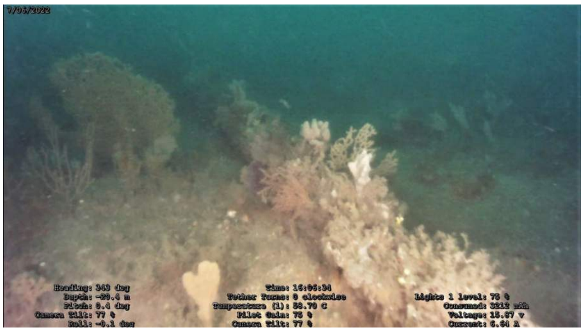


Figure 88: Chain between Clumps 2 and 3, Trot 16.

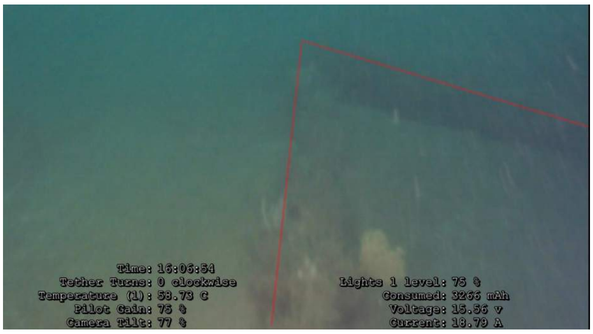


Figure 89: Chain south of Clump 2. Note right angle kink in chain (highlighted in red).

7.3.2 *Target 174 (winch, windlass, or bollard)*

Target 174 was located near KP 109, approximately 15m from the proposed GEP route. Investigation of the target by ROV found a small metal structure, reminiscent of a dumbbell weight, with two vertical protuberances sticking out of the seabed. The seabed around Target 174 was flat and sandy, relatively featureless, and showed no other debris or cultural material within the immediate vicinity of the target. A length of rope was observed wrapped around the centre of the object with a coil underneath one part. Initial identification suggested that the target was a small ship’s winch or windlass, or possibly a bollard. The lack of other identifiable cultural material in the area, i.e., wreckage, suggests that this is an isolated artefact that may have been deliberately discarded or accidentally lost. The exact nature of the cordage is unknown. If the rope is synthetic poly-rope, it would most likely be modern and not historically significant. If the rope is made of natural fibre, it is possible that the object is historic. Flexible steel wire rope has been in use since WWII and could represent historic cultural heritage.

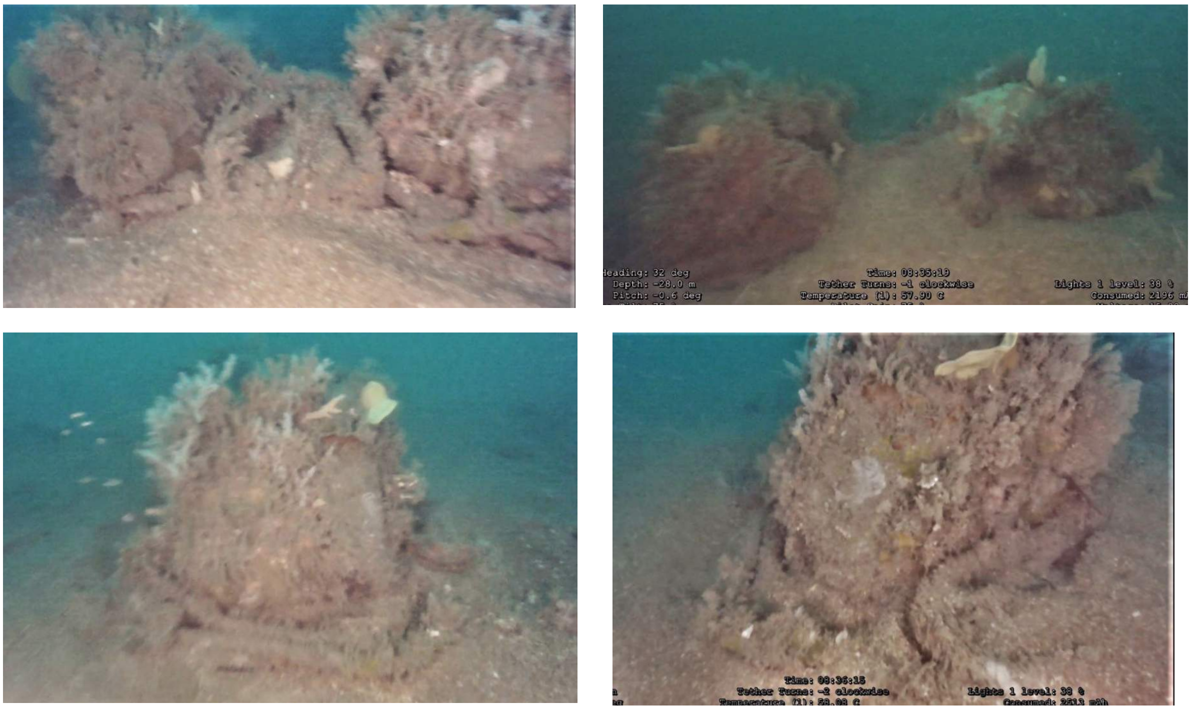


Figure 90: Images of Target 174 taken from ROV survey. Note rope wrapped around middle of structure.

Figure 91: "Coastal trading vessel MV **Zenalyn** ***(ex-Catalina refuelling vessel) in Darwin Harbour."*** Note winch on foredeck (detail of winch on right).[115]

[115] **Spillet, P. ca. 1950s-1960s**. "Coastal trading vessel MV Zenalyn (ex-Catalina refuelling vessel) in Darwin Harbour." Library & Archives NT, image PH0238/4149.

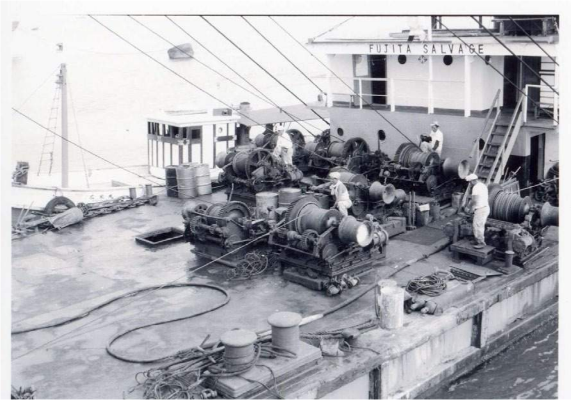


Figure 92: "Winches on the deck of Fujita Salvage Boat." Note bollard at bottom of picture.[116]

Figure 93: Small winch with rope used on Darwin working vessel, 1975.[117]

7.3.3 *MA_007 (unidentified metal structure)*

Target MA_007 was identified during geophysical surveys as a magnetic anomaly, with no discernible images seen on MBES and SSS. The target is located approximately halfway between KP 111 and 112 and is roughly 6m from the proposed GEP route.

ROV survey identified a field of debris located in a mostly sandy seabed. The debris was partially buried and had a low relief above the seabed. The primary artefact observed was a rectangular metallic structure made up of multiple rows of connected small beams. It was not possible to take measurements with the ROV, so the full scale and size of the structure, along with its composition, is unknown. The main structure is estimated to be roughly five metres long and 2 metres wide. Small fragments of apparently associated material were scattered around the primary structure in a debris field.

It is unknown, with the data available, whether Target MA_007 represents the wreckage of a vessel or aircraft, deliberate or accidental discard of materials, or disarticulated maritime infrastructure. The main structure bears some resemblance to historic photographs of small work barges as well as the internal support structures of some aircraft hulls and wings. Further investigation is needed to conclusively identify what the remains are likely to be.

[116] **Fujita Salvage Company, 1960**. "Winches on the deck of Fujita Salvage boat." Library & Archives NT, Senichiro Fujita Collection, PH0874/0120.
[117] **Bruce, H. 1975**. "Kay Laforest, Darwin." NLA PIC P805/30a LOC Q28.

Figure 94: Target MA_007 as seen during ROV survey.

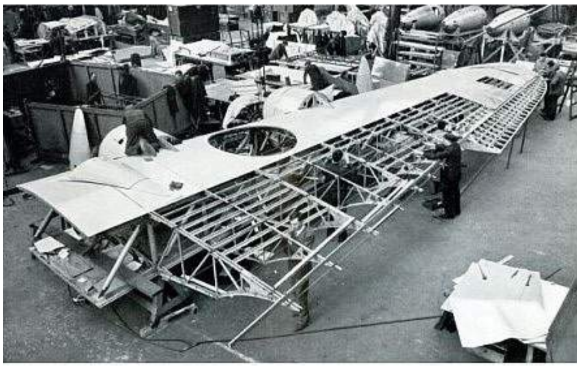


Figure 95: Short Empire flying boat wing under construction, showing structure of internal supports.

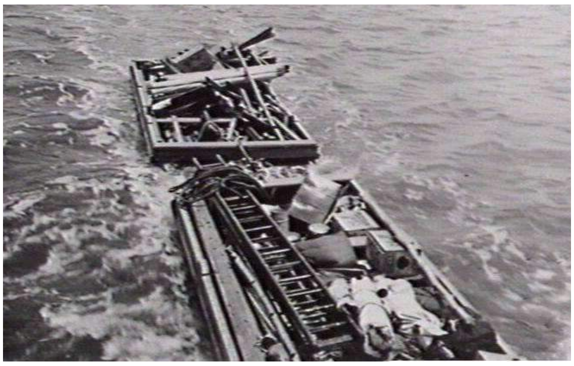


Figure 96: "Barges with materials for leper station being towed across harbour" 1937.[118]

7.3.4 *MA_001 (buoy mooring)*

Target MA_001 was identified during geophysical surveys as a magnetic anomaly, with no discernible images seen on MBES and SSS. The target is located approximately 150m north of KP 116 and is 35m from the proposed GEP route.

ROV survey identified three artefacts of cultural origin in the location of Target MA_001. The first located appeared to be a metal wheel rim and was mostly buried in sandy sediments. A small section of cable was observed protruding from the object. The second object, a length of metal cable with a loop tied in the end, was located a few metres away. It is believed that these two objects are related and represent the remains of a possible buoy mooring. The

[118] **Anon, 1937.** "Barges with materials for leper station being towed across harbour." Library & Archives NT, Australian Department of the Interior Collection, PH0125/0018.

wheel and cable are located within 70m of the wreck of USAT *Mauna Loa* and may be related to a navigational buoy used to identify the wreck site.

The third object noted was a piece of debris, likely concrete or metallic, with several wires protruding from the object. The exact composition of this artefact was impossible to determine by ROV survey, but may represent discard or a piece of wreckage, possibly from *Mauna Loa,* which was extensively salvaged in the 1950s (see section 4.3.1).

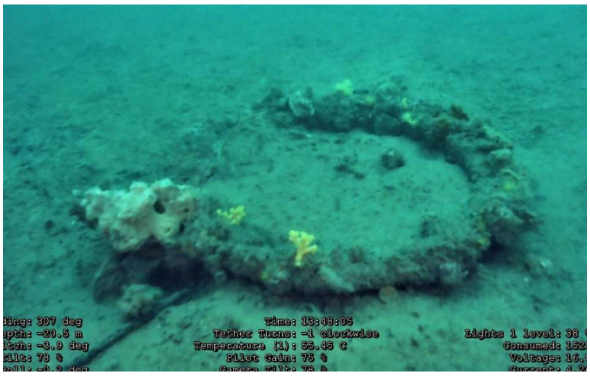


Figure 97: Metal wheel rim with cable protruding.

Figure 98: Mooring cable with loop at right of image.

Figure 99: Unidentified debris located several metres north of wheel rim and cable.

7.3.5 *NCL_SC_016 (cable)*

Target NCL_SC_016 was identified during geophysical surveys as a “likely cable support”, appearing as a small linear feature on SSS and MBES. The target is located approximately 145m north of KP 109 and is 25m from the proposed GEP route.

ROV survey located a section of cable lying on the seabed which appeared to be disarticulated at both ends. The section of cable was approximately 35m in total length with a width of less than 100mm. The precise make up and composition of the cable could not be determined by ROV survey, so its identity cannot be conclusively stated. The object is located in an area known to have contained 19th century telegraph cables (see section 4.3.3) and may represent a section of a cable that was cut or disarticulated.

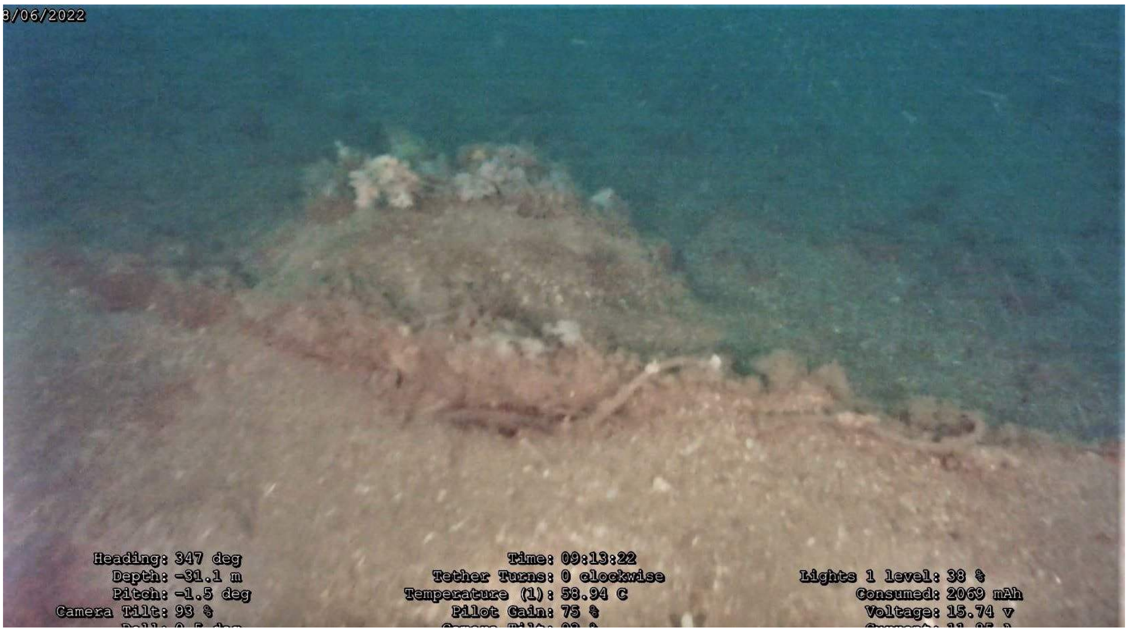


Figure 100: Detail of cable located at Target NCL_SC_016.

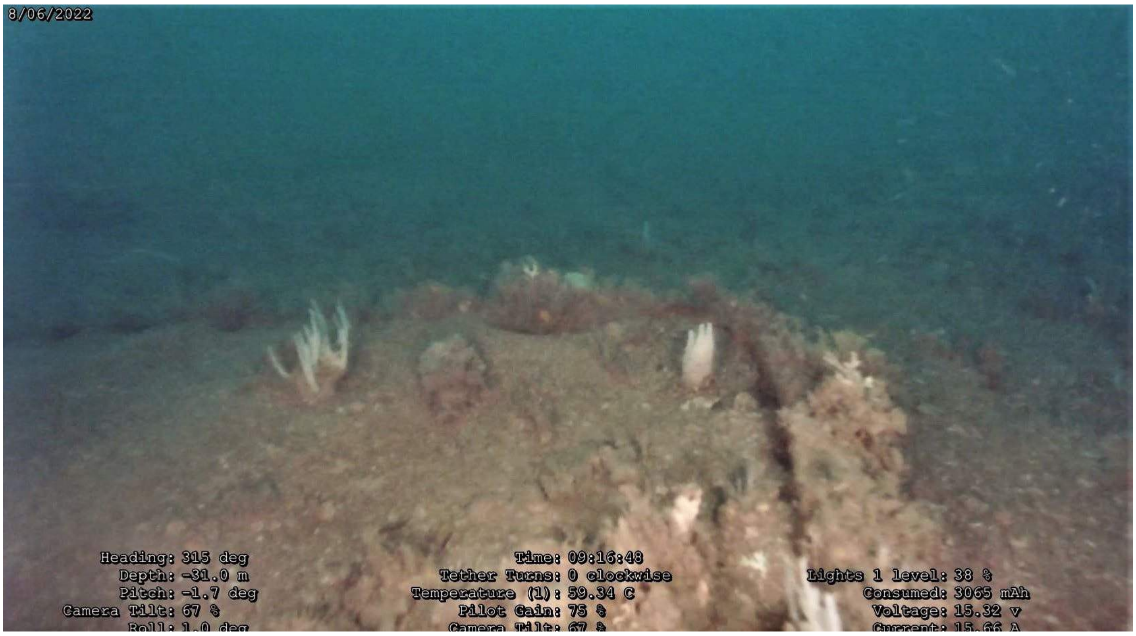


Figure 101: Detail of kink in cable.

8 DISCUSSION

8.1 Assessing cultural significance

Cultural Significance Criteria

All cultural objects have significance. The cultural significance of an object or a group of objects (a 'site') depends on what aspects of cultural activity the community values. In those jurisdictions where there are heritage laws, an established set of criteria is used to assess what objects or sites are eligible to be afforded greater statutory protection.

The Northern Territory *Heritage Act 2011* has provisions to declare a 'Heritage Place' or 'Heritage Object'. Such a declaration regulates activities within the site curtilage, hence protecting the site. To assist in the determination of whether a site, place, or object should be recommended for declaration under Part 2.2 of the Act, heritage assessment criteria (Part 1.2, Division 2, Section 11) have been established. The criteria are listed below.

A. *Whether it is important to the course, or pattern of the Territory's cultural or natural history;*

B. *Whether it possesses uncommon, rare or endangered aspects of the Territory's cultural or natural history;*

C. *Whether it has potential to yield information that will contribute to an understanding of the Territory's cultural or natural history;*

D. *Whether it is important in demonstrating the principal characteristics of a class of cultural or natural places or environments;*

E. *Whether it is important in exhibiting particular aesthetic characteristics;*

F. *Whether it is important in demonstrating a high degree of creative or technical achievement during a particular period;*

G. *Whether it has a strong or special association with a particular community or cultural group for social, cultural, or spiritual reasons, including the significance of a place to Aboriginal people as part of their continuing and developing cultural traditions;*

H. *Whether it has a special association with the life or works of a person, or group of persons, of importance in the Territory's history.*

The threshold for a site or object being declared is whether it can be demonstrated to have '…*special significance in the Territory'.* These cultural significance criteria have been adopted for this survey and all cultural objects found have been assessed against these criteria.

Cultural significance gradings

The Northern Territory heritage assessment criteria have been established to select sites/objects of 'special' significance to be protected. To date, no site/object found in the study area can be considered to have special significance. The significance of a site/object varies mostly depending on their rarity or representativeness and their condition; the latter point referring to the site/object's ability to provide information.

Table 12 provides five grades of cultural significance ranging from Minimal to Special. Identified cultural sites or objects have been assessed according to how well they may be able to contribute to the cultural heritage criteria set out in the Northern Territory Heritage Conservation Regulations.

Sites or objects can be considered of low significance if they are commonplace and recent even if they are associated with a significant individual or event. Such sites/objects, however, which are well preserved and are excellent representative examples can have an elevated level of significance. Higher significance tends to be given to those sites/objects which are older on the basis that such sites are rare and represent extinct or near extinct lifeways and/or technology. they can also be given higher significance because of their association with defining events in Northern Territory history; World War II being a good example.

Assessing the level of significance of each cultural object found will help determine what would be appropriate and proportionate mitigation measures against the proposed impacts. It may be sufficient for sites of low significance to be recorded *in situ* to a certain level before they are impacted. Other sites/objects could be considered significant enough to be excavated, relocated and/or recovered for conservation.

Table 12: Levels of cultural heritage significance.

Degree	Significance
Special	A rare or unique object or site in a relatively good state of preservation that provides an irreplaceable insight on the development of the Northern Territory and Australia. Eligible for listing as a 'Heritage Place' or 'Object'
High	A rare object or site type in a relatively good state of preservation that provides a new insight on the development of the Northern Territory and Australia.
Moderate	A rare object/site in a poor state of preservation or a common object/site in a relatively good state of preservation that provides an insight into the development of the Northern Territory.
Low	A common object or site type in a poor to fragmentary state of preservation that contributes to the understanding of the development of the Northern Territory.
Minimal	A ubiquitous object type, usually of recent manufacture, which provides little new information to the understanding of the development of the Northern Territory.

8.2 Preliminary evaluation

The following preliminary evaluation is based on the cultural significance of each of the 7 sites observed during the ROV surveys rather than individual objects (Table 13). Where the cultural significance of individual objects within a target varies, the significance rating of the target will be set to the highest rating object.

Table 13: Preliminary cultural significance assessments.

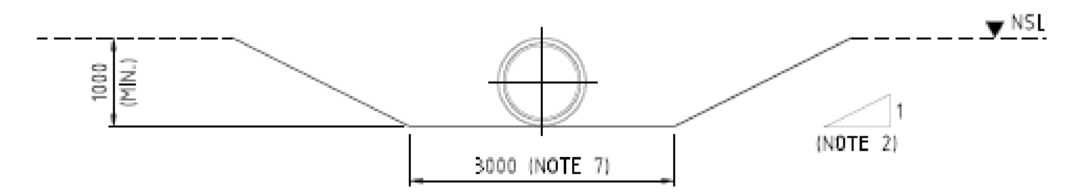
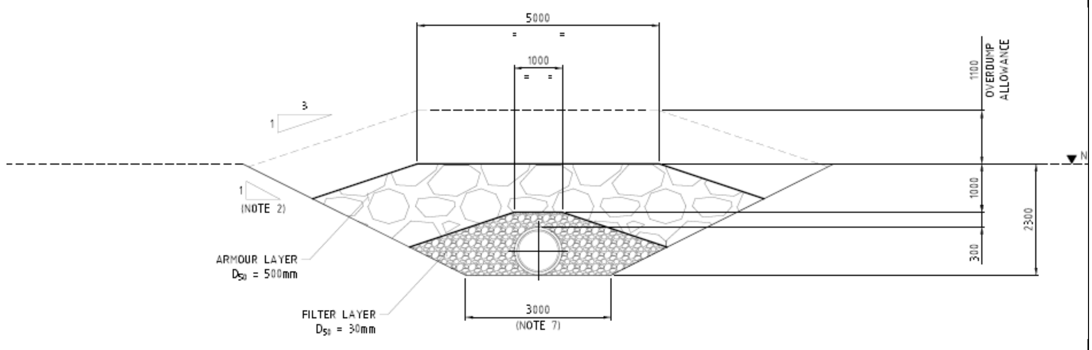
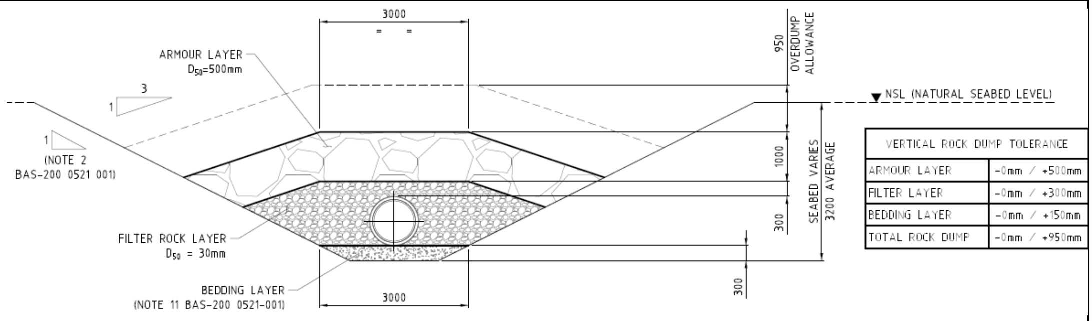
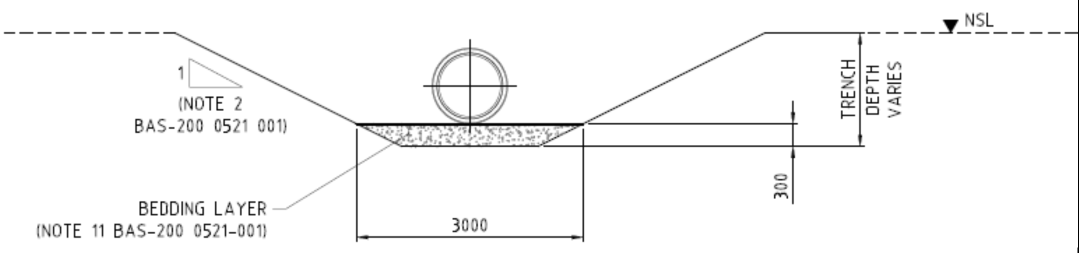
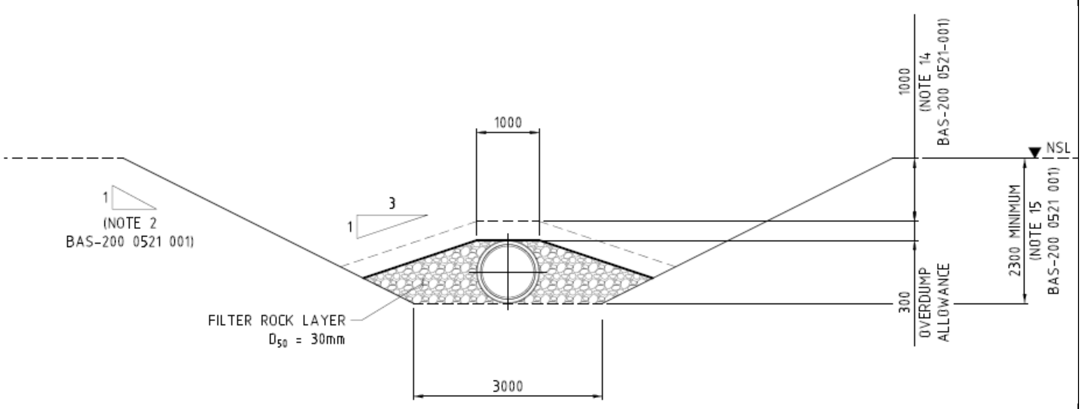
Target	Preliminary Significance Statement	Degree
Anti-submarine net Trot 16	WWII was a significant period in Australian and Northern Territory history and the remnants of the boom defence system related directly to the defence of Darwin Harbour during this period. Such items are rare as only a small number of boom defences were established in Australia during WWII. The anti-submarine defences of Darwin during WWII may have been the largest boom defence network in the world at the time. The boom defence mooring clumps and chains are *in situ* on the seafloor and in a good state of preservation. This makes them rare not only in the Northern Territory but in a National Context.	**High**

Target	Preliminary Significance Statement	Degree
Anti-submarine net mooring Trot 17	WWII was a significant period in Australian and Northern Territory history and the remnants of the boom defence system related directly to the defence of Darwin Harbour during this period. Such items are rare as only a small number of boom defences were established in Australia during WWII. The anti-submarine defences of Darwin during WWII may have been the largest boom defence network in the world at the time. The boom defence mooring clumps and chains are *in situ* on the seafloor and in a good state of preservation. This makes them rare not only in the Northern Territory but in a National Context.	**High**
Anti-submarine net mooring Trot 18	WWII was a significant period in Australian and Northern Territory history and the remnants of the boom defence system related directly to the defence of Darwin Harbour during this period. Such items are rare as only a small number of boom defences were established in Australia during WWII. The anti-submarine defences of Darwin during WWII may have been the largest boom defence network in the world at the time. The boom defence mooring clumps and chains are *in situ* on the seafloor and in a good state of preservation. In addition, the substitution of a conventional concrete mooring block with a repurposed ship's anchor increases the diagnostic value of this site by providing a unique display of adaptation and material scarcity during war time. The anchor itself is most likely of higher historic significance depending on its age and rarity. This makes them rare not only in the Northern Territory but in a National Context.	**High**
Target 174	The precise identity and nature of the object located at Target 174 cannot be conclusively determined based solely on a visual ROV survey. Further investigation would be needed to positively identify it within its historical context. However, if the object is a winch, windlass or bollard from a historic vessel its heritage significance could be substantially higher than if it was simply discarded. Target 174 is not believed to be part of a larger buried shipwreck.	Unknown, likely **Low**
MA_007	The precise identity and nature of the object located at Target MA_007 cannot be conclusively determined based solely on a visual ROV survey. Further investigation would be needed to positively identify it within its historical context. However, if the object is part of the wreckage of an historic aircraft or vessel, its heritage significance could be substantially higher than if it is discarded material.	Unknown, likely **Minimal** to **Moderate**
MA_001	The objects located at Target MA_001 are most likely the remains of a buoy mooring. Steel wire rope and steel wheel rims are commonly used as mooring devices across Australia, with numerous examples extant. The use of steel wire rope points to a likely late 20th century historical context. Not considered rare or culturally significant.	**Minimal**
NCL_SC_016	The precise identity and nature of the object located at Target NCL_SC_016 cannot be conclusively determined based solely on a visual ROV survey. Further investigation would be needed to positively identify it within its historical context. If the object is the remains of a 19th century telegraph cable, its cultural significance would be considerably higher than if it is modern material or discard.	Unknown, likely **Minimal** to **Low**

8.3 Potential impacts

Santos has advised that the pipeline will primarily be laid directly on the seabed. It is understood that trenching and placement of rock armour will be undertaken in several sections within Darwin Harbour (see Figure 103). The potential footprint of trenching has been identified as up to 40 m wide at top of batter due to use of cutter suction dredge. These sections include spans between KP 101 and 107, 110 and 114, 119 and 121, and 121 to terminus. It is understood, based on design documents provided by Santos, that five different trenching configurations will be used, types A2, C1b, D1, D3, and E. Cross sections detailing the designs of the five trench types are shown in Table 14.

Table 14: Trench type cross section. NSL - natural seabed level.

Trench Type	Cross Section
A2	
C1b	
D1	
D3	
E	

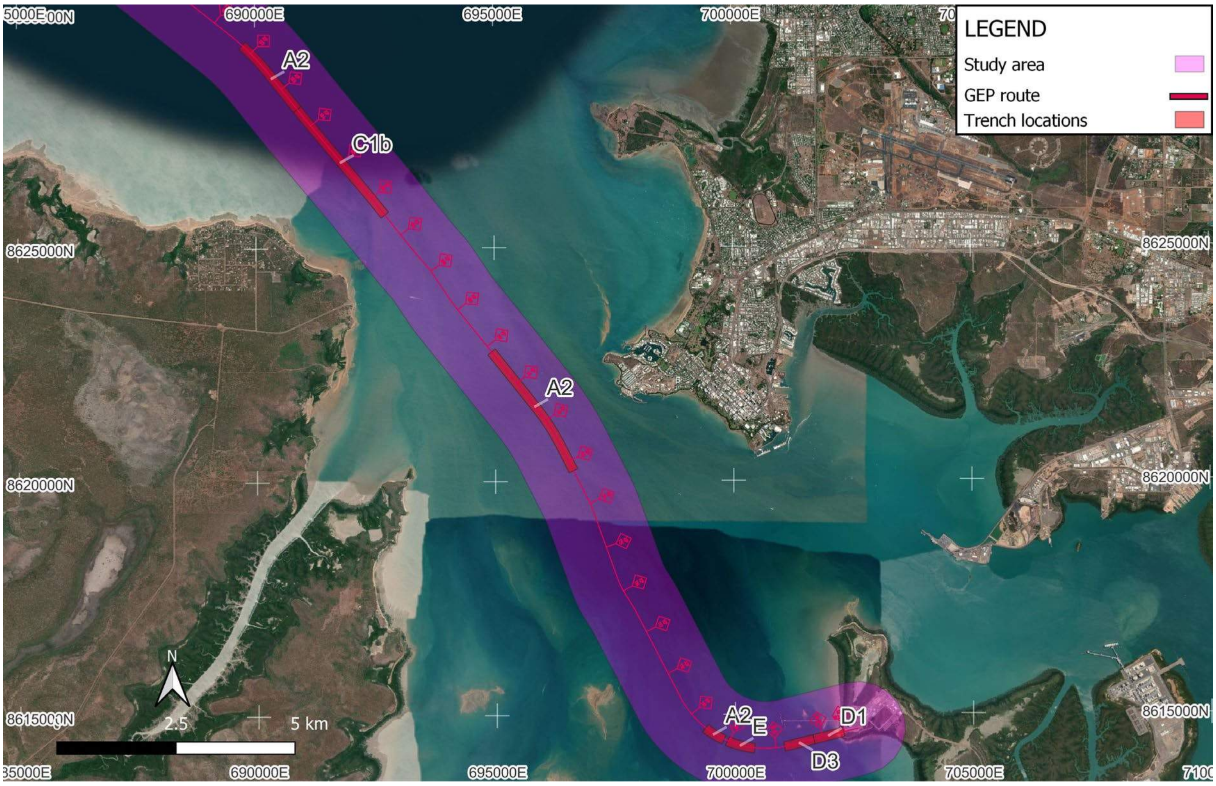


Figure 102: Map of proposed trenching locations with trench type labelled. (Polygons for trench locations are indicative of location only, not to scale by width).

One instance of underwater cultural heritage, Target MA_007, is within the trench extent overview. The target is located within the A2 trench between KP 111 and 113 (see Figure 104).

The laying of a pipe over a wreck site will not destroy such a site but will disturb or impact it. Such an activity, however, may damage and destabilise the site. It is understood that some sections will require the placement of mattresses to address spanning issues. Mattresses would cover parts of a site, which will protect it in the long term, but would negatively impact the site if it is not recorded before partial burial. If the wreck site is legally protected such disturbances could be considered unlawful without appropriate approvals under relevant heritage legislation. Additionally, Santos has identified a 900 m wide corridor on either side of the proposed GEP route between KP 91.5 and the terminus where work vessels may need to anchor. Anchor chains present a significant hazard to maritime cultural heritage sites within their deployment zone, as sweeping chains can damage or move archaeological sites and artefacts.

Within the anchoring corridor there are eight known shipwrecks (see Section 4.3.1, Table 2). Two of these, USAT *Mauna Loa* and USAT *Meigs,* fall under the protection of the NT *Heritage Act 2011* and may be protected under the USA *SMCA 2004.* The remaining six wrecks are under no legislative protection. Three objects of cultural heritage, inspected during ROV surveys, are also within the anchoring corridor, Targets 174, MA_007, and NCL_SC_016 (see Section 6.3.1). Additionally, the anti-submarine net mooring trots 16, 17, and 18 are within this corridor. It is highly likely, based on review of historical sources and geophysical survey data, that many of the remaining trots are also located within the anchoring corridor. In addition to trots 16, 17, and 18, an additional 90 geophysical targets within the anchoring corridor were identified as likely remains of anti-submarine net moorings (see Section 6.3.3).

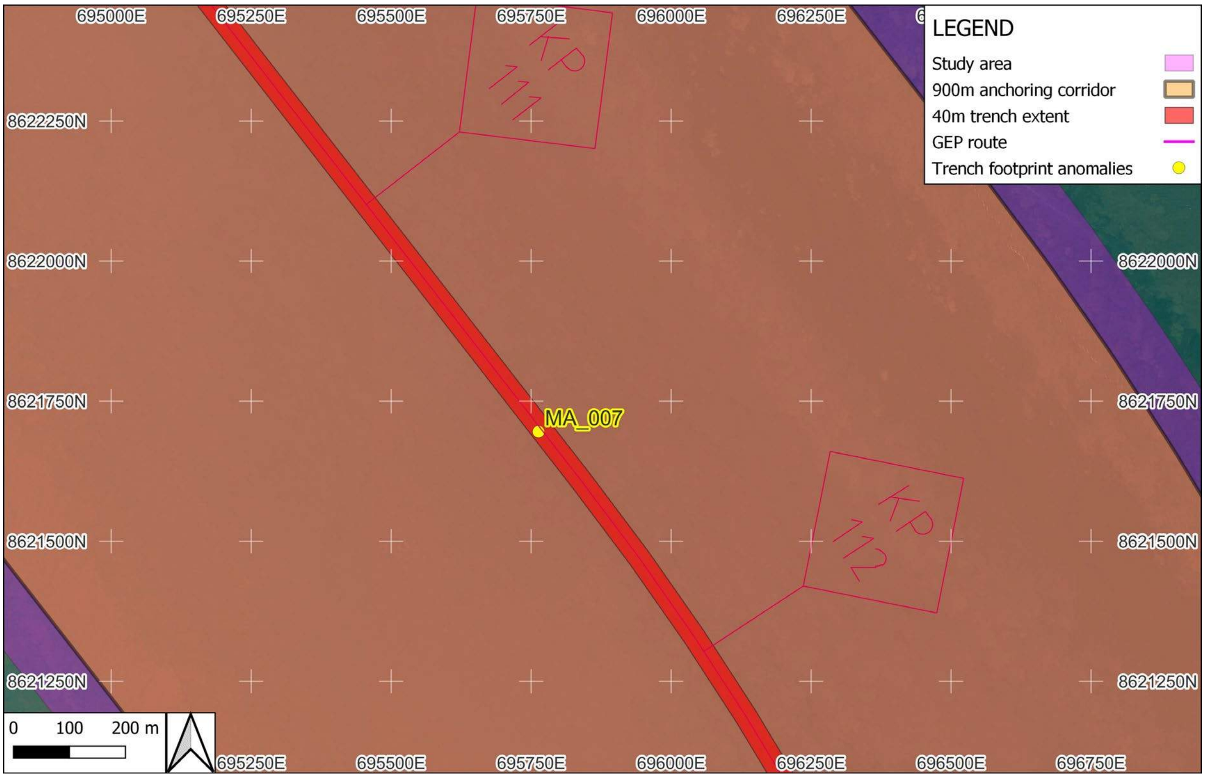


Figure 103: Underwater cultural heritage within trench extent overview.

A further 63 unverified geophysical anomalies, identified during geophysical survey data review but not inspected by ROV, are within the anchoring corridor (Figure 105). 18 of these targets were identified during review of Fugro survey data (see Section 6.3.1) and 45 were identified from review of the Geoscience Australia MBES dataset (see Section 6.3.2).

The location of these additional unverified anomalies, shipwrecks, and known cultural heritage is shown in Figure 105 and Table 15.

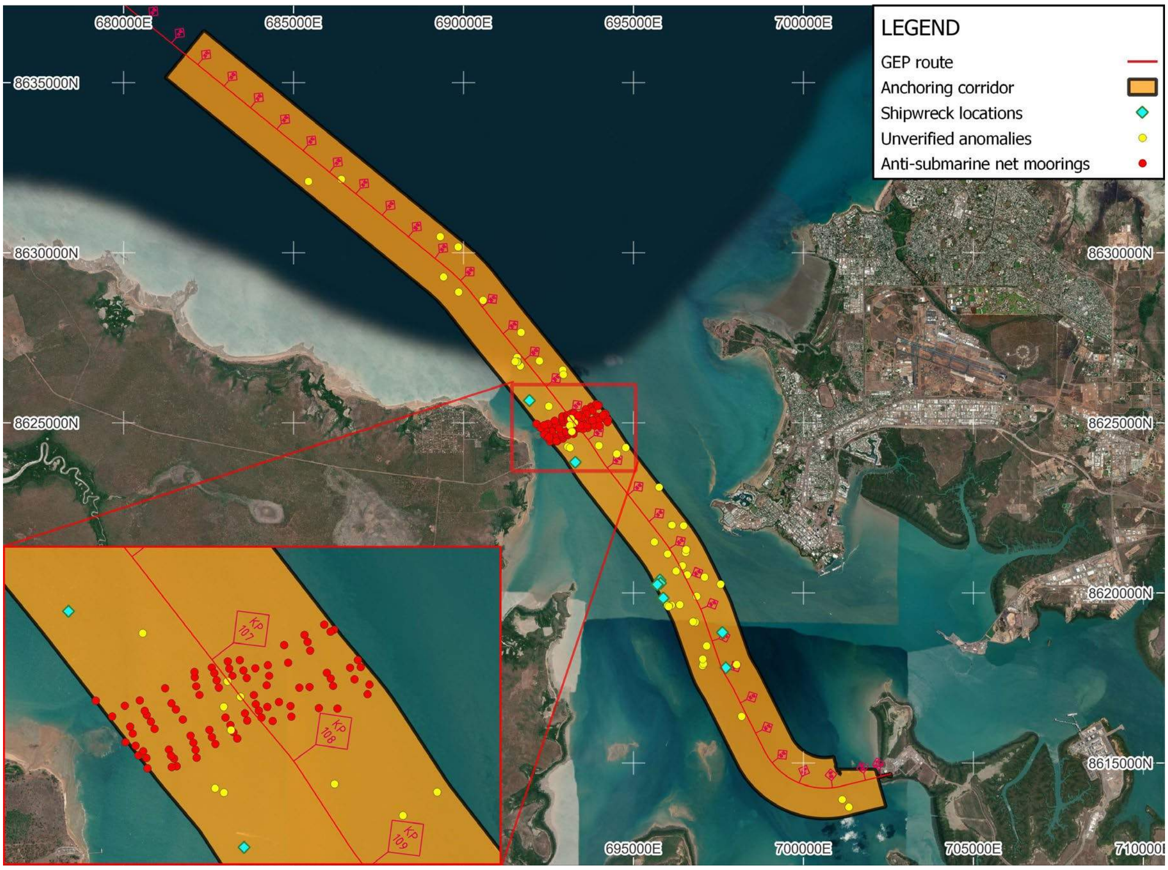


Figure 104: Location of unverified geophysical survey anomalies and other underwater cultural heritage within anchoring corridor.

Table 15: Unverified anomalies, shipwrecks, and known maritime cultural heritage within anchoring corridor.

Anomaly ID	Identification	Datum: GDA94 CRM: UTM Zone 52s		Distance from GEP (m)
		Easting	Northing	
138	Mound associated with anchor scar	686,407.37	8,632,159.33	59
141	Debris or rocks	690,574.96	8,628,606.67	137
191	Single object of high relief. Possible small boat.	696,438.36	8,620,800.13	73
192	Possible debris	696,253.89	8,620,643.48	147
196	Debris or rocks	696,859.94	8,619,902.39	53
210	Possible aircraft wreck or natural feature.	701,140.90	8,613,958.61	360
238	Possible scattered debris.	696,581.70	8,620,537.67	78
239	USAT *Mauna Loa*	697,710.77	8,617,774.90	90
240	Possible mooring block for anti-submarine defences	691,578.22	8,626,925.25	122
242	Steel wire rope and chain associated with anti-submarine defences. (boom net), UXO including mechanical fuses and fuse cones. (See Section 6.4)	691,589.94	8,626,799.20	186
243	Possible mooring block related to anti-submarine defences.	693,188.00	8,624,746.00	216
500	USAT *Meigs*	697,615.17	8,618,840.23	369
501	Medkhanun 3	695,875.84	8,619,850.01	847

Anomaly ID	Identification	Datum: GDA94 CRM: UTM Zone 52s		Distance from GEP (m)
		Easting	Northing	
502	*Ham Luong*	695,698.81	8,620,246.53	832
503	*Song Saigon*	695,794.02	8,620,287.72	728
504	John Holland Barge	695,778.93	8,620,381.31	700
505	*Mandorah Queen*	693,287.42	8,623,844.84	683
506	*NR Diemen*	691,938.35	8,625,657.51	642
573	Debris	692,508.78	8,625,489.01	295
574	WWII anti-sub boom net	691,574.41	8,626,791.47	209
575	Debris	691,518.71	8,626,801.77	245
576	Mound	689,856.12	8,628,847.08	268
577	Isolated object	689,412.76	8,629,288.62	263
578	Mound associated with trawl scar	685,439.11	8,632,096.37	603
579	Debris	689,314.84	8,630,473.13	592
580	Mound	689,842.70	8,630,171.05	691
581	Possible cable	691,692.88	8,627,659.36	431
582	Possible cable	692,233.25	8,626,819.69	320
583	Linear debris	692,918.80	8,626,550.93	682
584	Debris or boulder	692,936.90	8,626,417.56	613
588	Debris	693,982.49	8,624,331.38	165
585	Debris	694,508.35	8,624,088.70	472
586	Possible small boat or natural feature	694,770.88	8,624,269.65	791
587	Mooring block	695,753.15	8,623,106.77	852
589	Debris	696,110.51	8,621,995.74	452
590	Debris	696,133.59	8,621,994.69	470
591	Debris	696,472.78	8,621,975.02	727
592	Debris	696,535.45	8,621,187.11	345
593	Mooring block	696,548.46	8,621,272.90	399
594	Debris	697,090.00	8,620,464.24	513
595	Debris	697,563.09	8,620,256.32	845
597	Debris	698,035.82	8,617,894.98	443
598	Linear feature	697,030.36	8,617,864.23	504
599	Linear feature	697,055.70	8,617,918.12	462
600	Linear feature	697,036.34	8,618,057.64	434
601	Debris	696,815.85	8,619,144.52	286
602	Debris	696,751.52	8,619,156.36	343
603	Debris	696,112.03	8,619,639.40	729
604	Linear feature, log	696,043.52	8,619,624.92	797
605	Linear feature, log	696,000.91	8,619,629.09	833
606	Linear feature, log	696,032.94	8,619,598.74	818
607	Debris	696,362.60	8,619,654.65	497
609	Debris	696,003.49	8,621,145.27	132
610	Isolated object	695,614.51	8,621,498.95	244
611	Mooring block	693,064.64	8,624,298.00	599

Anomaly ID	Identification	Datum: GDA94 CRM: UTM Zone 52s		Distance from GEP (m)
		Easting	Northing	
612	Debris	693,132.32	8,624,265.69	568
620	Anti-submarine net mooring	692,571.44	8,624,809.47	663
621	Anti-submarine net mooring	692,539.74	8,624,860.74	656
622	Anti-submarine net mooring	692,523.80	8,624,892.44	649
623	Anti-submarine net mooring	692,599.70	8,624,754.58	674
624	Anti-submarine net mooring	692,709.75	8,624,594.89	685
625	Anti-submarine net mooring	692,769.99	8,624,467.63	716
626	Anti-submarine net mooring	692,749.61	8,624,525.87	696
627	Anti-submarine net mooring	692,726.33	8,624,548.70	700
628	Anti-submarine net mooring	692,147.90	8,624,971.06	898
629	Anti-submarine net mooring	692,431.95	8,624,717.81	829
630	Anti-submarine net mooring	692,412.02	8,624,771.61	812
631	Anti-submarine net mooring	692,453.33	8,624,625.24	869
632	Anti-submarine net mooring	692,922.97	8,624,532.76	556
633	Anti-submarine net mooring	692,914.46	8,624,593.08	525
634	Anti-submarine net mooring	692,897.79	8,624,648.33	504
635	Anti-submarine net mooring	692,876.05	8,624,702.14	488
636	Anti-submarine net mooring	692,763.55	8,624,903.58	453
637	Anti-submarine net mooring	692,729.14	8,624,950.23	452
638	Anti-submarine net mooring	692,816.54	8,624,826.14	459
639	Anti-submarine net mooring	693,066.90	8,624,638.82	377
640	Anti-submarine net mooring	693,040.27	8,624,691.00	365
641	Anti-submarine net mooring	693,020.88	8,624,746.07	347
642	Anti-submarine net mooring	692,944.62	8,625,014.99	242
643	Anti-submarine net mooring	692,919.53	8,625,081.20	221
644	Anti-submarine net mooring	692,908.66	8,625,150.86	187
645	Anti-submarine net mooring	692,905.94	8,625,190.98	164
646	Anti-submarine net mooring	693,039.04	8,625,225.45	38
647	Anti-submarine net mooring	693,058.79	8,625,182.69	49
648	Anti-submarine net mooring	693,076.54	8,625,127.44	69
649	Anti-submarine net mooring	693,093.03	8,625,071.10	90
650	Anti-submarine net mooring	693,205.80	8,624,728.36	213
651	Anti-submarine net mooring	693,234.87	8,624,680.26	222
652	Anti-submarine net mooring	693,144.21	8,624,841.13	191
653	Anti-submarine net mooring	693,182.07	8,624,784.25	196
654	Anti-submarine net mooring	693,311.23	8,624,817.58	75
655	Anti-submarine net mooring	693,293.93	8,624,874.10	53
656	Anti-submarine net mooring	693,197.83	8,625,161.77	48
657	Anti-submarine net mooring	693,162.23	8,625,272.64	88
658	Anti-submarine net mooring	693,173.46	8,625,217.02	63
659	Anti-submarine net mooring	693,400.45	8,624,893.93	42
660	Anti-submarine net mooring	693,420.92	8,624,841.76	24

Anomaly ID	Identification	Datum: GDA94 CRM: UTM Zone 52s		Distance from GEP (m)
		Easting	Northing	
661	Anti-submarine net mooring	693,376.72	8,624,944.02	56
662	Anti-submarine net mooring	693,282.43	8,625,202.62	140
663	Anti-submarine net mooring	693,307.79	8,625,145.38	125
664	Anti-submarine net mooring	693,254.26	8,625,282.33	167
665	Anti-submarine net mooring	693,362.50	8,625,014.22	88
666	Anti-submarine net mooring	693,460.95	8,625,089.13	211
667	Anti-submarine net mooring	693,555.33	8,624,959.96	203
668	Anti-submarine net mooring	693,650.62	8,624,848.92	204
669	Anti-submarine net mooring	693,506.97	8,624,814.32	72
670	Anti-submarine net mooring	693,465.48	8,624,923.37	111
671	Anti-submarine net mooring	693,643.69	8,624,929.98	251
672	Anti-submarine net mooring	693,469.78	8,625,242.93	313
673	Anti-submarine net mooring	693,711.60	8,625,070.97	394
674	Anti-submarine net mooring	694,135.50	8,625,135.19	759
675	Anti-submarine net mooring	694,161.68	8,625,283.10	875
676	Anti-submarine net mooring	694,183.69	8,625,228.03	856
677	Anti-submarine net mooring	694,250.36	8,625,094.43	821
678	Anti-submarine net mooring	693,923.28	8,625,184.46	629
679	Anti-submarine net mooring	693,952.90	8,625,141.07	624
680	Anti-submarine net mooring	693,970.93	8,625,083.92	601
681	Anti-submarine net mooring	693,751.64	8,625,475.17	678
682	Anti-submarine net mooring	693,775.01	8,625,422.23	664
683	Anti-submarine net mooring	693,794.64	8,625,355.29	638
684	Anti-submarine net mooring	693,902.95	8,625,554.38	846
685	Anti-submarine net mooring	694,101.63	8,625,224.18	791
686	Anti-submarine net mooring	693,979.35	8,625,516.11	883
687	Anti-submarine net mooring	693,951.72	8,625,500.98	852
688	Anti-submarine net mooring	693,595.12	8,625,397.09	506
689	Anti-submarine net mooring	693,625.83	8,625,262.22	448
690	Anti-submarine net mooring	693,861.92	8,624,914.00	408
691	Anti-submarine net mooring	694,235.64	8,625,020.33	763
692	Anti-submarine net mooring	694,004.85	8,624,910.74	515
693	Anti-submarine net mooring	693,790.27	8,625,076.31	458
694	Anti-submarine net mooring	692,680.70	8,625,066.80	418
695	Anti-submarine net mooring	692,486.05	8,624,972.60	630
696	Anti-submarine net mooring	692,274.19	8,624,850.32	872
697	Anti-submarine net mooring	692,370.93	8,624,932.20	746
698	Anti-submarine net mooring	692,376.54	8,624,652.46	913
699	Anti-submarine net mooring	693,479.77	8,625,162.13	271
700	Anti-submarine net mooring	693,373.52	8,625,219.83	223
701	Anti-submarine net mooring	692,476.81	8,624,552.19	895
702	Anti-submarine net mooring	692,545.01	8,624,451.33	903

Anomaly ID	Identification	Datum: GDA94 CRM: UTM Zone 52s		Distance from GEP (m)
		Easting	Northing	
703	Anti-submarine net mooring	692,536.68	8,624,530.67	861
704	Anti-submarine net mooring	692,512.14	8,624,583.21	848
705	Anti-submarine net mooring	692,731.65	8,624,460.66	750
706	Anti-submarine net mooring	693,612.40	8,625,501.30	584
707	Anti-submarine net mooring	693,639.40	8,625,450.30	414
708	Anti-submarine net mooring	693,667.30	8,625,396.10	435
709	Anti-submarine net mooring	693,801.20	8,625,027.90	562
710	Anti-submarine net mooring	693,812.30	8,624,981.60	576
MA_028	Inferred Cable	693,130.70	8,624,923.90	151
MA_031	Inferred Buried Debris	698,180.90	8,616,372.60	146
MA_037	Icthys GEP	701,335.50	8,613,704.20	651

Four geophysical anomalies were identified within 10m of the proposed GEP route, ID: 142, 175, 245, and 246. Targets 142, 175, 245, and 246 were observed during ROV surveys and determined to be natural. An additional six geophysical anomalies were identified within 50m of the proposed GEP route, ID: 166, 174, 233, 241, 244, and 247. Targets 166 and 244 were identified by ROV survey as part of Trot 18, while 233, 241, and 247 were identified to be natural features by ROV. Target 174 was identified as cultural in origin.

The ROV survey identified three anti-submarine net mooring trots, Trots 16, 17, and 18. Trot 17 directly crosses the path of the proposed GEP route. The northern most clump of Trot 16, identified as a repurposed ship's anchor, is located approximately 37m from the proposed GEP route, and the southernmost chain section of Trot 18 is located 32m from the proposed GEP route. The location of Clump 1, Trot 18, if still extant would likely be located within 25m of the proposed route.

In addition to the anti-submarine net trots, four isolated instances of cultural heritage were observed during ROV surveys. Target MA_007 is located 6m from the proposed GEP route. Targets 174, MA_001, and NCL_SC_016 are located 15-35m from the proposed GEP route.

Table 16: Targets and anomalies located within 50m of proposed GEP route.

Anomaly/Target ID	Target surveyed by ROV	Cultural/Natural	Within 10m of GEP route
Trot 16 (incl. Targets 166, NCL_SC_017, 018, and 019)	Yes	Cultural	No
Trot 17 (incl. Targets 165, 167, MA_011, NCL_SC_020, 021, 022, 023, 024, and 025)	Yes	Cultural	Yes
Trot 18 (incl. Targets 164, 167, 244, and NCL_SC_026)	Yes	Cultural	No
142	Yes	Natural	Yes
174	Yes	Cultural	Yes
175	Yes	Natural	Yes
233	Yes	Natural	No
241	Yes	Natural	No
245	Yes	Natural	Yes
246	Yes	Natural	Yes
247	Yes	Natural	No

Anomaly/Target ID	Target surveyed by ROV	Cultural/Natural	Within 10m of GEP route
MA_001	Yes	Cultural	No
MA_007	Yes	Cultural	Yes
NCL_SC_016	Yes	Cultural	No
NCL_SC_031	Yes	Natural	No

8.4 Legislative compliance

Certain objects may be protected under various local, state, and Commonwealth heritage acts, depending on their historical contexts and assessed heritage significance. Protected objects may require permits to be obtained before they may be disturbed. Noncompliance with heritage legislation may result in fines or criminal charges.

None of the cultural objects identified by ROV survey would be protected under the *NT Heritage Act 2011.*

The *UCH 2018* automatically protects shipwrecks over 75 years of age within all Australian waters (incorporating Territory internal and Commonwealth waters, see section 3.1), including articles associated with these shipwrecks. Although unlikely, if the objects located at Targets 174 and MA_007 are historic ship wreckage, over 75 years old, a permit may be required to disturb them.

The *UCH 2018* automatically protects aircraft wrecks over 75 years of age within Commonwealth waters. This excludes internal state waters, including Darwin Harbour and portions of Beagle Gulf. If the objects located at Target MA_007 are aircraft wreckage, it would **not** be protected under this act.

Installations including maritime infrastructure, such as the WWII anti-submarine boom net moorings and historic telegraph cables, are **not** automatically protected under the *UCH 2018*. Currently, the historic submarine telegraph landings are afforded statutory protection and are listed on the NT Heritage Register. The anti-submarine net moorings are not under statutory protection. Historic maritime infrastructure, especially infrastructure from the 19th century or associated with WWII, is likely of heritage interest and may rate as high heritage significance. Previously, the anti-submarine net moorings have been rated as having 'High' heritage significance.[119]

8.5 Mitigation measures

Mitigation for heritage objects and sites depends on the likelihood of potential impacts as well as the degree of heritage significance. Several of the targets identified as cultural during ROV surveys cannot have their heritage significance assessed due to lack of information. For cultural heritage sites, objects, and unverified anomalies likely to be impacted by proposed works, the first preference for mitigation is avoidance. If not possible, a more detailed investigation may be needed to conclusively identify their historical context and condition, to inform a heritage management plan with specific alternative mitigation measures. Such a management plan would only need to be adopted for those objects deemed likely to be impacted.

Cosmos Archaeology has previously completed impact assessments for anti-submarine net mooring trots that were likely to be impacted by the installation of the Icthys GEP.[120] This

[119] **Cosmos Archaeology, 2012,** *Icthys Project Darwin Harbour, East Arm Gas Export Pipeline: Assessment of Heritage Impact of 7 side scan targets,* Report prepared for Tek Ventures Pty Ltd.
[120] Op. Cit., **Cosmos Archaeology, 2012.**

assessment rated the trots and clump weights as **High** significance, and **Certain** to be impacted by installation of the GEP. Recommended mitigation was as follows:

> *Prior to disturbance undertake video recording of the concrete boom defence mooring blocks and chain. The chain is to be followed to either side of the block to see where they end. The distance between the blocks is expected to range from 30 to 60 m.*
>
> *Each block should be placed in an upright position with the chain laid alongside close – without the possibility of causing a hindrance – to the proposed pipeline route.*
>
> *Once the blocks and chain are in place, video footage, a site map and description, is to be obtained, preferably by a maritime archaeologist.*[121]

For this project, it was determined sufficient that the mooring trots were recorded fully *in situ* before being moved out of the path of the GEP. Once relocated, the trot was recorded again, and its location was documented. The proposed Barossa GEP route directly crosses the path of mooring Trot 17, identified during ROV survey Heritage Transect 1. Ideally, the proposed GEP alignment could be altered to avoid anti-submarine net mooring Trot 17 and Target MA_007 however relocation of chain and mooring blocks from this trot as done for theINPEX project would be acceptable if the GEP route cannot be changed to avoid impacting this site.

All other anomalies, targets, and surveyed cultural heritage is considered unlikely to be impacted by the direct action of GEP installation. However, unassessed cultural heritage, identified significant cultural heritage, and unverified anomalies should be avoided during the works, including during ship anchoring. Establishment of no-anchoring zones around these will help ensure significant maritime cultural heritage is not adversely impacted.

If the identified cultural material cannot be avoided, then a detailed heritage impact assessment will need to be conducted, consistent with the NT Heritage Branch Archaeological Scope of Works.[122] The impact assessment will likely require further inspections, diving would produce best results, to conclusively assess the significance of Target MA_007. A work class ROV may assist with accurate measurements and precise positioning but would not allow the tactile investigation that a diver could do. This would inform a Maritime Heritage Management Plan, which would include specific mitigation measures and management recommendations for each target, such as, but not confined to, archaeological recording, clearance, removal, and/or recovery. For example, any clearance of cultural material from the seabed could be recorded by a maritime archaeologist on-site. For the INPEX project this involved maritime archaeologists with suitable diving qualifications embedded with the commercial dive teams.

It is recommended that any further remote sensing undertaken for the proposed GEP should be reviewed by a qualified maritime archaeologist.

Finally, there is always the possibility of unexpected finds being made during the construction phase. Prior to the commencement of construction an Unexpected Maritime Archaeological Finds Protocol should be prepared by a suitably qualified maritime archaeologist. If a Maritime Heritage Management Plan is deemed necessary, this would be a component of such a plan. This protocol should include:

- Unexpected finds, stop work triggers and notification procedures
- Heritage induction for contractors
- Recording and reporting methods and procedures

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[121] *Op. Cit.* **Cosmos Archaeology, 2012:**27.
[122] **NT Heritage Branch, 2021,** Archaeological Scope of Works: Gas export pipeline Barossa gas field to Middle Arm, Darwin Harbour.

- Artefact collection and retention policies

9 CONCLUSION

9.1 Summary of findings

A review of historical sources, databases and marine geophysical information has found that;

- Within the study area, Larrakia and Tiwi people conducted maritime travel and subsistence activities – likely concentrated in coastal environments. Macassan trepang fishing and trade occurred throughout the 18th to early 20th centuries.
- British exploration and surveying began in the early 19th century, following which a wide range of colonial shipping including Government and commercial cargo and passenger transport, fishing and pearling industry trade and transport, and recreational shipping occurred, from the establishment of colonial settlement in Darwin in 1860s to present.
- In the 1870s and 1880s three subsea telegraph cables were laid.
- Quarantine and leper station transport and service supply were established in Middle Arm throughout late 19th to early 20th century.
- The study area saw significant military action during World War II, including air and sea combat between Allied and Japanese forces, which resulted in the sinking of numerous ships and aircraft within Beagle Gulf and Darwin Harbour.
- The entrance to Darwin Harbour was the location of numerous anti-submarine defences during WWII, including anti-submarine boom nets and indicator loops, some of which have been located and recorded by previous CA surveys.
- There are seventeen known, located shipwrecks within the study area, along with five known locations of UXO and six instances of maritime infrastructure (including the above-mentioned anti-submarine defences and telegraph cables). Four of five instances of UXO are related to WWII shipwrecks and are protected by statutory legislation. One instance, Contact 2, was identified and disposed of during INPEX heritage investigations. See Section 4.3.5, Table 4 for details and locations.
- There are 29 known but unlocated shipwrecks and 25 known but unlocated aircraft wrecks recorded to have sunk within the vicinity of the study area. Any of these could potentially be located within the study area.
- The remains of these vessels, and their contents and fittings, are automatically protected under the Cwlth *Underwater Cultural Heritage Act 2018*. Remains within the TSB are protected under the NT *Heritage Act 2011,* and United States military shipwrecks and aircraft wrecks are protected under the US *Sunken Military Craft Act 2004.*
- Side scan sonar, magnetometer, and MBES data from a marine geophysical survey conducted by Fugro in 2022 was reviewed, as well as MBES data published by Geosciences Australia.
- Clear evidence of eight shipwrecks was identified within the study area, and no aircraft wrecks were identified. Two of these shipwrecks, USAT *Meigs* and USAT *Mauna Loa* are under statutory heritage protection. Furthermore, there is a possibility that anomaly ID: 210 could potentially be aircraft remains.
- Thirty-nine sonar, MBES, and magnetometer contacts were identified by CA within the Fugro geophysical survey corridor as being probably cultural and hence of potential cultural heritage significance.

- An additional 133 anomalies were identified by CA from publicly available MBES data within the anchoring corridor, but outside of the Fugro geophysical survey corridor. These 133 anomalies were identified as being probably cultural and hence of potential cultural heritage significance. Ninety of these targets were identified as likely WWII anti-submarine net mooring devices located between KP 107 and KP 108.
- These anomalies could be remains of anti-submarine defences, 19th century telegraph cables, possible aircraft wreckage, debris fields, or isolated instances of debris and/or discard.
- An ROV survey was conducted between 6-8 June 2022 on 16 targets identified by the geophysical survey review as being within 50m of the proposed GEP route. Survey included three dive transects conducted on the likely remains of WWII anti-submarine net moorings.
- 11 anti-submarine net moorings, connected by heavy grade chain were identified during ROV survey, located between KP 107 and KP 108. These moorings and chain represent three “trots”, or lines of moorings, used to anchor WWII anti-submarine nets. Based on historic chart overlays, it is believed that heritage transects 1, 2, and 3 corresponded to Trots 17, 16, and 18, respectively. 10 moorings were conventional trapezoidal concrete weights, while one mooring, Target 164, was identified as a large ship’s anchor, repurposed for use as mooring.
- In addition to the anti-submarine net moorings, a further 10 isolated geophysical survey targets were inspected during ROV surveys. Six of these (Targets NCL_SC_002, NCL_SC_031, 142, 175, 241, and 245) were determined to be natural features. The other four targets (Targets MA_001, MA_007; Target NCL_SC_016; Target 174) were determined to be cultural in origin.
- Due to the limitations of a visual ROV survey, the identity of Targets 174, MA_007, and NCL_SC_016 could not be conclusively confirmed. Therefore, their heritage significance, as well as the significance of any other uninspected geophysical anomalies, cannot be properly assessed without further investigation.
- The proposed GEP installation will likely impact the central trot, Trot 17, identified by ROV heritage transect 1, and MA_007. Additionally, vessel anchoring as part of proposed works could impact any anomalies or cultural heritage within a 900 m corridor on either side of the GEP route. Therefore, the establishment of no-anchoring zones around uninspected anomalies and cultural heritage objects and sites within this corridor is recommended. A 15 m radius is considered appropriate for isolated anomalies, while a radius of 50 m is generally considered acceptable for larger sites, such as shipwrecks or aircraft wrecks. It is recommended that a buffer of 15 m is also afforded to the linear space between lines of potential anti-submarine net mooring trots to protect the chain in between moorings.
- If Trot 17 and Target MA_007 cannot be avoided, then a detailed heritage impact assessment will need to be conducted, consistent with the NT Heritage Branch Archaeological Scope of Works. Likewise, if no-anchoring zones cannot be established around other cultural heritage or unverified anomalies within the 900 m anchoring corridor, these will need to be assessed as well. Depending on the identity and historical significance of said objects, permits to disturb may be required under the *UCH 2018* Act.
- It is recommended that if further remote sensing surveys of the proposed GEP are undertaken, the additional survey data should be reviewed by a qualified maritime archaeologist.

- In the event of significant maritime archaeological remains being discovered during the construction phase, an Unexpected Maritime Archaeological Finds Protocol to responsibly manage such finds should be prepared and implemented.

9.2 Recommendations

Recommendation 1 ***If feasible, the proposed GEP alignment should be altered to avoid the WWII anti-submarine net mooring Trot 17 as well as cultural heritage objects identified at Target MA_007.***

Recommendation 2 ***If potentially cultural anomalies objects identified in this assessment are likely to be impacted, undertake a detailed heritage impact assessment by a qualified maritime archaeologist.***

If the identified anomalies cannot be avoided and are likely to be impacted, then a detailed heritage impact assessment would need to be conducted, consistent with the NT Heritage Branch Archaeological Scope of Works.[123] The impact assessment may include further ROV and/or dive inspections to assess significance of the anomalies. This would inform a Maritime Heritage Management Plan, which would include specific mitigation measures – such as relocation of certain objects - and management recommendations.

Recommendation 3 ***Establish no-anchoring zones around shipwreck locations, the anti-submarine net moorings, and unverified geophysical anomalies within the anchoring corridor.***

50 m radius for larger sites such as shipwrecks, 15 m for isolated anomalies and anti-sub net moorings/chains.

Review of Geosciences Australia MBES data with full coverage of Darwin Harbour from the proposed GEP terminus to KP 85 has identified eight shipwrecks within the 900 m anchoring corridor. Two of these wrecks, USAT *Meigs* and USAT *Mauna Loa,* are under statutory heritage protection. No-anchoring zones should be established around all eight wrecks, as well as the anti-submarine net corridor and any unverified geophysical anomalies. This information should be included in a Maritime Heritage Management Plan.

Recommendation 4 ***If additional remote sensing data is collected for the proposed GEP it should be reviewed by a qualified maritime archaeologist.***

Recommendation 5 ***Prepare and implement an Unexpected Maritime Archaeological Finds Protocol.***

Prior to the commencement of the construction phase an Unexpected Maritime Archaeological Finds Protocol should be prepared by a suitably qualified maritime archaeologist. This protocol should include:

- *Unexpected finds, stop work triggers and notification procedures*
- *Heritage induction for contractors*

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[123] **NT Heritage Branch, 2021,** Archaeological Scope of Works: Gas export pipeline Barossa gas field to Middle Arm, Darwin Harbour.

- *Recording and reporting methods and procedures*
- *Artefact collection and retention policies*

This protocol would form a component of the Maritime Heritage Management Plan referenced in Recommendation 2.

Recommendation 6 Review of this assessment if proposed alignment of pipeline changes.

This review should be undertaken by a suitably qualified maritime archaeologist.

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10 ANNEX A: ROV SURVEY TECHNICAL MEMO

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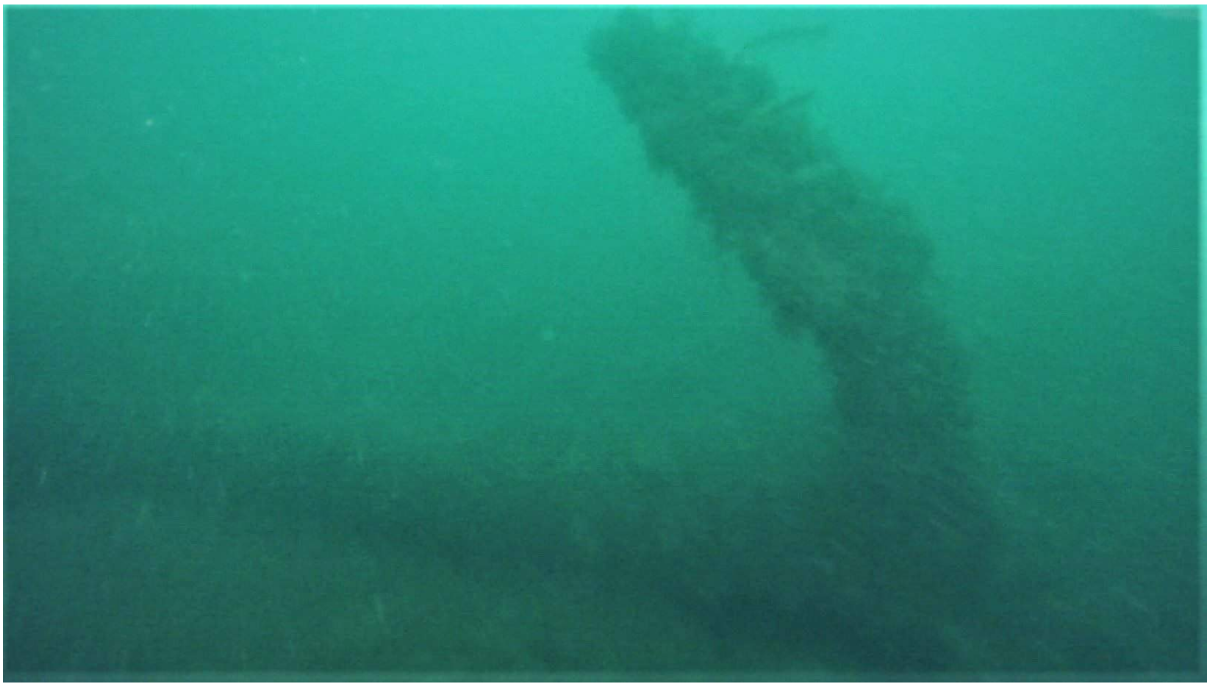
Barossa Pipeline



Maritime Cultural Heritage

ROV Survey

June 2022

Darwin Harbour

NT

June 2022

Barossa Pipeline
Maritime Cultural Heritage ROV Survey June 2022

Prepared for:

Santos Pty Ltd

By:

Connor McBrian

June 2022

Cosmos Archaeology Job Number J21/22

Cover Image: *Anchor located during survey.*

Revision	Description	Date	Originator	Reviewer	Approver
V1	DRAFT Darwin Harbour ROV Survey	28-06-2022	CM		

Abbreviations

CA	Cosmos Archaeology	MBES	Multi-beam echosounder
GPS	Global Positioning System	ROV	Remote operated vehicle
m	Metres	SSS	Side Scan Sonar

TABLE OF CONTENTS

1 Introduction ... 1

1.1 Background ... 1

1.1.1 Objectives ... 1

2 Maritime Archaeological Dive Survey ... 2

2.1 Dates and Personnel ... 2

2.2 Weather and Tide Conditions ... 2

2.3 Conduct of Survey ... 3

2.3.1 Target inspection dives ... 3

2.4 Findings of the Diving Survey ... 4

2.4.1 Heritage Transect 1 ... 4

2.4.1.1 T1_1 ... 5

2.4.1.2 T1_2 ... 7

2.4.1.3 T1_3 ... 8

2.4.1.4 T1_4 ... 9

2.4.1.5 T1_6 ... 11

2.4.1.6 T1_7 ... 13

2.4.2 Heritage Transect 2 ... 15

2.4.2.1 T2_1 ... 16

2.4.2.2 T2_2 ... 18

2.4.3 Heritage Transect 3 ... 20

2.4.3.1 T3_1 ... 21

2.4.4 Individual Heritage Targets ... 23

2.4.4.1 Target 142 ... 23

2.4.4.2 Target 245 ... 24

2.4.4.3 Target 241 ... 25

2.4.4.4 Target NCL_SC_031 ... 27

2.4.4.5 Target 175 ... 29

2.4.4.6 Target 174 ... 31

2.4.4.7 Target NCL_SC_016 ... 33

2.4.4.8 Target MA_007 ... 35

2.4.4.9 Target MA_001 ... 37

2.4.4.10 Target NCL_SC_002 ... 39

3 ROV survey summary ... 41

Annex A – Dive Log ... 42

Annex B – Video Log ... 43

1 INTRODUCTION

1.1 Background

The Santos (Barossa) Gas Export Pipeline is a proposed installation a gas export pipeline (GEP) off the northwest coast of the Northern Territory (NT). The proposed GEP begins at the Barossa gas field, north of the Tiwi Islands, and extends south to feed the Darwin LNG plant, located in Middle Arm, Darwin Harbour. The first proposed route is a GEP from the Barossa gas field to a tie in point into the existing Bayu-Undan to Darwin pipeline, tying in at a point southwest of Bathurst Island. The second proposal is to extend the GEP from Barossa to the Darwin LNG plant. This second proposal traverses through the entrance of Darwin Harbour directly to the Darwin LNG at Middle Arm.

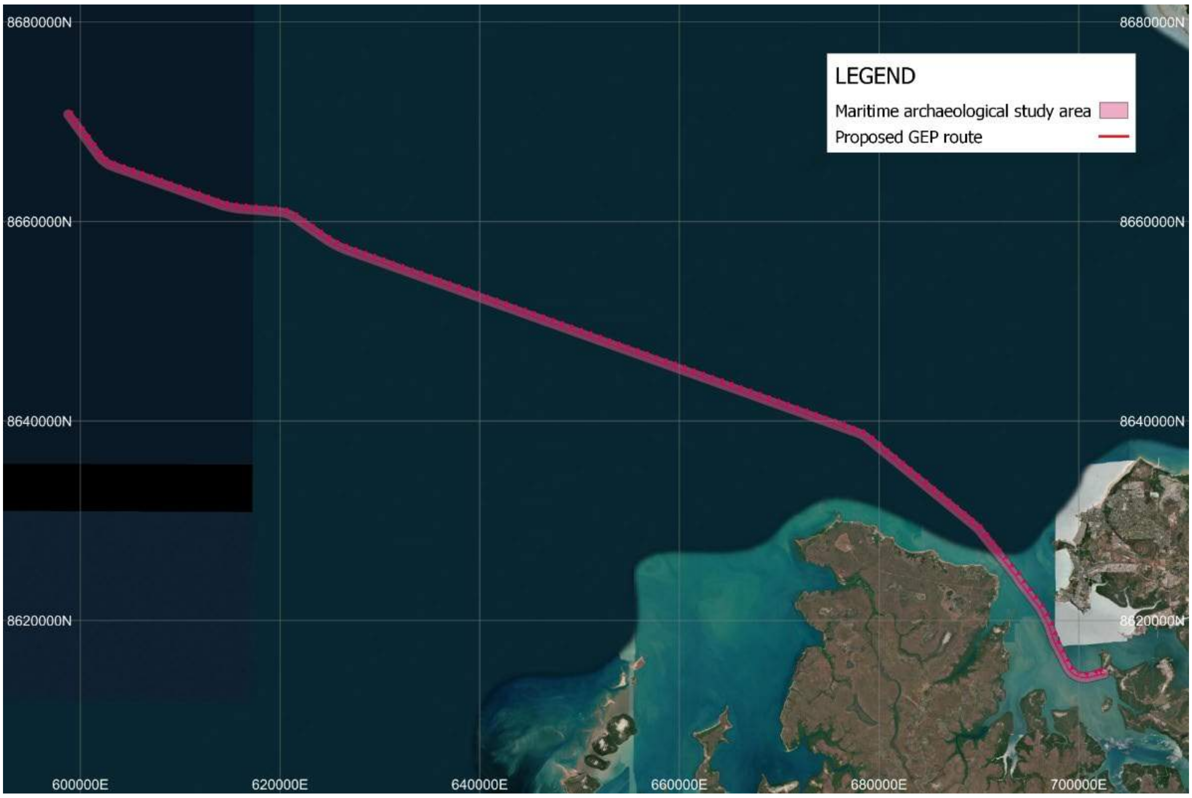


Figure 1: Proposed route of the Barossa GEP in Beagle Gulf and Darwin Harbour.

As part of environmental and heritage impact assessments, a suite of geophysical surveys were conducted including multi-beam bathymetry (MBES), side scan sonar (SSS), and magnetometer surveys to identify locations of potential cultural material. Review of the available geophysical survey identified forty targets of possible cultural origin. Sixteen of these targets were located within 50m of the proposed GEP route and were shortlisted for visual survey to confirm their identity and origin. The sixteen chosen targets were inspected over the course of three days between 6-8 June 2022.

1.1.1 *Objectives*

The objectives of this dive survey were to:

> *Visually inspect targets identified through geophysical data for their potential cultural heritage significance and recommend measures to reduce impacts to their cultural heritage values.*

2 MARITIME ARCHAEOLOGICAL DIVE SURVEY

2.1 Dates and Personnel

The dive survey was carried out over three days: 6-9 June 2022. Connor McBrian from Cosmos Archaeology was the maritime archaeologist supervising the heritage inspections. ROV support was provided by FUGRO in the form of two ROVs, while boat and marine services were supplied by Bhagwan Marine. In addition to this, a representative from Santos Pty Ltd was on board to supervise surveys along with an environmental specialist from RPS. ROV operations were run and supervised by FUGRO. Personnel involved during the inspection are listed in Table 1.

Table 1: Dive inspection personnel

Name	Title	Company
Connor McBrian	Maritime Archaeologist	Cosmos Archaeology
James Clarke	Survey Party Chief	Fugro
Luke Eller	ROV Pilot / Tech	Fugro
Simon Bochow	Skipper	Bhagwan Marine
Pete Ivicevich	Client Representative	Santos NA Barossa Pty Ltd
Garnet Hooper	Environmental Specialist	RPS Group

2.2 Weather and Tide Conditions

Weather and tide conditions are factors when operating an ROV within the study area. Tides were especially considered in relation to the current and visibility, which could limit ROV operations. As much as possible, dives were conducted at slack tides to avoid excessive current and drift. The tide conditions during the surveys are provided in Table 2 and weather conditions during the survey are provided in Table 3.

Table 2: Tides for the days of survey.

06-06-2022	Time	0341	1016	1612	2147
	Height (m LAT)	2.3	6.1	3.3	5.2
07-06-2022	Time	0430	1102	1721	2300
	Height (m LAT)	2.6	5.8	3.4	4.9
08-06-2022	Time	0534	1200	1847	0031 (next day)
	Height (m LAT)	3.0	5.7	3.3	4.9

Note: For ease of identifying high and low tide, low tide is blue and high tide is red.

Table 3: Rain and wind conditions for the day previous to the dive inspections and the days of the inspection.

Date	Rain (mm)	Wind 09:00 (km/h)	Wind 15:00 (km/h)
05-06-2022	0.0	13 ESE	17 N
06-06-2022	0.0	9 SE	13 NW
07-06-2022	0.0	11 E	17 ENE
08-06-2022	0.0	20 E	17 ESE

2.3 Conduct of Survey

The underwater survey was conducted with the use of an ROV, operated by crew from FUGRO under the direction of the maritime archaeologist. Certain features, such as the anti-submarine net mooring trots were surveyed along transects following the features in a linear pattern. Isolated targets were targeted by dropping a clump weight with a buoy attached on the target coordinates while the vessel was moving, and then following the buoy line to the seabed with the ROV once the vessel was anchored. Once on the bottom, the ROV was manoeuvred in cross shaped search patterns using the clump weight as a reference point.

The ROV was battery powered and controlled remotely by the pilot from inside the survey vessel cabin. Because the ROV was not equipped with transponders or any location fixing devices, the exact location of the ROV had to be estimated based on identifiable features on the seabed that could be compared to MBES data, course headings, and position relative to the *Warrigal.*

2.3.1 Target inspection dives

The targeted inspection dives required the ROV pilot and maritime archaeologist to locate and identify seafloor anomalies from existing geophysical data. GPS locations of targets derived from MBES data was used to locate the potential targets and manoeuvre the *Warrigal* into position.

Targets identified within the location of WWII submarine netting were surveyed along three transects, as these consisted of large concrete clump weights connected by thick chain. The chain was easily visible above the seabed, and provided a reliable way of tracking and locating the ROV as it completed the linear transects.

From review of the geophysical survey data, 15 targets were identified for visual investigation, based on their assessed likelihood of being cultural material, and their proximity (within 50m) of the proposed GEP route. These targets were given a priority status for the targeted inspections. These were:

- A = top priority
    - Images appear to be cultural and representative of a ‘site’ such as a small wreck.
- B = secondary
    - Images appear to be cultural but are representative of an individual object, or discard and less likely to constitute a site.
- C = tertiary
    - Targets unlikely to be cultural, or known to be culturally insignificant.

2.4 Findings of the Diving Survey

For organisational purposes, the following list of targets is separated into the three heritage transects, T1, T2, and T3, used to record the anti-submarine net moorings, and isolated targets surveyed individually.

2.4.1 *Heritage Transect 1*

T1 followed a line of concrete clump weights, connected by heavy chain, that were identified as the moorings for the WWII anti-submarine net. This transect was located between KP 107 and KP 108, and ran NNW from a target just south of 165, located at 693309.60 m E, 8624815.60 m N to target 244, located at 693195.40 m E, 8625165.60 m N. The transect continued at the same heading north from Target 244 to a final concrete clump weight located at 693162.30 m E, 8625272.50 m N.

Along this transect, attempts were made to locate two isolated anomalies, Targets 246 and 247, without success.

7 dives were attempted on T1, of which one (T1_5) had to be aborted due to currents overpowering the capabilities of the ROV.

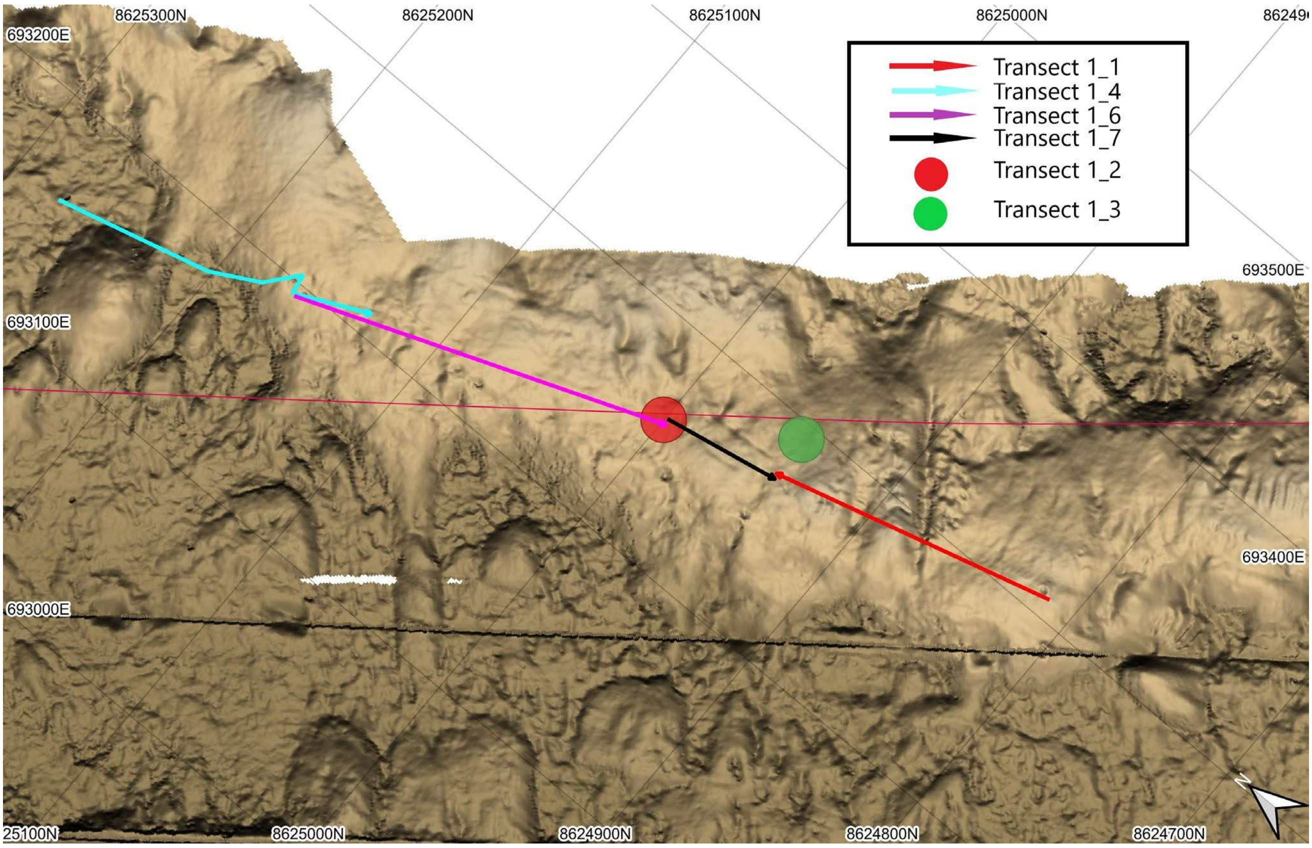


Figure 2: Dive locations for Heritage Transect 1.

The datum for all coordinates for the targets is GDA94.

2.4.1.1 T1_1

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Depth	Distance from GEP route (m)
3	693309.76	8624814.97	Anti-submarine net moorings. Large concrete trapezoidal mooring blocks connected by lengths of thick chain.	Width: 0.00 Height: 0.00 Length: 1.54 Shadow: 0.00	29 m	Variable, from 25 to 80

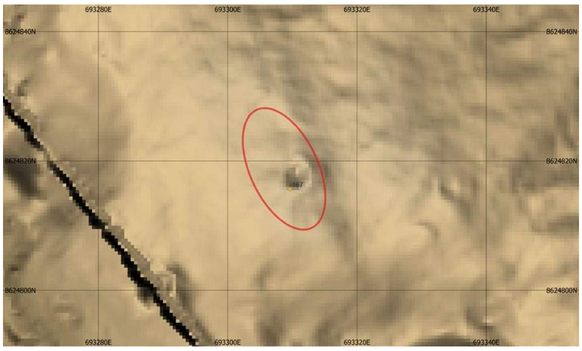


Figure 3: Target 167 MBES image.

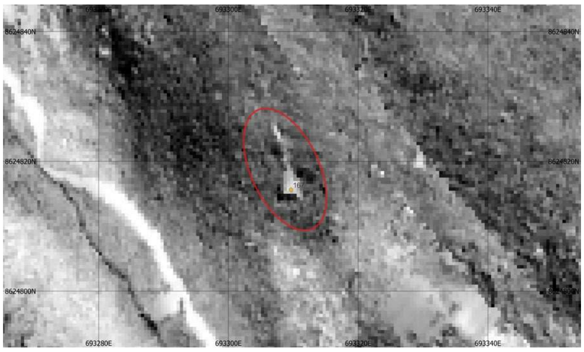


Figure 4: Target 167 SSS image.

Inspection details for T1_1		
Date: 06-06-2022	**Method:** ROV	**Tide:** Slack
Distance and direction: 125 m, 345° NNW		
Swim start (min): 1027	**Swim end (min):** 1138	**Total time (min):** 71
Depth: 14.2 m	**Water visibility:** 1 m	**Seabed visibility:** Poor

Target description: The seabed within the search area was generally rocky with a layer of easily disturbed sediment and large amount of marine growth, including soft corals. Transect 1_1 began by locating Target 167 and following a length of chain extending from Target 167 at a heading of 345° NNW for approximately 125m. Despite low visibility, target 167 was quickly located through the use of the ROV's sonar. 167 was determined to be a large concrete mooring block, used as part of the anchoring system for the anti-submarine nets installed during WWII (Figure 7). A cable connected to the southern end of the block appeared to anchor to the seafloor, while length of thick chain (Figure 8) was attached to the northern face of the concrete block and connected 167 to a twin set of mooring blocks, located at 693294 m E 8624875 m N (Target ID: NCL_SC_020; Figure 9 and Figure 10). Another section of the same chain continued further north from the twin blocks before disappearing into the seabed ~30m further NNW. The ROV's tether ran out before the next mooring block could be positively located.

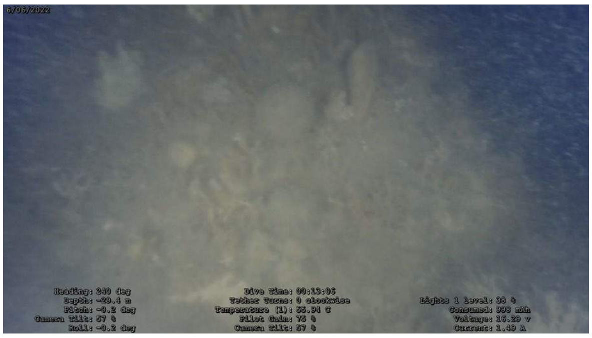


Figure 5: Screen grab of Target 167, concrete anti-sub net mooring block. (Video 2022-06-06_10.27.18; 11:17).

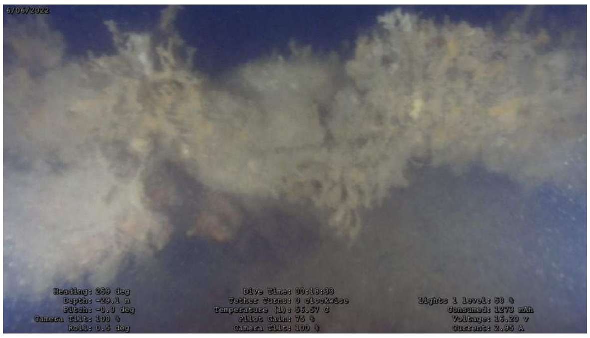


Figure 6: Screen grab of chain leading NNW from Target 167. (Video 2022-06-06_10.27.18; 16:47).

Figure 7: Screen grab of NCL_SC_020, first concrete block. (Video 2022-06-06_10.58.29; 01:29).

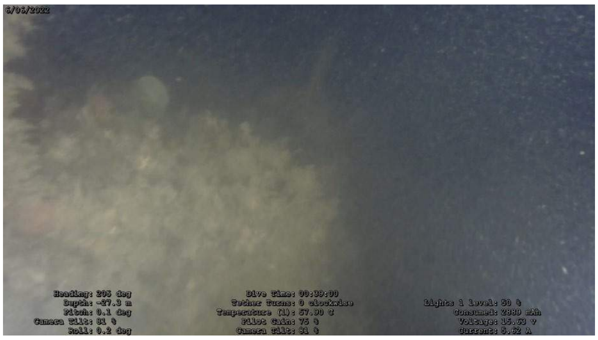


Figure 8: Screen grab of NCL_SC_020, second concrete block. (Video 2022-06-06_10.58.29; 06:01).

2.4.1.2 T1_2

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
4	693286.00	8624946.00	Target 247, aka MA_003	Width: 0.00 Height: 0.00 Length: 7.96 Shadow: 0.00	0	28 m

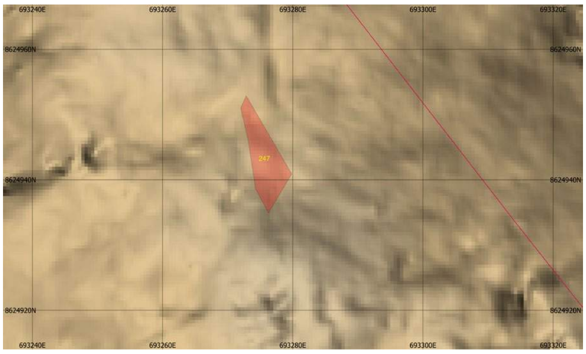


Figure 9: Target 247 MBES image.

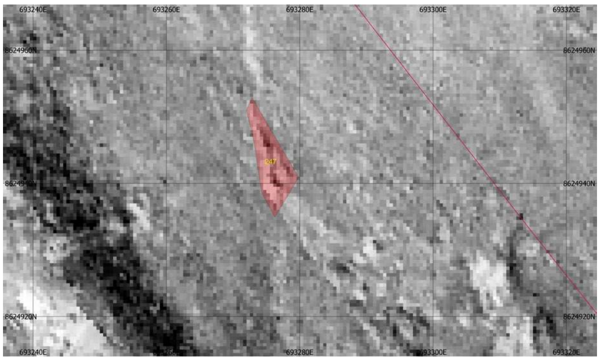


Figure 10: Target 247 SSS image.

Inspection details for T1_2		
Date: 06-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Circular search 10 m		
Swim start (min): 1215	**Swim end (min):** 1238	**Total time (min): 13**
Depth: 28 m	**Water visibility:** 0 m – 1 m	**Seabed visibility:** Poor

Target description: This dive was an attempt to locate Target 247, possibly associated with magnetometer target MA_003. In addition to locating 247, an attempt was made to locate the anti-sub net chain that disappeared into the seabed at the end of transect T1_1. The seabed in the search area was similar to Transect T1_1 with fine grain sandy sediment as well as scattered rocks and marine growth. Not cultural features were identified during the dive. While an attempt at a circular 10m search was made, strong current and low visibility meant only a small portion of the seafloor was able to be surveyed before the dive was aborted.

2.4.1.3 T1_3

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
5	693293.00	8624947.00	Debris scatter, or possible anti-submarine net remains FUGRO ID: NCL_SC_021	Width: 0.00 Height: 0.00 Length: 0.59 Shadow: 0.00	10	27 m

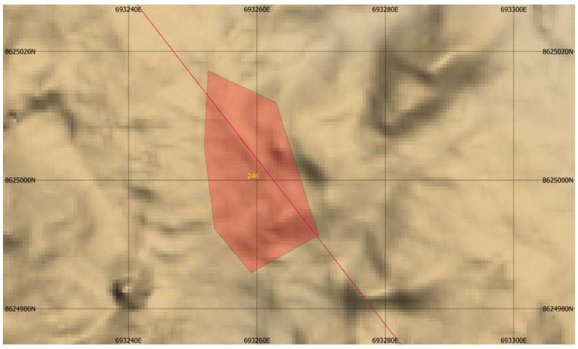


Figure 11: Target 246, MBES image.

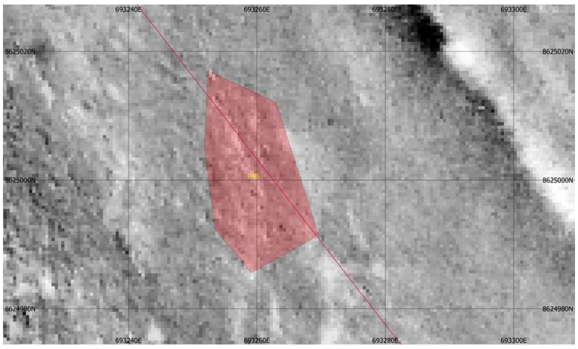


Figure 12: Target 246, SSS image.

Inspection details for T1_3		
Date: 06-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Circular search 10 m		
Swim start (min): 1247	**Swim end (min):** 1311	**Total time (min):** 24
Depth: 27 m	**Water visibility:** 0 m – 1 m	**Seabed visibility:** Poor

Target description: This dive was an attempt to locate Target 246 aka NCL_SC_021. In addition to locating 246, an attempt was made to locate the anti-sub net chain that disappeared into the seabed at the end of transect T1_1. The seabed in the search area was similar to Transect T1_1 with fine grain sandy sediment as well as scattered rocks and marine growth. Not cultural features were identified during the dive. While an attempt at a circular 10m search was made, strong current and low visibility meant only a small portion of the seafloor was able to be surveyed before the dive was aborted.

2.4.1.4 T1_4

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
8	693163.04	8625273.25	Anti-submarine net mooring blocks and chain NCL_SC_022 and Target ID: 244 (aka NCL_SC_023, 024, 025)	Width: 2.18 m Height: 0.00 m Length: 6.65 m Shadow: 0.00m	Variable, from 40 to 86	21 m

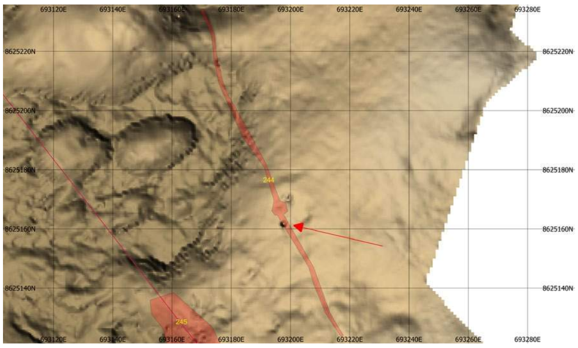


Figure 13: Target 244 (aka NCL_SC_023, 024, 025) MBES image.

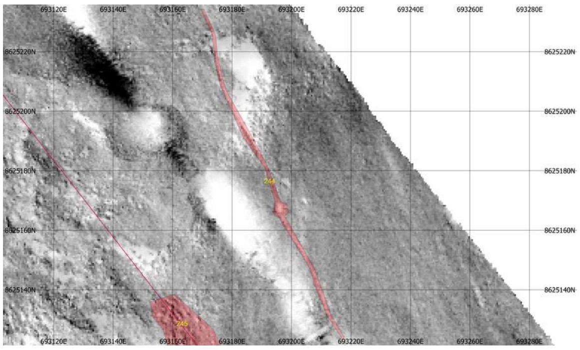


Figure 14: Target 244 (aka NCL_SC_023, 024, 025) SSS image.

Inspection details for T1_4		
Date: 06-06-2022	**Method:** ROV	**Tide:** Slack
Distance and direction: 150 m, 160° SSE		
Swim start (min): 1605	**Swim end (min):** 1644	**Total time (min):** 39
Depth: 21 m	**Water visibility:** 1 – 2 m	**Seabed visibility:** Poor

Target description: The ROV was dropped on a target that appeared on MBES data to be a concrete block mooring used for the anti-submarine netting, located at 693163.04 m E, 8625273.25 m N. The target chosen was not identified previously by FUGRO or CA but was identified immediately upon visual inspection by the ROV. This concrete block was determined to be the northern terminus of the “trot” of moorings (running to the southern terminus at Target 167) because no chain extended from the northern side of the block. After identification, the ROV followed the chain in a SSE course at 160° for approximately 55m until reaching target NCL_SC_022. This target was again identified as a concrete mooring block for the anti-sub netting. Following the chain at roughly the same heading, the ROV was piloted to the location of Target 244 (aka NCL_SC_023, 024, 025), approximately 60m SSE of NCL_SC_022. Between NCL_SC_022 and Target 244, the chain was seen to have several breaks along its length and appeared to have been dragged out of position by an anchor or trawl. A sharp kink in the line of chain was seen immediately north of target 244. The ROV continued following the chain SSE from Target 244 until tether ran out, approximately 50m further SSE.

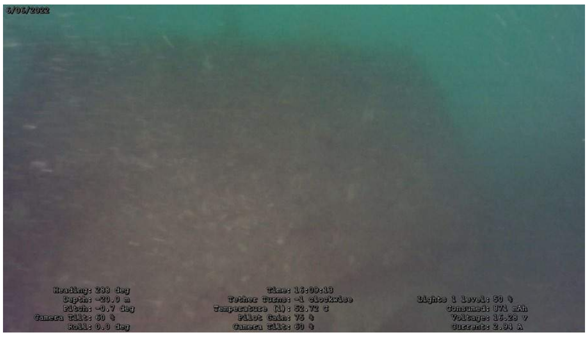


Figure 15: Mooring block at northern terminus of trot. (Video 2022-06-06_16.08.58; 00:15).

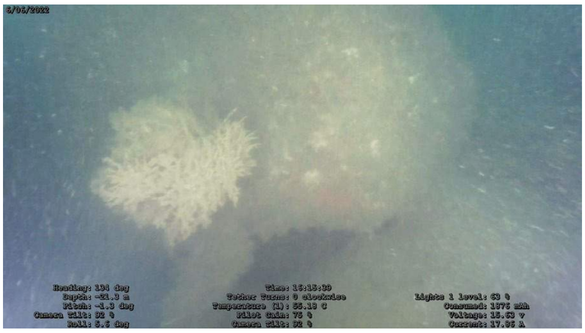


Figure 16: Mooring block NCL_SC_022 with chain extending from north face. (Video 2022-06-06_16.08.58; 06:40).

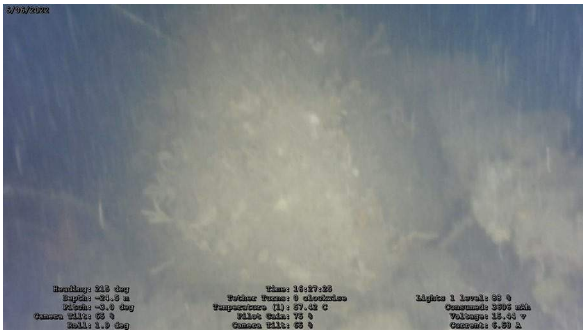


Figure 17: Mooring block Target 244 with chain extending from north face. (Video 2022-06-06_16.08.58; 18:24).

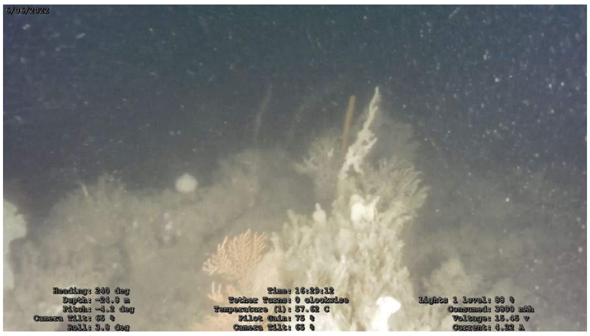


Figure 18: Kinked chain near Target 244. (Video 2022-06-06_16.08.58; 20:11).

2.4.1.5 T1_6

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
14	693212.30	8625132.30	Anti-submarine net mooring blocks and chain	Width: 0.00 Height: 0.00 Length: 0.00 Shadow: 0.00	Variable, from 46 to 0	28 m

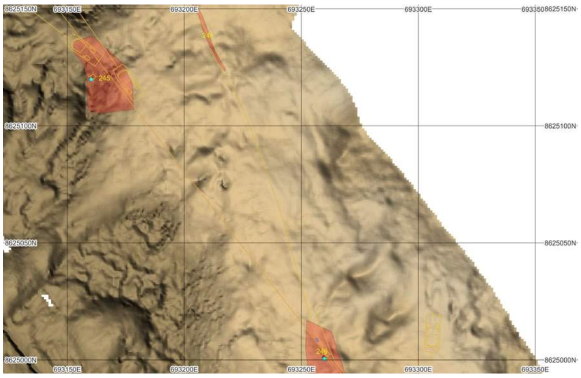


Figure 19: MBES image of general area of T1_6.

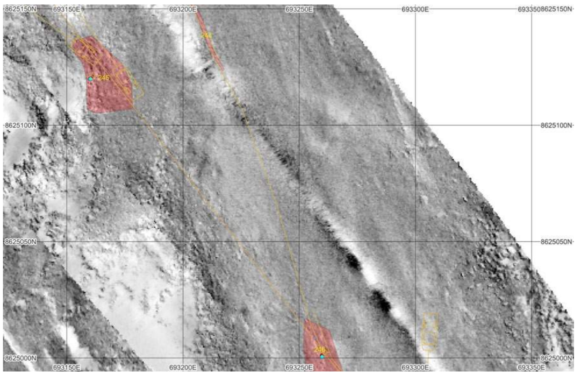


Figure 20: SSS image of general area of T1_6.

Inspection details for T1_6		
Date: 07-06-2022	**Method:** ROV	**Tide:** Slack
Distance and direction: 200 m, 160° SSE		
Swim start (min): 1045	**Swim start (min):** 1106	**Total time (min):** 21
Depth: 28 m	**Water visibility:** 2 – 3 m	**Seabed visibility:** Fair

Target description: Dive 14, transect T1_6, was started approximately 40 metres south-southeast of target 166 at a point close to or overlapping the termination of T1_4. A previous attempt at this transect, Dive 10 (T1_5), had been aborted due to heavy currents preventing the ROV from submerging. The anchor chain was quickly located upon descent and was followed in a similar SSE heading to T1_4, at approximately 160° for around 200 metres until the ROV's tether ran out (Figure 22). Throughout the length of T1_6, the chain was periodically buried under silty sediment, occasionally to the point where no marine growth could be seen above the seabed. At the end of the tether, the chain occurred to have several kinks, and a potential area of debris field or small rocks (Figure 23). Marine growth inhibited identification of the exact nature of these objects. No concrete blocks were seen along the length of the T1_6.

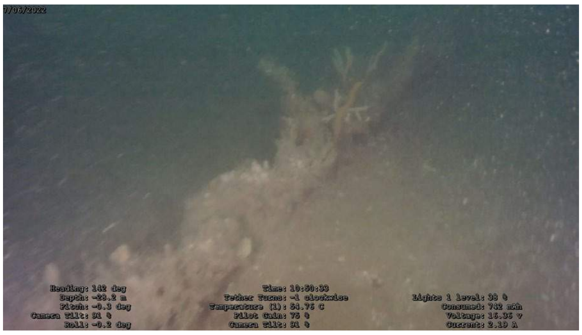


Figure 21: Length of chain southeast of target 166. (Video 2022-06-07_10.46.37; 03:54).

Figure 22: Kink in chain near end of T1_6. (Video 2022-06-07_10.46.37; 14:30).

2.4.1.6 T1_7

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
15	693255.71	8625021.11	Anti-submarine net mooring blocks and chain	Width: 0.00 Height: 0.00 Length: 0.00 Shadow: 0.00	Variable, from 26 to 0	29 m

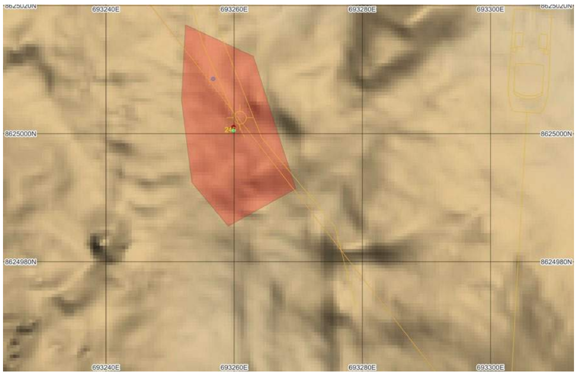


Figure 23: MBES image of general area of T1_7.

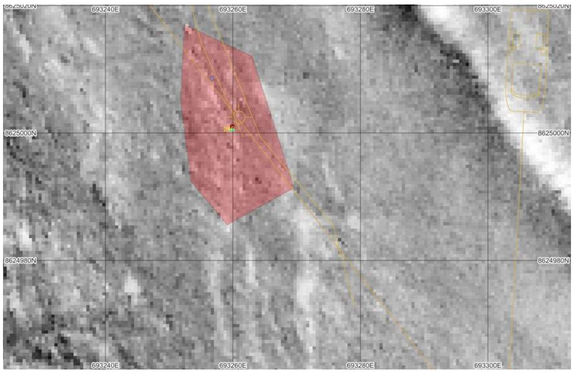


Figure 24: SSS image of general area of T1_7.

Inspection details for T1_7		
Date: 07-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: 200 m, 160° SSE		
Swim start (min): 1130	**Swim end (min):** 1200	**Total time (min):** 30 min
Depth: 29 m	**Water visibility:** 0 – 1 m	**Seabed visibility:** Poor

Target description: T1_7 was intended to “close the gap” between T1_6 and T1_1, approximately covering the area where Target 246 was thought to be. The ROV was dropped close to the position of 246 and was able to locate the chain identified in T1_6 (Figure 27). Following the chain SSE, the ROV recorded the chain ending at an indeterminate point in the seabed. At this location, a pile of branching metal debris was seen (Figure 28). The debris appeared to be either steel wire rope or cable, not chain, and extended several metres in multiple directions from a central point, near the end of the chain (Figure 29 & Figure 30). Heavy current and low visibility inhibited the ROV from obtaining a clear picture of the area, however, a cross shaped search pattern of 20m east-west-south from the branching cable indicated that a gap existed along the anti-submarine net trot chain, about 20m south of the proposed GEP route.

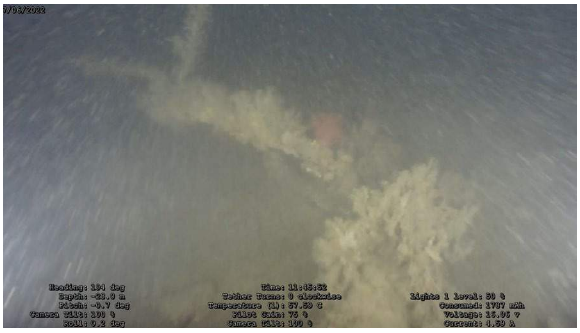


Figure 25: Screen grab of chain at a southern heading, with a large protuberance extending to the west. (Video 2022-06-07_11.30.28; 15:20).

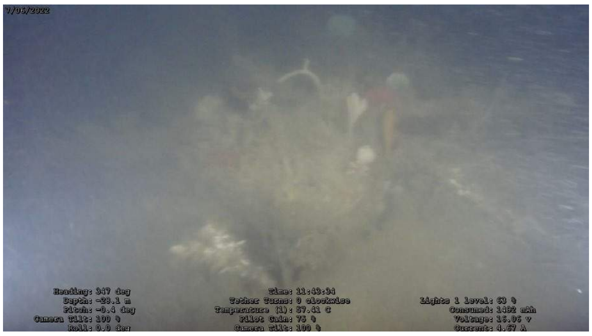


Figure 26: Screen grab of central location of branching "cable" or steel rope. (Video 2022-06-07_11.30.28; 13:01).

Figure 27: Screen grab of several arms of branching "cable". (Video 2022-06-07_11.30.28; 13:41).

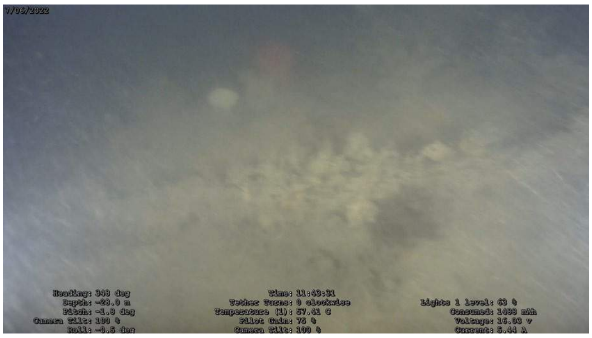


Figure 28: Detail of "cable". (Video 2022-06-07_11.30.28; 12:40).

2.4.2 *Heritage Transect 2*

T2_1 followed a line of concrete clump weights, connected by heavy chain, that were identified as the moorings for the WWII anti-submarine net. This transect was located between KP 107 and 108, adjacent to KP 107 and ran NNW from target 167, located at 693076.70 m E, 8625127.70 m N to target 164 (aka MA_002), located at 693039.84 m E, 8625225.61 m N. It was determined that the northernmost mooring device for the anti-submarine net trot was a large admiralty style anchor. A second dive (T2_2) was conducted on the anchor to take clearer images and aid in identification.

Chain was also seen extending south from Target 167 and targets likely to be mooring blocks were seen on MBES and SSS indicating that the trot extended further south to the Bayu-Undan GEP. It was decided that the proximity of these targets to the existing pipeline, and their distance from the proposed GEP, meant that further investigation in this direction was unnecessary.

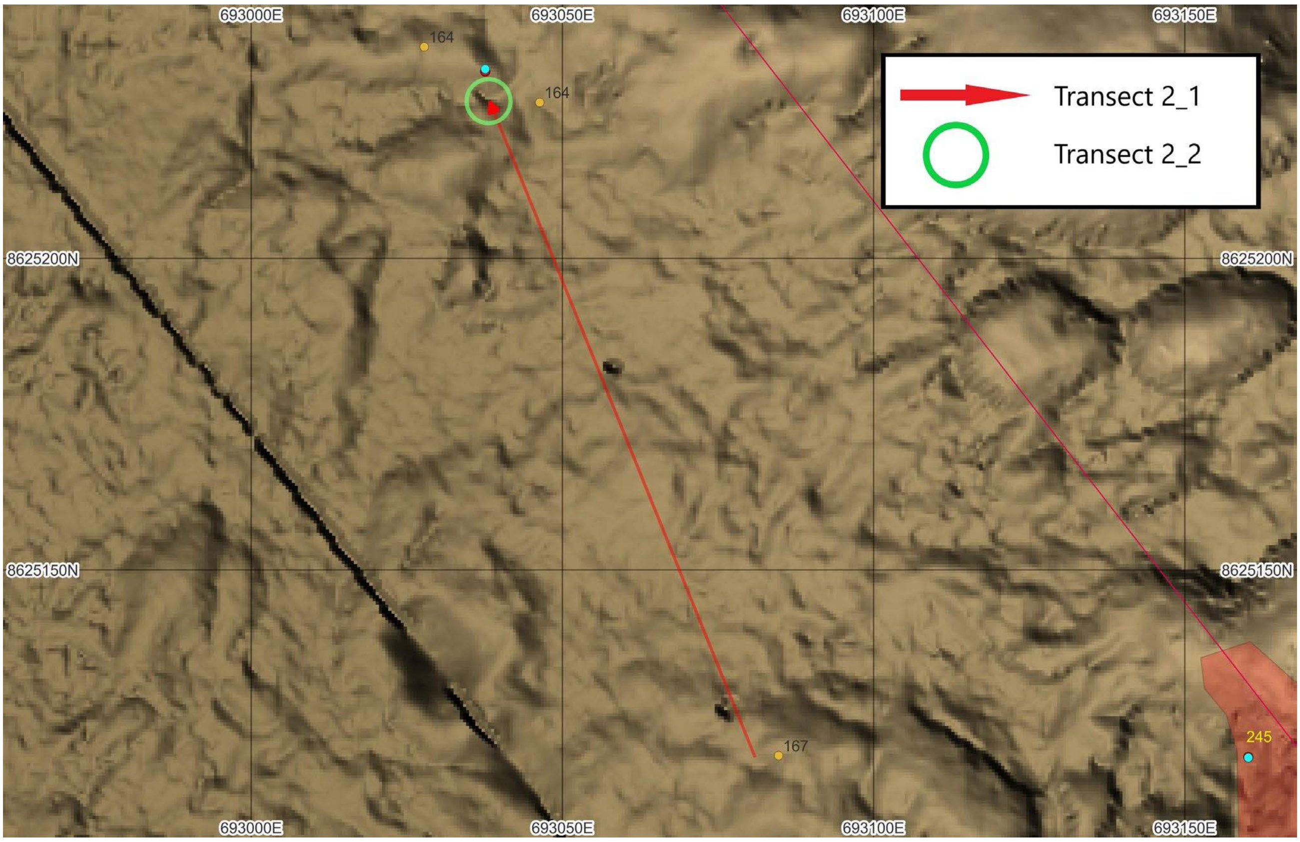


Figure 29: Dive locations for Heritage Transect 2.

2.4.2.1 T2_1

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
16	693077.90	8625120.30	Anti-submarine net mooring blocks and chain.	Width: 0.00 Height: 0.00 Length: 0.00 Shadow: 0.00	Variable, from 33 to 87	20 m

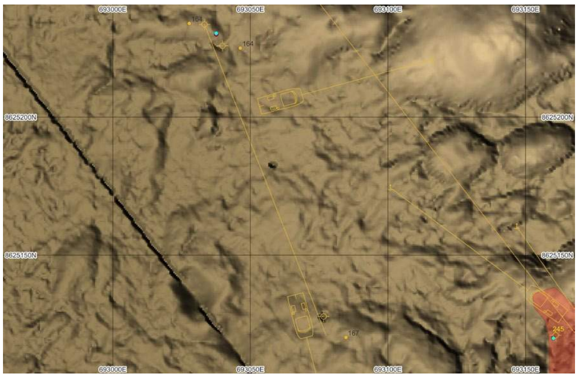


Figure 30: MBES image of general area of T2_1.

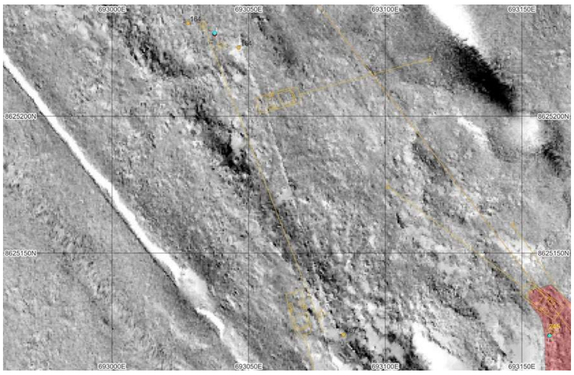


Figure 31: SSS image of general area of T2_1.

Inspection details for T2_1		
Date: 07-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: 123 m at 345° NNE		
Swim start (min): 1231	**Swim end (min):** 1255	**Total time (min):** 24
Depth: 20 m	**Water visibility:** 0.5 - 1 m	**Seabed visibility:** Poor - Fair

Target description: ROV was dropped almost exactly Target 167, identified as an anti-submarine net mooring block (Figure 34). The ROV confirmed that chain was extant in a southerly direction from Target 167, away from the proposed GEP route. The ROV was then turned at a NNE heading and continued along the line of the chain to the second mooring block located at 693058.40 m E and 8625182.00 m N (Figure 35). The ROV again continued along the chain until reaching Target 164 (aka NCL_SC_026, MA_002). Upon reaching Target 164, it was immediately clear that this target was an anchor adapted for use as a mooring device for the anti-submarine net chain. Due to poor visibility and worsening currents, it was decided to finish the dive at this point and return to investigate Target 164 when a slack tide would provide more favourable conditions.

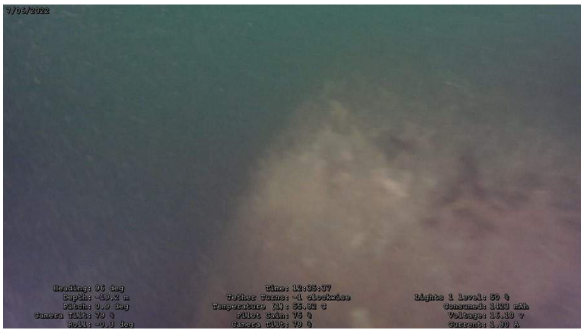


Figure 32: Screen grab Target 167, mooring block. (Video 2022-06-07_12.31.43; 03:35).

Figure 33: Screen grab of second anti-submarine net mooring block and chain, southern side of block. (Video 2022-06-07_12.31.43; 06:46).

2.4.2.2 T2_2

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
21	693036.33	8625230.54	Large ship's anchor, adapted for use as anti-submarine net mooring device.	Width: 4.00 Height: 1.90 Length: 7.00	33	18 m

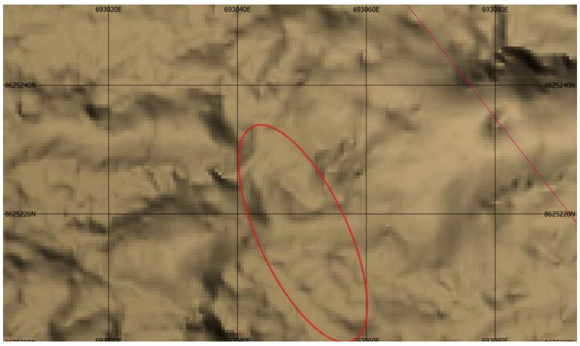


Figure 34: MBES image of Target 164 and chain extending south.

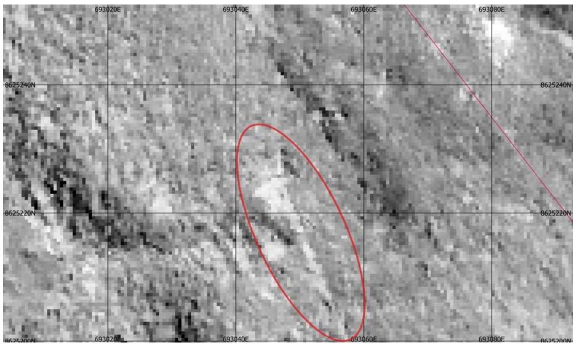


Figure 35: SSS image of Target 164 and chain extending south.

Inspection details for T2_2		
Date: 07-06-2022	**Method:** ROV	**Tide:** Slack
Distance and direction: Investigation of specific feature		
Swim start (min): 1646	**Swim end (min):** 1702	**Total time (min):** 16
Depth: 18 m	**Water visibility:** 3 m - 4 m	**Seabed visibility:** Good

Target description: T2_2 was undertaken specifically to record higher quality images of Target 164 and to determine if any portion of the anti-submarine trot extended north towards the proposed GEP route. Upon relocating the chain, the ROV was manoeuvred north to Target 164, a large anchor, seemingly admiralty pattern in style. The ROV made a full three-dimensional survey of the anchor and determined that the anti-submarine net chain was attached by a large D-shackle to the head of the anchor (Figure 41). The anchor had a large rectangular stock with possible evidence of iron bands, suggesting that the stock may be made of wood (Figure 43). The ROV took measurements of the length of the arm protruding from the seabed by measuring the depth at the tip of the fluke to the crown, determining the arm to be approximately 1.9m in length (Figure 38, Figure 39, and Figure 42). The relatively narrow, round shank extended north from the stock, ending at a fluke and arm protruded at a 90-degree angle from the seabed (Figure 40). No further mooring devices, chain or cable was identified to the north of Target 164, indicating that the anchor was the northern terminus of this trot.

Figure 36: Arm and fluke of anchor, looking west. (Video 2022-06-07_16.47.23; 04:08).

Figure 37: Detail of fluke, looking west. (Video 2022-06-07_16.47.23; 05:46).

Figure 38: Anchor shank, looking east. (Video 2022-06-07_16.47.23; 11:22).

Figure 39: Anchor ring, head, and stock, looking northwest. Note chain extending from D-shackle attached to head, and possible iron band on stock on right side of photo. (Video 2022-06-07_16.47.23; 05:51).

Figure 40: Anchor throat, crown, and arm, looking southwest. (Video 2022-06-07_16.47.23; 05:19).

Figure 41: Transverse view of stock, shank, and head, looking west. Note possible iron band around stock in foreground. (Video 2022-06-07_16.47.23; 07:37).

2.4.3 *Heritage Transect 3*

T3_1 followed a line of concrete clump weights, connected by heavy chain, that were identified as the moorings for the WWII anti-submarine net. This transect was located approximately halfway between KP 107 and 108 and ran NNW from a location several metres south of target NCL_SC_017, at 693417.30 m E, 8624861.20 m N to target 166 (aka NCL_SC_018), and beyond before finishing at a location near 693375.80 m E, 8624949.10 m N. The chain was clearly seen extending north from this location, however, it was determined that because this was in the opposite direction from the proposed GEP route, no further investigation was required.

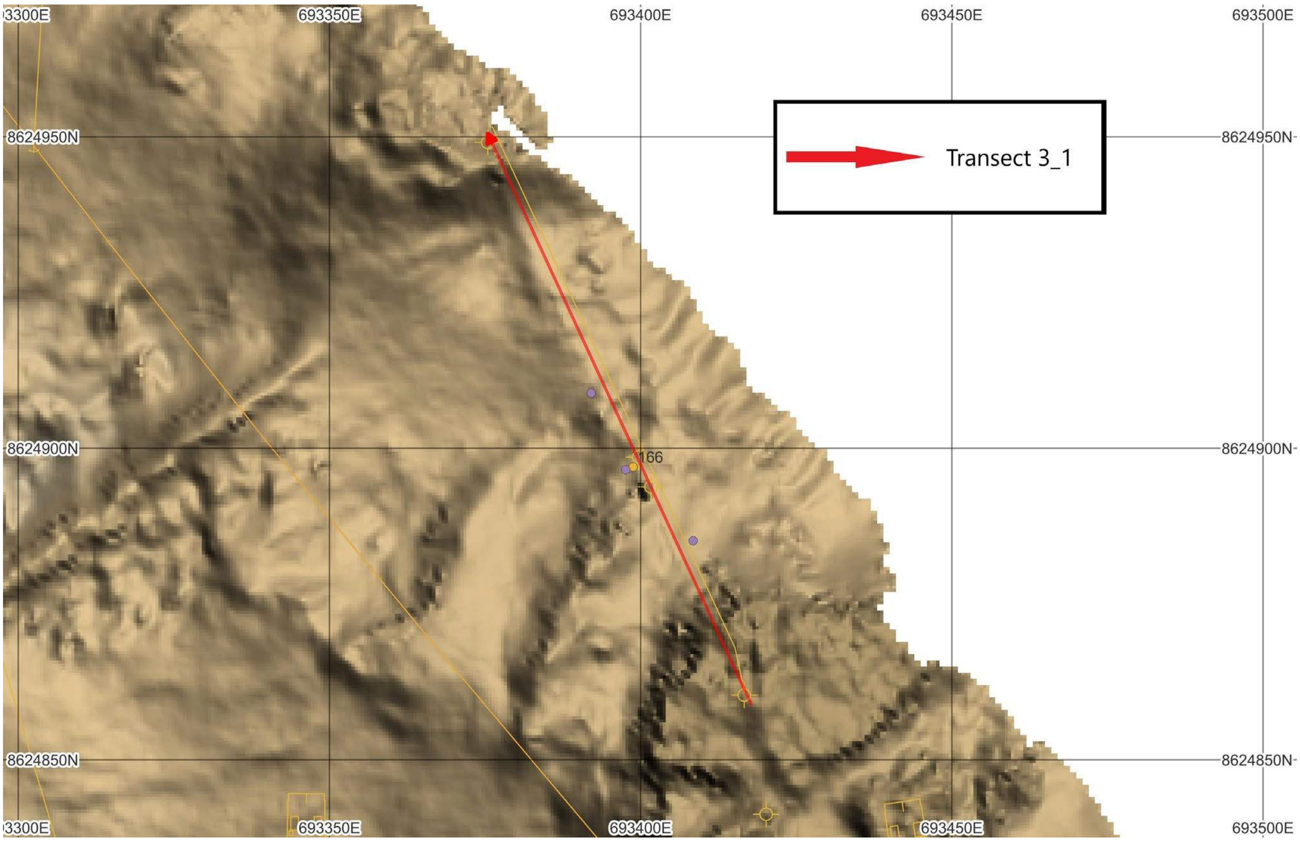


Figure 42 : Dive location for Heritage Transect 3.

2.4.3.1 T3_1

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
20	693416.67	8624860.36	Anti-submarine net mooring blocks and chain.	Width: 0.00 Height: 0.00 Length: 0.00 Shadow: 0.00	Variable, from 21 to 62	20 m

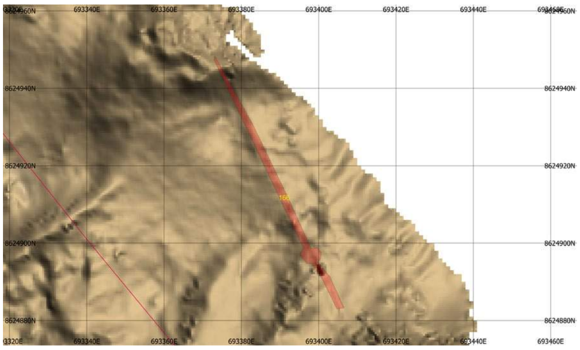


Figure 43: MBES image of general area of T3_1 and target 166.

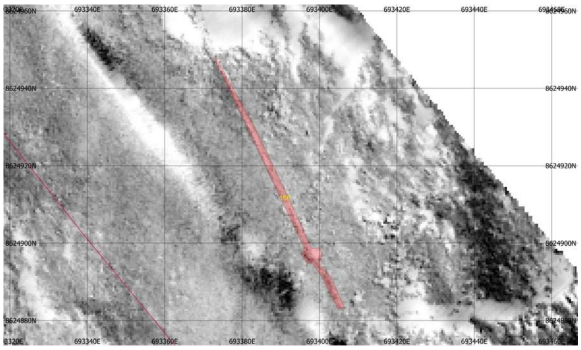


Figure 44: SSS image of general area of T3_1 and target 166.

Inspection details for T3_1		
Date: 07-06-2022	**Method:** ROV	**Tide:** Slack
Distance and direction: 150 m at 336° NNE		
Swim start (min): 1558	**Swim end (min):** 1626	**Total time (min):** 28
Depth: 20 m	**Water visibility:** 2 m – 3 m	**Seabed visibility:** Fair

Target description: The ROV was dropped on an area of seabed that was very rocky, with large rock shelfs and individual pebbles scattered around. This seabed topography made locating the chain and mooring blocks difficult, as potential cultural objects may have been obscured by the rocky seafloor and marine growth. Once the chain was located, the ROV took a southern heading and followed the chain towards the proposed GEP location at a heading of 120° ESE (Figure 47). Approximately 20 m further the chain was kinked at almost a 90-degree angle, with a clear break (Figure 48). Further investigation south found no further sign of the chain or mooring blocks, indicating that the chain had likely been broken and possibly removed or buried in this area. Turning north, the ROV followed the chain at a heading of 325° NW, finding this length of chain broken around the rocks and rock shelfs. Four more sections of broken chain were identified, all oriented on approximately the same heading, before the mooring block at Target 166 was located (Figure 49). The chain continued unbroken NNW from Target 166 for approximately 60 m before a second mooring block was identified (Figure 50). This second block appeared to be flipped upside down and had possible debris trapped under it (Figure 51). The chain continued the same heading from the north side of the second block, but as this was in the opposite direction of the proposed GEP route, it was decided to end investigation.

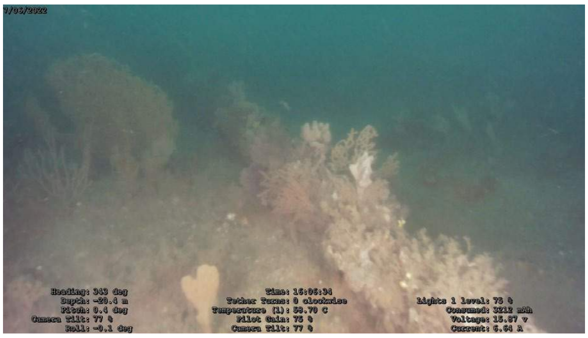


Figure 45: Chain located near ROV drop site. (Video 2022-06-07_15.56.55; 09:37).

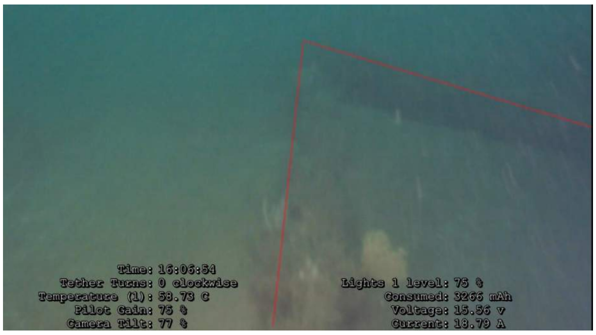


Figure 46: Chain kinked south of drop site. Direction of chain shown by red line. (Video 2022-06-07_15.56.55; 09:56).

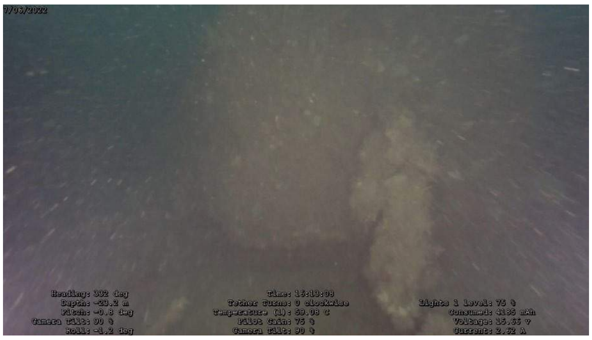


Figure 47: Target 166, mooring block, facing north. (Video 2022-06-07_15.56.55; 16:10).

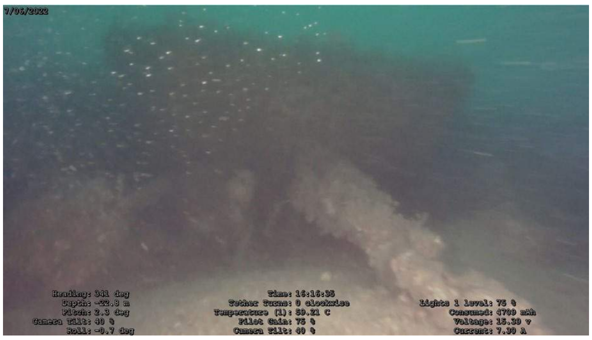


Figure 48: Second mooring block, apparently flipped upside down. (Video 2022-06-07_15.56.55; 19:37).

Figure 49: Apparent debris wedged under second mooring block. (Video 2022-06-07_15.56.55; 21:23).

2.4.4 *Individual Heritage Targets*

In addition to the three heritage transects undertaken on the anti-submarine net mooring trots, an additional 10 isolated targets located within 50m of the proposed GEP route were investigated.

2.4.4.1 Target 142

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
7	690559.00	8628514.00	Large boulders FUGRO ID: NCL_SC_042	Width: 12.00 Height: 0.00 Length: 15.00 Shadow: 0.00	0	32 m

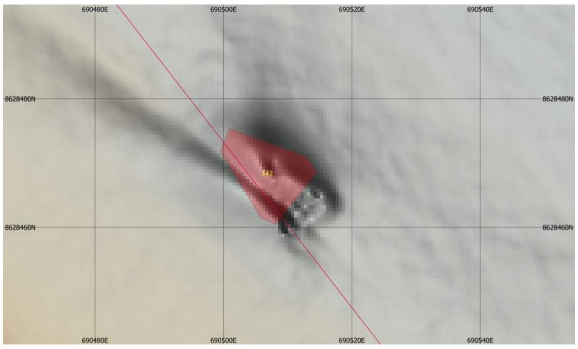


Figure 50: MBES image of Target 142.

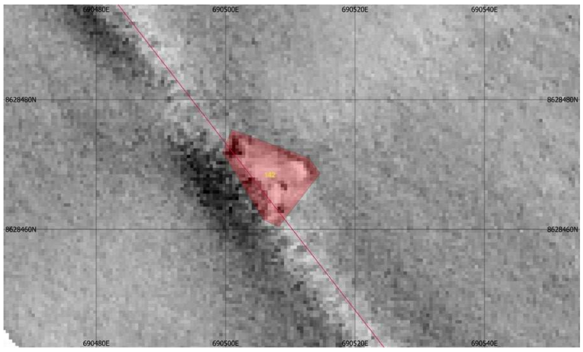


Figure 51: SSS image of Target 142.

Inspection details for Target 142		
Date: 06-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Circular search 10 m		
Swim start (min): 1458	**Swim end (min):** 1535	**Total time (min):** 37
Depth: 32 m	**Water visibility:** 0 m – 2 m	**Seabed visibility:** Poor

Target description: The investigation for Target 142 was combined with ecology survey 26_BACI-5P. Target was located and determined to be numerous large boulders, non-cultural. Boulders ranged from 2 – 5 metres in size (Figure 54, Figure 55).

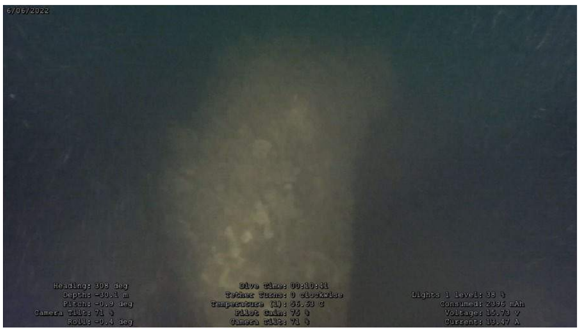


Figure 52: Boulder located at Target 142. (Video 2022-06-06_15.00.03; 05:01).

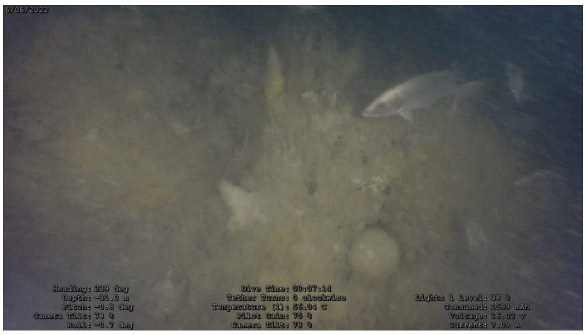


Figure 53: Detail of large boulder at Target 142. (Video 2022-06-06_15.00.03; 04:30).

2.4.4.2 Target 245

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
9	693164.00	8625128.00	Field of pebbles and rocks. Possibly MA_012	Width: 22.00 Height: 0.00 Length: 31.00 Shadow: 0.00	0	21 m

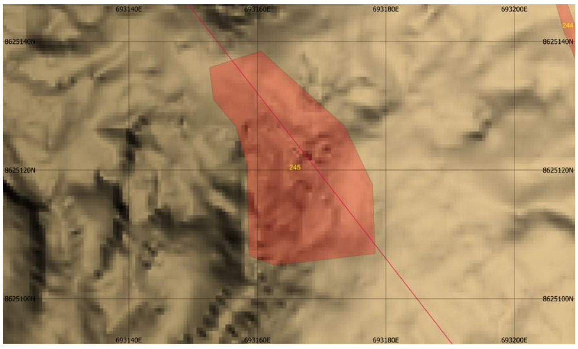


Figure 54: MBES image of Target 245, area of debris field highlighted.

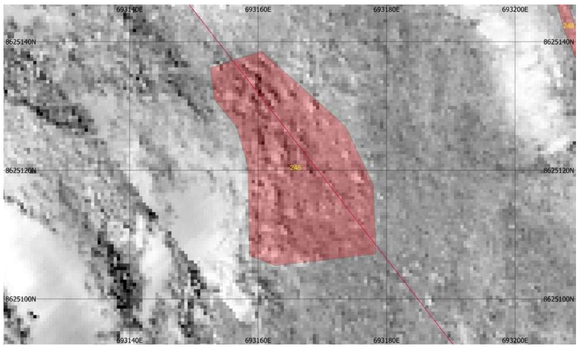


Figure 55: SSS image of Target 245, area of debris field highlighted.

Inspection details for Target 245		
Date: 06-06-2022	**Method:** ROV	**Tide:** Flowing
Distance and direction: Circular search 10 m		
Swim start (min): 1701	**Swim end (min):** 1710	**Total time (min):** 9
Depth: 21 m	**Water visibility:** 0 m – 2 m	**Seabed visibility:** Poor

Target description: Target 245 was located and determined to be a mound or field of rocks and pebbles, ranging in size from several centimetres to 2 metres across (Figure 58, Figure 59).

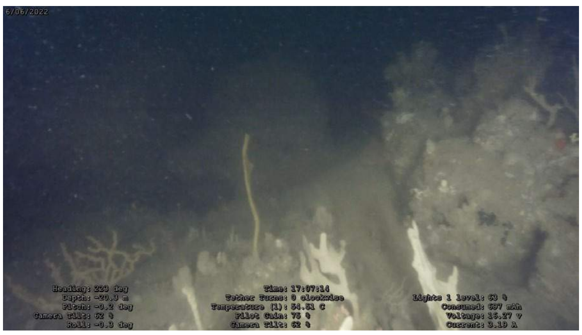


Figure 56: Larger rocks located at Target 245. (Video 2022-06-06_17.02.18; 03:20).

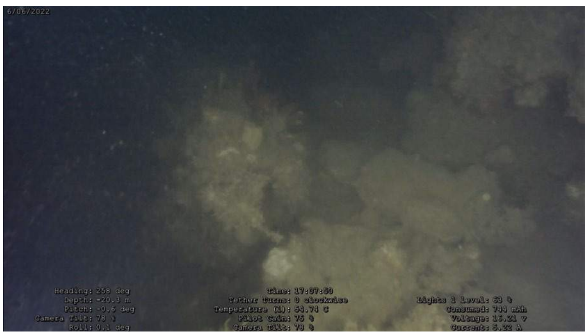


Figure 57: Smaller rocks located at Target 245. (Video 2022-06-06_17.02.18; 05:29).

2.4.4.3 Target 241

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
19	691791.84	8626921.00	Seabed depression FUGRO ID: NCL_SC_032	Width: 8.00 Height: 0.00 Length: 9.00 Shadow: 0.00	42	24 m

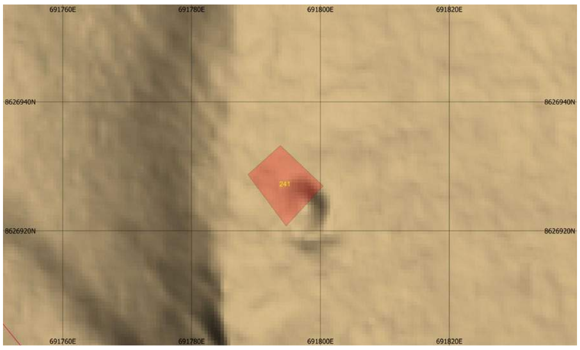


Figure 58: MBES image of Target 241.

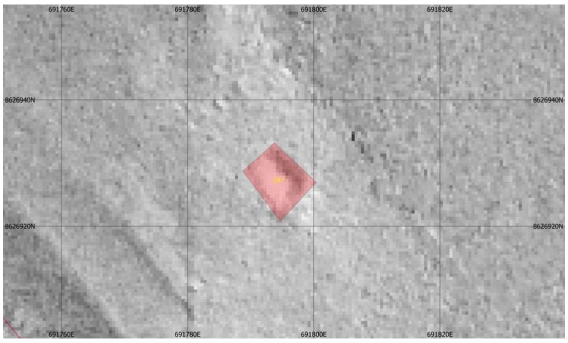


Figure 59: SSS image of Target 241.

Inspection details for Target 241		
Date: 07-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Circular search 10m		
Swim start (min): 1453	**Swim end (min):** 1529	**Total time (min):** 36
Depth: 24 m	**Water visibility:** 2 – 3 m	**Seabed visibility:** Fair

Target description: Target 241 was determined to be a shallow depression in the seabed, approximately 1.5m deep with gently sloping sides. Dive for 241 was combined with investigation of NCL_SC_031 and ecology survey 24_BACI-4P.

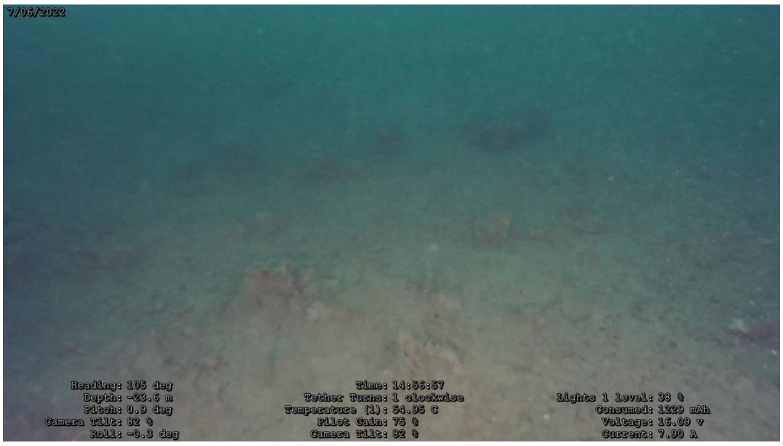


Figure 60: Detail of seabed in depression located at Target 241. (Video 2022-06-07_14.54.13; 02:42).

2.4.4.4 Target NCL_SC_031

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
19	691791.84	8626921.00	Possible debris.	Width: 0.70 Height: 0.00 Length: 1.40 Shadow: 0.00	25	24 m

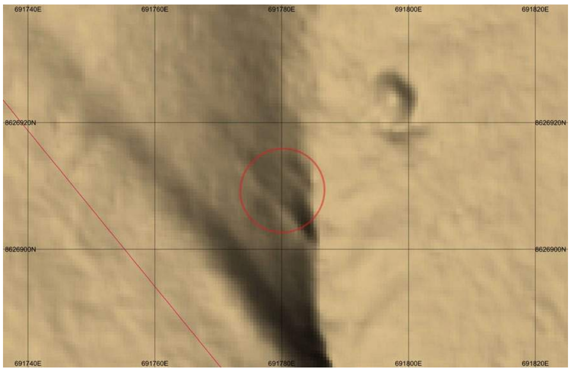


Figure 61: MBES image of Target NCL_SC_031.

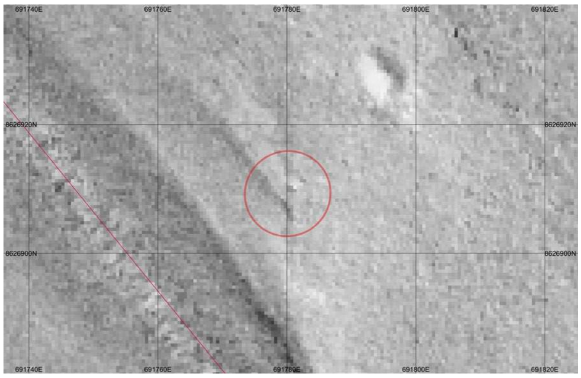


Figure 62: SSS image of Target NCL_SC_031.

Inspection details for Target NCL_SC_031		
Date: 07-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Circular search 10m		
Swim start (min): 1453	**Swim end (min):** 1529	**Total time (min):** 36
Depth: 24 m	**Water visibility:** 2 – 3 m	**Seabed visibility:** Fair

Target description: The ROV continued directly from Target 241 to the location of NCL_SC_031 at a bearing of 232° SW. No cultural material was identified at this location. Seabed consisted of fine sand with numerous sand ripples.

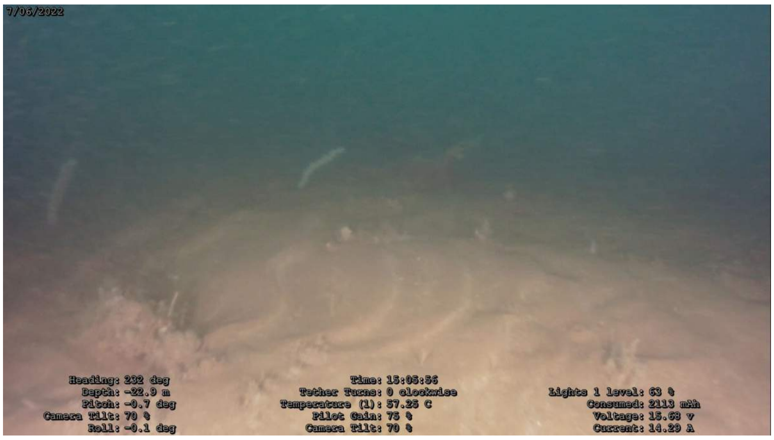


Figure 63: Seabed and sand ripples at NCL_SC_031. (Video 2022-06-07_15.04.06; 01:48).

2.4.4.5 Target 175

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
22, 23	694295.02	8623601.00	Linear ridge. Possibly associated with MA_009	Width: 5.00 Height: 0.00 Length: 24.00 Shadow: 0.00	1.5	28 m

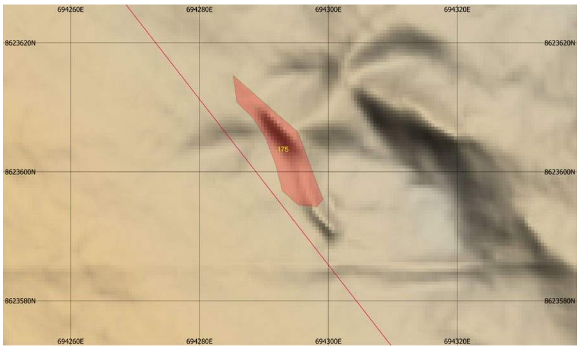


Figure 64: MBES image of Target 175.

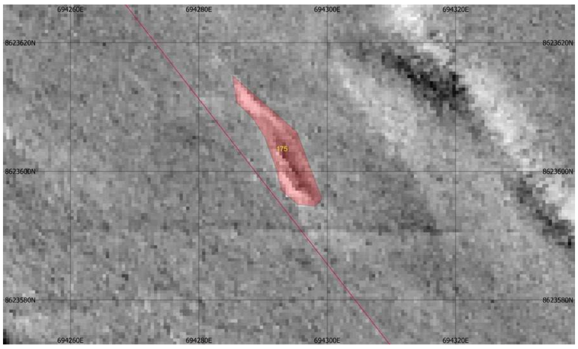


Figure 65: SSS image of Target 175.

Inspection details for Target 175		
Date: 08-06-2022	**Method:** ROV	**Tide:** Flowing
Distance and direction: 25 m at 147° SE		
Swim start (min): 0748	**Swim end (min):** 0810	**Total time (min):** 22
Depth: 28 m	**Water visibility:** 3 m – 4 m	**Seabed visibility:** Good

Target description: Two dives were attempted on Target 175. The first, dive 22, was unsuccessful in finding the target, and was aborted. The second, dive 23, was successful in locating the target.

Target 175 appeared to be a low ridge of rock and coral, rising approximately 1 – 2 m from the surrounding seabed, which was mostly sand. The ridge measured approximately 25 m in total length and 2-3 m in width and was separated in two sections by a small gap about halfway along the ridge. No obvious cultural material was seen during the dive.

Figure 66: North section of ridge, facing northeast. (Video 2022-06-08_07.51.14; 01:05).

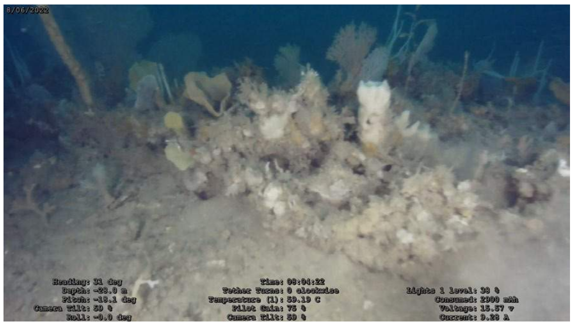


Figure 67: Detail of southern section of ridge. (Video 2022-06-08_07.51.14; 13:04).

2.4.4.6 Target 174

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
24	694194.61	8623695.89	Single discrete object in close location to series of mag strikes across KP 109 FUGRO ID: NCL_SC_013, MA_010	Width: 2.00 Height: 1.00 Length: 3.00 Shadow: 0.00	15	28 m

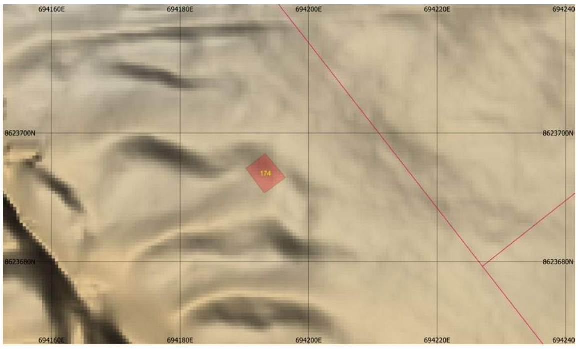


Figure 68: MBES image of Target 174.

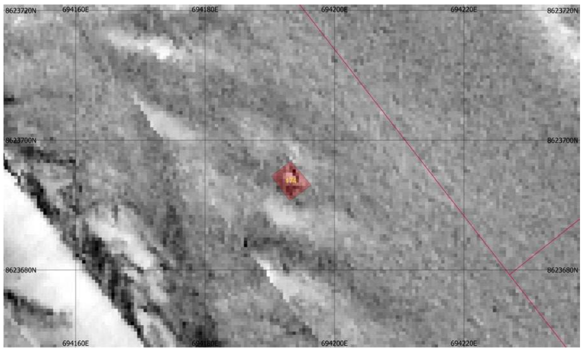


Figure 69: SSS image of Target 174.

Inspection details for Target 174		
Date: 08-06-2022	**Method:** ROV	**Tide:** Flowing
Distance and direction: Cross search pattern, 10m NESW		
Swim start (min): 0826	**Swim end (min):** 0841	**Total time (min):** 15
Depth: 28 m	**Water visibility:** 3 m – 4 m	**Seabed visibility:** Good

Target description: In an improvement on target locating, a clump weight with a line attached to the buoy was dropped on the location of the target while the vessel was moving. Once the vessel was anchored, the ROV used the buoy line as a target reference and descended on the line to the seabed. Once on the bottom, the ROV began a cross shaped search pattern with 10 m transects out from the clump weight in all four cardinal directions.

Target 174 was located a short distance west of the drop weight and appeared as two round mounds protruding from a sandy seabed, similar to a dumbbell in form. A full 360° visual survey of the object was completed. The whole structure was estimated to measure 2-3 m from end to end, 1 m wide, and 1 m above the seabed. The remains of cable or rope appeared to be wrapped around the middle arm connecting the two ends, with a coil wedged underneath the western end. The shape and presence of cable or rope suggests that Target 174 may be a windlass or winch. No other cultural objects were identified in the surrounding area.

Figure 70: Target 174, facing north. (Video 2022-06-08_08.26.18; 08:58).

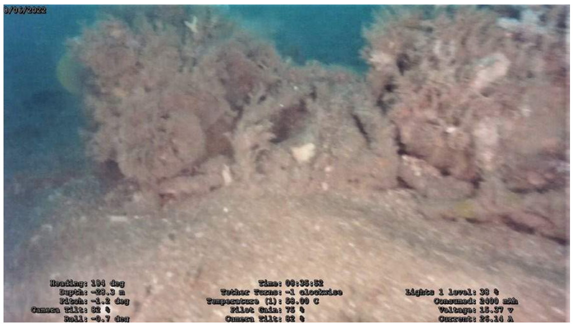


Figure 71: Target 174 facing south. Note possible cable or rope remains wrapped around middle. (Video 2022-06-08_08.26.18; 09:31).

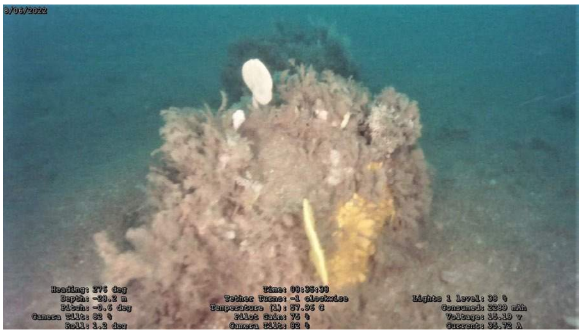


Figure 72: Target 174, facing west. (Video 2022-06-08_08.26.18; 09:17).

Figure 73: Target 174, facing east. Notice cable coiled underneath. (Video 2022-06-08_08.26.18; 09:35).

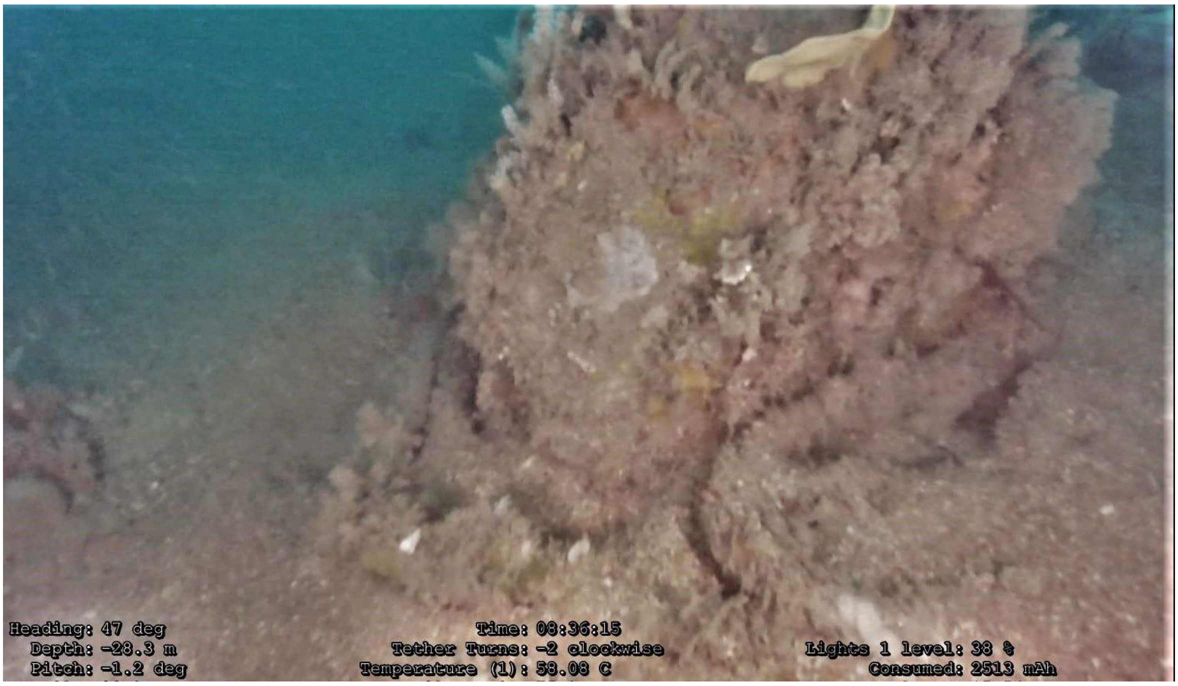


Figure 74: Detail of coil, facing east. (Video 2022-06-08_08.26.18; 09:55).

2.4.4.7 Target NCL_SC_016

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
25, 26	694168.64	8623820.49	Possible cable support or isolated non-ferrous object	Width: 1.60 Height: 0.00 Length: 3.50 Shadow: 0.00	39	30 m

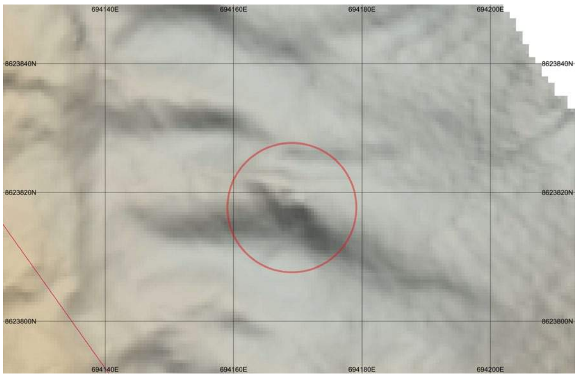


Figure 75: MBES image of Target NCL_SC_016.

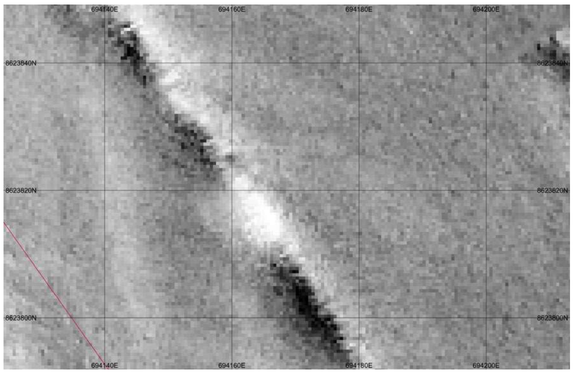


Figure 76: SSS image of Target NCL_SC_016.

Inspection details for Target NCL_SC_016		
Date: 08-06-2022	**Method:** ROV	**Tide:** Flowing
Distance and direction: Cross search pattern, 10m NESW		
Swim start (min): 0907	**Swim end (min):** 0933	**Total time (min):** 26
Depth: 30 m	**Water visibility:** 2 m – 3 m	**Seabed visibility:** Good

Target description: Two dives were attempted on Target NCL_SC_016. The first was aborted because the ROV lost sight of the guide rope. The second dive, 26, was successful in locating the target using the same methodology adopted for dive 24.

Target NCL_SC_016 was located several metres north of the drop weight and appeared to be a length of cable running in a generally east-west orientation (Figure 79). The cable was approximately 70mm in diameter and extended for about 35m in total length. Portions of the cable were buried in the sandy seabed, with both ends disappearing into the sand. Around 20 m west of the drop weight, the cable veered slightly north before turning sharply southwest and a 90-degree dogleg (Figure 80). The portion of the cable at the dogleg was clearly visible above the seabed and appeared to be ferrous (Figure 81). The location of the cable is roughly in the location of the 1879 telegraph cable and may be the disarticulated section of a 19th century telegraph cable.

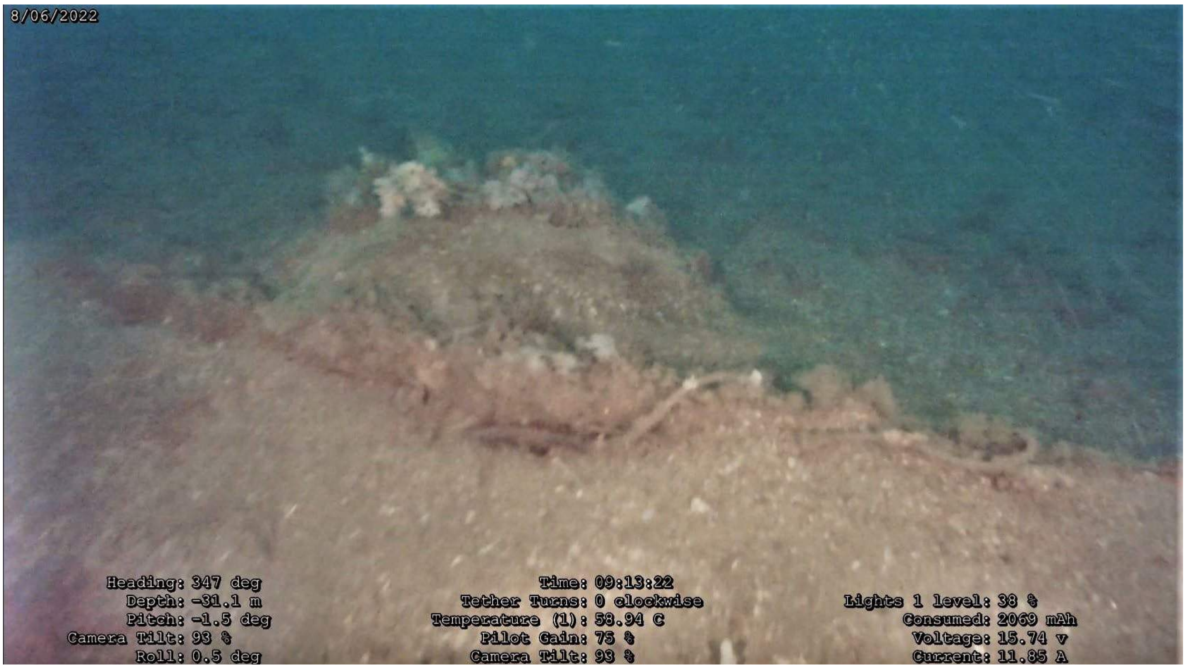


Figure 77: Target NCL_SC_016 just north of drop line. Cable running at heading of 274° W. (Video 2022-06-08_09.06.58; 06:10).

Figure 78: Dogleg in cable. (Video 2022-06-08_09.06.58; 09:47).

Figure 79: Detail of cable at dogleg. Note possible ferrous nature of cable. (Video 2022-06-08_09.06.58; 10:56).

2.4.4.8 Target MA_007

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
29	695763.20	8621695.50	Inferred buried debris	21.5 nT	6	24 m

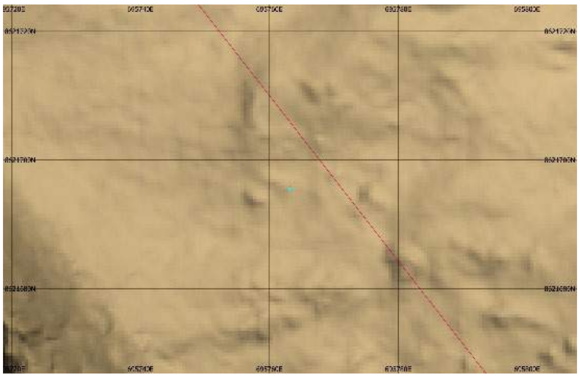


Figure 80: MBES image of the general area of Target MA_007.

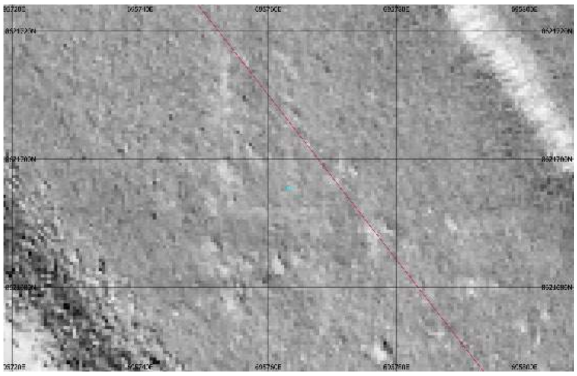


Figure 81: SSS image of the general area of Target MA_007.

Inspection details for Target MA_007		
Date: 08-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Cross search pattern, 10m NESW		
Swim start (min): 1256	**Swim end (min):** 1312	**Total time (min):** 16
Depth: 24 m	**Water visibility:** 2 m – 3 m	**Seabed visibility:** Good

Target description: Dive methodology was repeated from previous dives. A clump weight with buoy was dropped on the target from the moving vessel. Once anchored, the ROV was placed in the water and followed the line down to the seabed. Once on bottom, a cross shaped search pattern was conducted, with 10m transects in each cardinal direction from the clump weight.

The clump weight was dropped almost directly on top of Target MA_007, which was located 2m west. The target appeared to be a rectangular structure made of steel I-beams with very low relief above the sandy seabed. The structure consisted of at least 10 beams and possibly more as it was partially buried in the seabed. Three long beams delimited the structure on three sides, with the fourth side buried. Between these several smaller beams extended from one side of the structure, parallel with the other two sides. The main structure is estimated to be roughly five metres long and 2 metres wide. In addition to this contiguous material, there were several isolated and disarticulated beams scattered nearby. MA_007 may represent the remains of a steel barge, or possible discard.

Figure 82: Overview of structure located at Target MA_007, facing south. Note rectangular shape of outer beams, with interior beams. (Video 2022-06-08_12.56.09; 06:23).

Figure 83: Overview of structure, facing west. (Video 2022-06-08_12.56.09; 04:10).

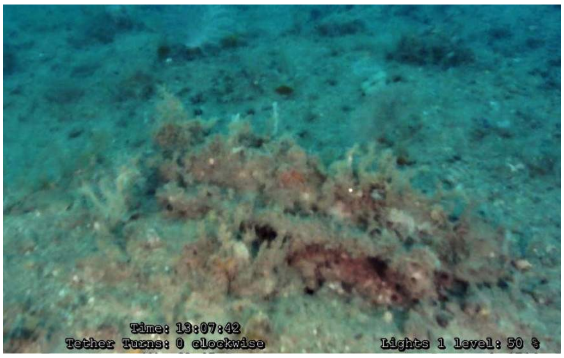


Figure 84: Isolated debris likely associated with the contiguous structure at MA_007. Debris located approximately 5m from structure. (Video 2022-06-08_12.56.09; 11:31).

2.4.4.9 Target MA_001

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
30	697628.20	8617803.70	Inferred buried debris	13.3 nT	35	20 m

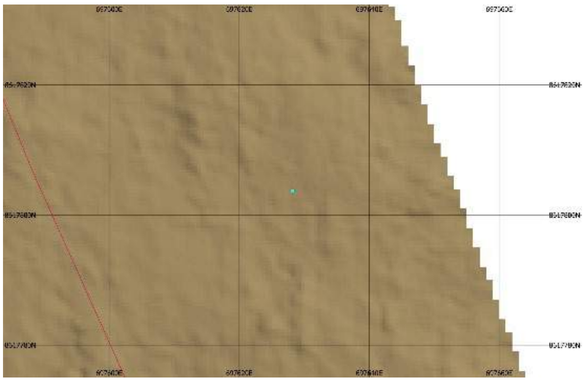


Figure 85: MBES image of the general area of Target MA_001.

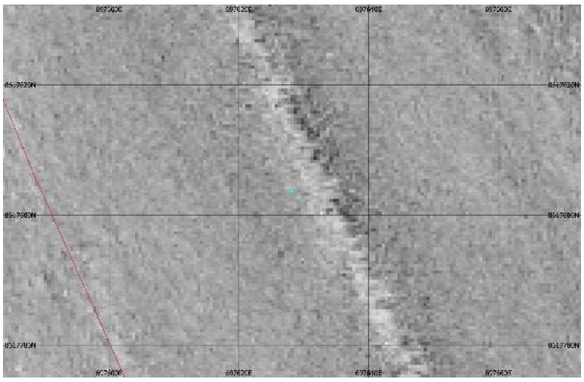


Figure 86: SSS image of the general area of Target MA_001.

Inspection details for Target MA_001		
Date: 08-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Cross search pattern, 10m NESW		
Swim start (min): 1338	**Swim end (min):** 1358	**Total time (min):** 20
Depth: 20 m	**Water visibility:** 2 m – 3 m	**Seabed visibility:** Good

Target description: Dive methodology was repeated from previous dives. A clump weight with buoy was dropped on the target from the moving vessel. Once anchored, the ROV was placed in the water and followed the line down to the seabed. Once on bottom, a cross shaped search pattern was conducted, with 10m transects in each cardinal direction from the clump weight.

The cross search found three instances of debris in the search area. A metal wheel rim was located 5m south of the clump weight, mostly buried in soft sediment (Figure 89). Next to the wheel was a length of steel rope, with one end tied in a loop (Figure 90 and Figure 91). These two objects are likely related and may represent a mooring for a buoy or other device.

A third piece of debris was located about 5m north of the clump weight. This object consisted of a cement block or possible metal scrap with two wires protruding (Figure 92). No other debris or cultural objects were seen in the area.

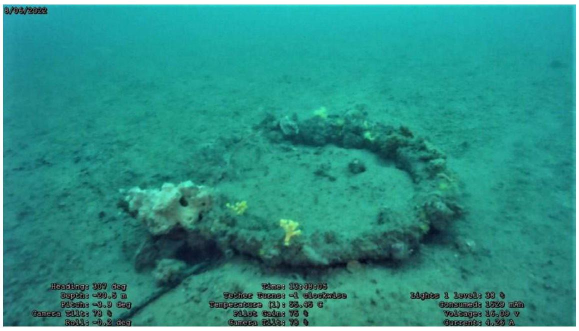


Figure 87: Metal wheel rim located at MA_001. Note wire protruding from side. (Video 2022-06-08_13.43.09; 04:54).

Figure 88: Steel rope or cable located next to the wheel rim. (Video 2022-06-08_13.43.09; 05:56).

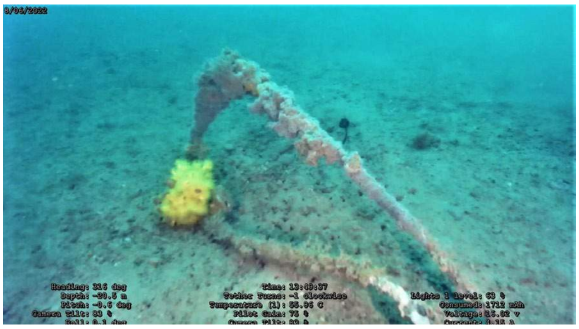


Figure 89: Detail of loop in cable. (Video 2022-06-08_13.43.09; 06:27).

Figure 90: Debris located north of clump weight. (Video 2022-06-08_13.43.09; 07:57).

2.4.4.10 Target NCL_SC_002

ROV dive	Dive Start Easting	Dive Start Northing	Interpretation	Dimensions	Distance from GEP (m)	Depth
31	698297.94	8616489.78	Single isolated object, possible debris or natural feature	Length: 1.00 Width: 0.40	11	14 m

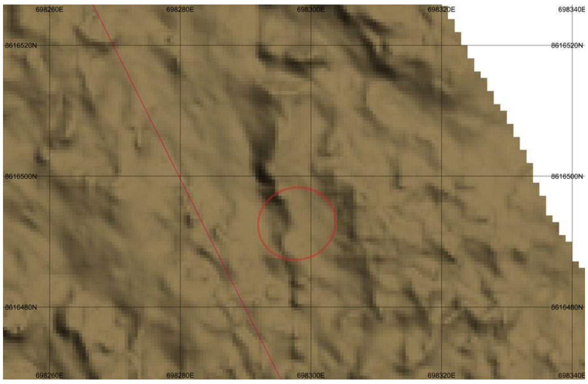


Figure 91: MBES image of Target NCL_SC_002

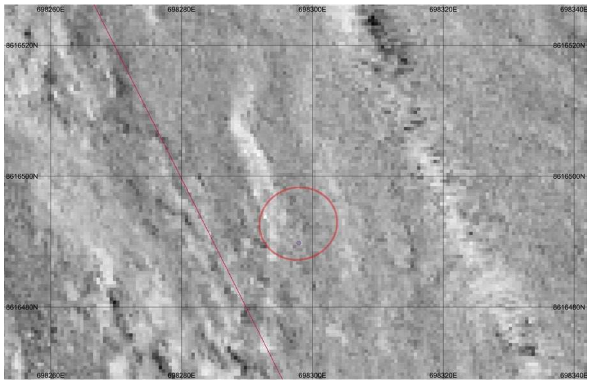


Figure 92: SSS image Target NCL_SC_002.

Inspection details for Target NCL_SC_002		
Date: 08-06-2022	**Method:** ROV	**Tide:** Ebbing
Distance and direction: Cross search pattern, 10m NESW		
Swim start (min): 1420	**Swim end (min):** 1440	**Total time (min):** 20
Depth: 14 m	**Water visibility:** 2 m – 3 m	**Seabed visibility:** Good

Target description: Dive methodology was repeated from previous dives. A clump weight with buoy was dropped on the target from the moving vessel. Once anchored, the ROV was placed in the water and followed the line down to the seabed. Once on bottom, a cross shaped search pattern was conducted, with 10m transects in each cardinal direction from the clump weight.

A small piece of possible debris was located 5m south of the clump weight. The object was long and thin, possibly aluminium if metal. After locating this object, the ROV lost the location of the clump weight and surfaced to locate the target again. After reaching the bottom again, the ROV swam north of the weight, and completed its cross-pattern search. No other cultural material was seen in the area.

Figure 93: Possible debris located south of clump weight. (Video 2022-06-08_14.22.27; 03:23).

Figure 94: Natural feature north of clump weight. (Video 2022-06-08_14.22.27; 15:11).

3 ROV SURVEY SUMMARY

In total, 21 dives were attempted to locate and identify geophysical survey targets. Of these 21 dives, 3 were aborted due to poor conditions or issues with the ROV. Despite these failed attempts, ROV surveys were conducted on all 16 targets shortlisted for ROV survey.

Heritage Transects 1, 2, and 3 identified the remains of WWII anti-submarine net moorings near the entrance to Darwin Harbour. It was concluded based on these surveys that the northern and southern mooring trots (Transects 2 and 3) did not cross the proposed GEP route. It was noted that the northern end of the trot surveyed by Transect 2 was anchored with a potentially historical ships anchor, likely of cultural heritage significance.

ROV survey of the middle trot (Transect 1) identified mooring chains that did cross the proposed GEP route. However, it was also seen that a gap exists between sections of the chain, southeast of the location of Target 246, which was not located.

Individual dives on 10 isolated heritage targets identified 5 instances of natural features, not considered to be cultural in origin. Of the remaining 5, four are conclusively cultural, while one was inconclusive. The table below summarizes the results of the survey of these features.

Target ID	Likely identification	Cultural/Natural
142	Boulders	Natural
245	Rock rubble	Natural
241	Shallow depression	Natural
NCL_SC_031	Sand ripples	Natural
175	Narrow rock/coral ridge	Natural
174	Winch or windlass	Cultural
NCL_SC_016	Telegraph cable	Cultural
MA_007	Remains of barge	Cultural
MA_001	Buoy mooring and cable	Cultural
NCL_SC_002	Metal debris	Inconclusive

ANNEX A – DIVE LOG

Dive	Date	Objective of dive	Swim Start	Swim Finish	Total bottom time (min)
3	06/06/2022	T1_1	10:27	11:38	11
4	06/06/2022	T1_2	12:15	12:38	13
5	06/06/2022	T1_3	12:47	13:11	24
7	06/06/2022	Target 142	14:58	15:35	37
8	06/06/2022	T1_4	16:05	16:44	39
9	06/06/2022	Target 245	17:01	17:10	9
10	07/06/2022	T1_5	8:09	8:11	2
14	07/06/2022	T1_6	10:45	11:06	21
15	07/06/2022	T1_7	11:30	12:00	30
16	07/06/2022	T2_1	12:31	12:55	24
19	07/06/2022	Targets 241 and NCL_SC_031	14:53	15:29	36
20	07/06/2022	T3_1	15:58	16:26	28
21	07/06/2022	T2_2	16:46	17:02	16
22	08/06/2022	Target 175	7:18	7:34	16
23	08/06/2022	Target 175	7:48	8:10	22
24	08/06/2022	Target 174	8:26	8:41	15
25	08/06/2022	Target NCL_SC_016	8:53	9:00	7
26	08/06/2022	Target NCL_SC_016	9:07	9:33	26
29	08/06/2022	MA_007	12:56	13:12	16
30	08/06/2022	MA_001	13:38	13:58	20
31	08/06/2022	NCL_SC_002	14:20	14:40	20
Total Dives	**21**			Total bottom time	**432**

ANNEX B – VIDEO LOG

Dive	Name	File	Size (GB)	Length
3	2022-06-06_10.27.18	MKV	2.00	31:08
	2022-06-06_10.58.29	MKV	3.22	41:18
4	2022-06-06_12.24.46	MKV	0.68	12:37
5	2022-06-06_12.48.12	MKV	1.51	21:01
7	2022-06-06_15.00.03	MKV	0.68	13:47
8	2022-06-06_16.08.58	MKV	2.30	32:31
	2022-06-06_16.41.31	MKV	0.25	03:55
9	2022-06-06_17.02.18	MKV	0.45	07:53
10	2022-06-07_08.06.12	MKV	0.00	00:02
14	2022-06-07_10.46.37	MKV	0.79	16:17
15	2022-06-07_11.30.28	MKV	1.79	30:19
16	2022-06-07_12.31.43	MKV	1.86	23:41
19	2022-06-07_14.54.13	MKV	0.55	09:51
	2022-06-07_15.04.06	MKV	0.28	03:37
20	2022-06-07_15.56.55	MKV	2.30	29:18
21	2022-06-07_16.47.23	MKV	0.87	14:23
22	2022-06-08_07.19.04	MKV	0.68	15:45
23	2022-06-08_07.51.14	MKV	0.91	19:44
24	2022-06-08_08.26.18	MKV	0.79	14:40
25	2022-06-08_08.58.47	MKV	0.38	05:37
26	2022-06-08_09.06.58	MKV	1.28	24:43
29	2022-06-08_12.56.09	MKV	1.27	16:06
30	2022-06-08_13.43.09	MKV	1.17	14:50
31	2022-06-08_14.22.27	MKV	1.62	20:39

11 ANNEX B: CONSOLIDATED TARGET LIST

The table below is a consolidated list of all targets identified as potentially cultural from geophysical survey data review. Additionally, several known shipwrecks within the study area and anchoring corridor are included, as well as targets surveyed during ROV surveys (see main report, Section 7, and Annex A).

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
B	MA_001 *	697,628.20	8,617,803.70	Likely buoy mooring and cable	1	1	0.25	20	35
A	MA_007 *	695,763.20	8,621,695.50	Metal frame and debris	5	2	0.25	24	6
B	MA_028	693,130.70	8,624,923.90	Buried ferrous object near anti-sub net moorings	N/A	N/A	N/A	21	150
B	MA_031	698,180.90	8,616,372.60	Buried ferrous object	N/A	N/A	N/A	13	146
B	MA_037	701,335.50	8,613,704.20	Buried ferrous object	N/A	N/A	N/A	19	651
A	112	623 013.42	8 659 220.00	Single object of high relief. Possible debris related to I-124.	8	6	N/A	46	68
A	138	686 407.37	8 632 159.33	Mound associated with anchor scars	13	16	N/A	17	59
A	149	691 670.76	8 626 677.01	Unknown, may be related to pipeline or another cultural feature.	Total length: 258m Ind. Diamete r: 5m	19	N/A	19	200
A	164*	693 038.56	8 625 231.53	Part of anti-submarine net mooring trot 18 FUGRO ID: NCL_SC_026	209	2	N/A	16	30
A	166*	693 399.74	8 624 898.55	Part of anti-submarine net mooring trot 16 FUGRO ID: NCL_SC_017, 018, 019	73	5	N/A	21	41

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	167*	693 085.69	8 625 121.75	Part of anti-submarine net mooring trot 17 Likely connected to Target ID: 164	3	3	N/A	16	76
A	191	696 438.36	8 620 800.13	Single object of high relief. Possible small boat.	8	3	N/A	19	73
A	210	701 140.90	8 613 958.61	Possible aircraft wreck or natural feature.	12	7	N/A	17	389
A	234	647 746.21	8 649 692.16	Single mound, indicating lone discarded object.	5	4	N/A	43	173
A	238	696 581.70	8 620 537.67	Possible scattered debris.	70	10	N/A	21	78
A	239	697 710.77	8 617 774.90	USAT *Mauna Loa*	124.97	16.46	N/A	19	90
A	240	691 578.22	8 626 925.25	Possible mooring block for anti-submarine defences	4	2	N/A	16	122
A	242	691 589.94	8 626 799.20	Steel wire rope and chain associated with anti-submarine defences. (boom net), UXO including mechanical fuses and fuse cones. (See Section 6.4)	23	13	N/A	17	186
A	243	693 188.00	8 624 746.00	Possible mooring block related to anti-submarine defences.	2	2	N/A	15	216
A	244*	693 196.00	8 625 167.00	Part of anti-submarine net mooring trot 18 FUGRO ID: NCL_SC_022, 023, 024, 025	120	5	N/A	22	50
A	248	693 131.66	8 624 925.53	Debris scatter, or possible anti-submarine net remains	Var.	Var.	N/A	16	150

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
B	NCL_SC_002*	698 297.94	8 616 489.78	Debris	1	0.4	N/A	17	11
B	NCL_SC_010	694 982.00	8 622 822.59	Linear debris, likely cable remains.	17	0.5	N/A	20	70
A	NCL_SC_016*	694 168.64	8 623 820.49	Cable, possible telegraph	3.5	1.6	N/A	24	40
B	NCL_SC_031*	691 780.61	8 626 909.95	Single isolated non-ferrous object, likely debris.	1.4	0.7	N/A	16	26
B	115	649 361.40	8 649 116.46	Shallow depressions with low relief object.	8	4	N/A	44	86
B	130	665 465.07	8 643 481.67	Possible debris scatter.	18	8	N/A	29	208
B	135	621 286.34	8 660 259.37	Likely natural feature, closest proximity target to I-124	62	58	N/A	48	143
B	136	622 455.26	8 659 969.89	Possible debris scatter or natural feature.	98	32	N/A	49	214
B	141	690 574.96	8 628 606.67	Debris or rocks FUGRO ID: NCL_SC_043, 044, 045, 046	53	20	N/A	30	137
A	174*	694 194.43	8 623 696.01	Winch or windlass with rope FUGRO ID: NCL_SC_013	5	4	N/A	24	16
B	192	696 253.89	8 620 643.48	Possible debris	24	22	N/A	14	147
B	196	696 859.94	8 619 902.39	Debris or rocks	9	6	N/A	19	53
B	233*	639 844.98	8 652 470.81	Triangular depression, Likely natural feature.	39	8	N/A	41	34
A	500	697,615.17	8,618,840.23	USAT Meigs	121.00	20.00	3.30	20	369
A	501	695,875.84	8,619,850.01	Medkhanun 3	25.00	8.00	7.00	19	847
A	502	695,698.81	8,620,246.53	Ham Luong	18.00	5.00	3.00	25	832
A	503	695,794.02	8,620,287.72	Song Saigon	40.00	10.00	5.00	24	728
A	504	695,778.93	8,620,381.31	John Holland Barge	38.00	15.00	5.00	25	700

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	505	693,287.42	8,623,844.84	Mandorah Queen	12.00	5.00	2.00	20	683
A	506	691,938.35	8,625,657.51	NR Diemen	29.00	5.00	0.00	8	642
A	573	692,508.78	8,625,489.01	Debris	26.00	15.00	0.50	17	295
A	574	691,574.41	8,626,791.47	WWII anti-sub boom net	41.00	21.00	1.00	21	209
A	575	691,518.71	8,626,801.77	Debris	10.00	6.00	0.75	20	245
B	576	689,856.12	8,628,847.08	Mound	7.00	6.50	0.40	25	268
B	577	689,412.76	8,629,288.62	Isolated object	4.00	4.50	0.50	24	263
B	578	685,439.11	8,632,096.37	Mound associated with trawl scar	8.00	4.50	0.40	17	603
A	579	689,314.84	8,630,473.13	Debris	20.00	9.00	1.30	31	592
B	580	689,842.70	8,630,171.05	Mound	5.00	4.00	1.50	30	691
A	581	691,692.88	8,627,659.36	Possible cable	312.00	2.50	1.40	31	431
A	583	692,918.80	8,626,550.93	Linear debris	11.00	2.00	1.50	39	682
A	584	692,936.90	8,626,417.56	Debris or boulder	7.00	6.00	3.50	39	613
A	588	693,982.49	8,624,331.38	Debris	8.00	4.00	2.50	35	165
A	585	694,508.35	8,624,088.70	Debris	9.00	3.00	0.50	32	472
B	586	694,770.88	8,624,269.65	Possible small boat or natural feature	17.00	4.00	1.25	35	791
A	587	695,753.15	8,623,106.77	Mooring block	3.00	2.50	0.80	33	852
A	589	696,110.51	8,621,995.74	Debris	17.00	7.00	2.50	33	452
A	590	696,133.59	8,621,994.69	Debris	4.50	2.50	2.00	33	470
A	591	696,472.78	8,621,975.02	Debris	6.40	6.20	1.50	32	727
A	592	696,535.45	8,621,187.11	Debris	8.50	2.70	1.30	25	345
A	593	696,548.46	8,621,272.90	Mooring block	1.40	1.40	0.75	25	399
A	594	697,090.00	8,620,464.24	Debris	3.50	3.00	1.75	25	513
A	595	697,563.09	8,620,256.32	Debris	6.50	4.20	1.75	32	845
A	597	698,035.82	8,617,894.98	Debris	3.00	3.00	2.00	20	443
B	598	697,030.36	8,617,864.23	Linear feature	59.00	2.00	0.75	12	504
B	599	697,055.70	8,617,918.12	Linear feature	24.00	2.00	0.75	13	462
B	600	697,036.34	8,618,057.64	Linear feature	33.00	2.00	1.00	16	434
A	601	696,815.85	8,619,144.52	Debris	40.00	8.00	0.50	19	286

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	602	696,751.52	8,619,156.36	Debris	24.00	11.00	0.75	16	343
A	603	696,112.03	8,619,639.40	Debris	8.00	6.60	3.00	14	729
B	604	696,043.52	8,619,624.92	Linear feature, log	18.70	2.40	1.00	13	797
B	605	696,000.91	8,619,629.09	Linear feature, log	15.80	2.40	0.50	13	833
B	606	696,032.94	8,619,598.74	Linear feature, log	13.00	2.40	0.75	13	818
B	607	696,362.60	8,619,654.65	Debris	7.00	6.50	1.00	12	497
A	609	696,003.49	8,621,145.27	Debris	16.00	7.50	3.00	21	132
B	610	695,614.51	8,621,498.95	Isolated object	3.30	1.50	0.60	18	244
A	611	693,064.64	8,624,298.00	Mooring block	1.70	1.70	0.50	17	599
A	612	693,132.32	8,624,265.69	Debris	3.00	2.50	0.90	18	568
A	620	692,571.44	8,624,809.47	Ant-sub net mooring	1.00	1.00	1.00	12	663
A	621	692,539.74	8,624,860.74	Ant-sub net mooring	1.00	1.00	1.00	15	656
A	622	692,523.80	8,624,892.44	Ant-sub net mooring	1.00	1.00	1.00	15	649
A	623	692,599.70	8,624,754.58	Ant-sub net mooring	1.00	1.00	1.00	11	674
A	624	692,709.75	8,624,594.89	Ant-sub net mooring	1.00	1.00	1.00	15	685
A	625	692,769.99	8,624,467.63	Ant-sub net mooring	1.00	1.00	1.00	10	716
A	626	692,749.61	8,624,525.87	Ant-sub net mooring	1.00	1.00	1.00	10	696
A	627	692,726.33	8,624,548.70	Ant-sub net mooring	1.00	1.00	1.00	11	700
A	628	692,147.90	8,624,971.06	Ant-sub net mooring	1.00	1.00	1.00	12	898
A	629	692,431.95	8,624,717.81	Ant-sub net mooring	1.00	1.00	1.00	7	829
A	630	692,412.02	8,624,771.61	Ant-sub net mooring	1.00	1.00	1.00	7	812
A	631	692,453.33	8,624,625.24	Ant-sub net mooring	1.00	1.00	1.00	9	869
A	632	692,922.97	8,624,532.76	Ant-sub net mooring	1.00	1.00	1.00	16	556
A	633	692,914.46	8,624,593.08	Ant-sub net mooring	1.00	1.00	1.00	16	525

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	634	692,897.79	8,624,648.33	Ant-sub net mooring	1.00	1.00	1.00	18	504
A	635	692,876.05	8,624,702.14	Ant-sub net mooring	1.00	1.00	1.00	15	488
A	636	692,763.55	8,624,903.58	Ant-sub net mooring	1.00	1.00	1.00	11	453
A	637	692,729.14	8,624,950.23	Ant-sub net mooring	1.00	1.00	1.00	11	452
A	638	692,816.54	8,624,826.14	Ant-sub net mooring	1.00	1.00	1.00	17	459
A	639	693,066.90	8,624,638.82	Ant-sub net mooring	1.00	1.00	1.00	20	377
A	640	693,040.27	8,624,691.00	Ant-sub net mooring	1.00	1.00	1.00	18	365
A	641	693,020.88	8,624,746.07	Ant-sub net mooring	1.00	1.00	1.00	19	347
A	642	692,944.62	8,625,014.99	Ant-sub net mooring	1.00	1.00	1.00	22	242
A	643	692,919.53	8,625,081.20	Ant-sub net mooring	1.00	1.00	1.00	15	221
A	644	692,908.66	8,625,150.86	Ant-sub net mooring	1.00	1.00	1.00	15	187
A	645	692,905.94	8,625,190.98	Ant-sub net mooring	1.00	1.00	1.00	16	164
A	646	693,039.04	8,625,225.45	Ant-sub net mooring	1.00	1.00	1.00	19	38
A	647	693,058.79	8,625,182.69	Ant-sub net mooring	1.00	1.00	1.00	18	49
A	648	693,076.54	8,625,127.44	Ant-sub net mooring	1.00	1.00	1.00	19	69
A	649	693,093.03	8,625,071.10	Ant-sub net mooring	1.00	1.00	1.00	18	90
A	650	693,205.80	8,624,728.36	Ant-sub net mooring	1.00	1.00	1.00	17	213
A	651	693,234.87	8,624,680.26	Ant-sub net mooring	1.00	1.00	1.00	18	222
A	652	693,144.21	8,624,841.13	Ant-sub net mooring	1.00	1.00	1.00	18	191
A	653	693,182.07	8,624,784.25	Ant-sub net mooring	1.00	1.00	1.00	19	196
A	654	693,311.23	8,624,817.58	Ant-sub net mooring	1.00	1.00	1.00	27	75
A	655	693,293.93	8,624,874.10	Ant-sub net mooring	1.00	1.00	1.00	26	53

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	656	693,197.83	8,625,161.77	Ant-sub net mooring	1.00	1.00	1.00	26	48
A	657	693,162.23	8,625,272.64	Ant-sub net mooring	1.00	1.00	1.00	21	88
A	658	693,173.46	8,625,217.02	Ant-sub net mooring	1.00	1.00	1.00	21	63
A	659	693,400.45	8,624,893.93	Ant-sub net mooring	1.00	1.00	1.00	24	42
A	660	693,420.92	8,624,841.76	Ant-sub net mooring	1.00	1.00	1.00	22	24
A	661	693,376.72	8,624,944.02	Ant-sub net mooring	1.00	1.00	1.00	24	56
A	662	693,282.43	8,625,202.62	Ant-sub net mooring	1.00	1.00	1.00	28	140
A	663	693,307.79	8,625,145.38	Ant-sub net mooring	1.00	1.00	1.00	25	125
A	664	693,254.26	8,625,282.33	Ant-sub net mooring	1.00	1.00	1.00	27	167
A	665	693,362.50	8,625,014.22	Ant-sub net mooring	1.00	1.00	1.00	26	88
A	666	693,460.95	8,625,089.13	Ant-sub net mooring	1.00	1.00	1.00	26	211
A	667	693,555.33	8,624,959.96	Ant-sub net mooring	1.00	1.00	1.00	25	203
A	668	693,650.62	8,624,848.92	Ant-sub net mooring	1.00	1.00	1.00	27	204
A	669	693,506.97	8,624,814.32	Ant-sub net mooring	1.00	1.00	1.00	21	72
A	670	693,465.48	8,624,923.37	Ant-sub net mooring	1.00	1.00	1.00	25	111
A	671	693,643.69	8,624,929.98	Ant-sub net mooring	1.00	1.00	1.00	26	251
A	672	693,469.78	8,625,242.93	Ant-sub net mooring	1.00	1.00	1.00	28	313
A	673	693,711.60	8,625,070.97	Ant-sub net mooring	1.00	1.00	1.00	32	394
A	674	694,135.50	8,625,135.19	Ant-sub net mooring	1.00	1.00	1.00	36	759
A	675	694,161.68	8,625,283.10	Ant-sub net mooring	1.00	1.00	1.00	36	875
A	676	694,183.69	8,625,228.03	Ant-sub net mooring	1.00	1.00	1.00	36	856
A	677	694,250.36	8,625,094.43	Ant-sub net mooring	1.00	1.00	1.00	34	821

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	678	693,923.28	8,625,184.46	Ant-sub net mooring	1.00	1.00	1.00	34	629
A	679	693,952.90	8,625,141.07	Ant-sub net mooring	1.00	1.00	1.00	28	624
A	680	693,970.93	8,625,083.92	Ant-sub net mooring	1.00	1.00	1.00	28	601
A	681	693,751.64	8,625,475.17	Ant-sub net mooring	1.00	1.00	1.00	35	678
A	682	693,775.01	8,625,422.23	Ant-sub net mooring	1.00	1.00	1.00	35	664
A	683	693,794.64	8,625,355.29	Ant-sub net mooring	1.00	1.00	1.00	35	638
A	684	693,902.95	8,625,554.38	Ant-sub net mooring	1.00	1.00	1.00	36	846
A	685	694,101.63	8,625,224.18	Ant-sub net mooring	1.00	1.00	1.00	35	791
A	686	693,979.35	8,625,516.11	Ant-sub net mooring	1.00	1.00	1.00	34	883
A	687	693,951.72	8,625,500.98	Ant-sub net mooring	1.00	1.00	1.00	33	852
A	688	693,595.12	8,625,397.09	Ant-sub net mooring	1.00	1.00	1.00	36	506
A	689	693,625.83	8,625,262.22	Ant-sub net mooring	1.00	1.00	1.00	34	448
A	690	693,861.92	8,624,914.00	Ant-sub net mooring	1.00	1.00	1.00	33	408
A	691	694,235.64	8,625,020.33	Ant-sub net mooring	1.00	1.00	1.00	35	763
A	692	694,004.85	8,624,910.74	Ant-sub net mooring	1.00	1.00	1.00	34	515
A	693	693,790.27	8,625,076.31	Ant-sub net mooring	1.00	1.00	1.00	33	458
A	694	692,680.70	8,625,066.80	Ant-sub net mooring	1.00	1.00	1.00	16	418
A	695	692,486.05	8,624,972.60	Ant-sub net mooring	1.00	1.00	1.00	16	630
A	696	692,274.19	8,624,850.32	Ant-sub net mooring	1.00	1.00	1.00	7	872
A	697	692,370.93	8,624,932.20	Ant-sub net mooring	1.00	1.00	1.00	10	746
A	698	692,376.54	8,624,652.46	Ant-sub net mooring	1.00	1.00	1.00	6	913
A	699	693,479.77	8,625,162.13	Ant-sub net mooring	1.00	1.00	1.00	26	271

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	700	693,373.52	8,625,219.83	Ant-sub net mooring	1.00	1.00	1.00	25	223
A	701	692,476.81	8,624,552.19	Ant-sub net mooring	1.00	1.00	1.00	9	895
A	702	692,545.01	8,624,451.33	Ant-sub net mooring	1.00	1.00	1.00	13	903
A	703	692,536.68	8,624,530.67	Ant-sub net mooring	1.00	1.00	1.00	14	861
A	704	692,512.14	8,624,583.21	Ant-sub net mooring	1.00	1.00	1.00	10	848
A	705	692,731.65	8,624,460.66	Ant-sub net mooring	1.00	1.00	1.00	10	750
A	706	693,612.40	8,625,501.30	Ant-sub net mooring	1.00	1.00	1.00	37	584
A	707	693,639.40	8,625,450.30	Ant-sub net mooring	1.00	1.00	1.00	37	414
A	708	693,667.30	8,625,396.10	Ant-sub net mooring	1.00	1.00	1.00	36	435
A	709	693,801.20	8,625,027.90	Ant-sub net mooring	1.00	1.00	1.00	33	562
A	710	693,812.30	8,624,981.60	Ant-sub net mooring	1.00	1.00	1.00	32	576

*Targets with starred ID's have been visually inspected during ROV surveys (see Section 7).

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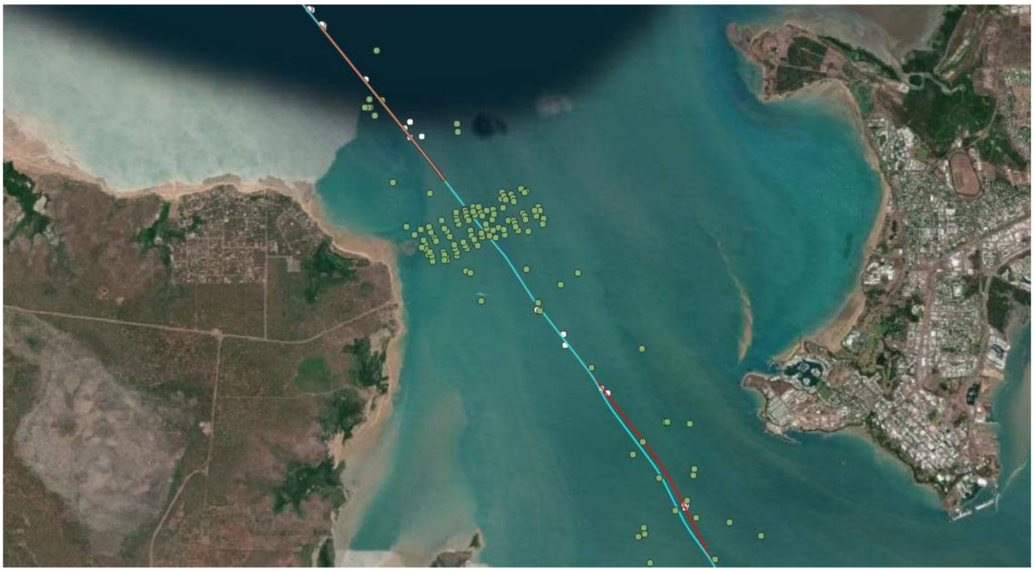
Santos (Barossa)
Gas Export Pipeline

Additional and Nearshore Barossa GEP Stage
(Beagle Gulf and Darwin Harbour)



GEP Realignment Maritime Heritage Assessment – Technical Memo

Darwin Harbour

NT

May 2023

Santos (Barossa) Gas Export Pipeline

Additional and Nearshore Barossa GEP Stage (Beagle Gulf and Darwin Harbour)

GEP Realignment Maritime Heritage Assessment Technical Memo

Prepared for:

Santos Pty Ltd

By:

Connor McBrian

May 2023

Cosmos Archaeology Job Number J21/22e

Cover Image: *Map of new GEP alignment in Darwin Harbour.*

Revision	Description	Date	Originator	Reviewer	Approver
V0	DRAFT Tech Memo	17-04-2023	CM	CC	CC
V1	FINAL Tech Memo	08-05-2023	CM	CC	CC

TABLE OF CONTENTS

1 Introduction 1

1.1 Background..... 1

2 Impact Assessment of New GEP Route 4

2.1 Previously identified impacts 4

2.2 Targets with altered distance to GEP 4

2.3 Adjusted trenching locations 2

3 Updated Recommendations 4

3.1 Previous recommendations..... 4

3.2 Conclusion 5

4 ANNEX A: Updated Target Table 6

1 INTRODUCTION

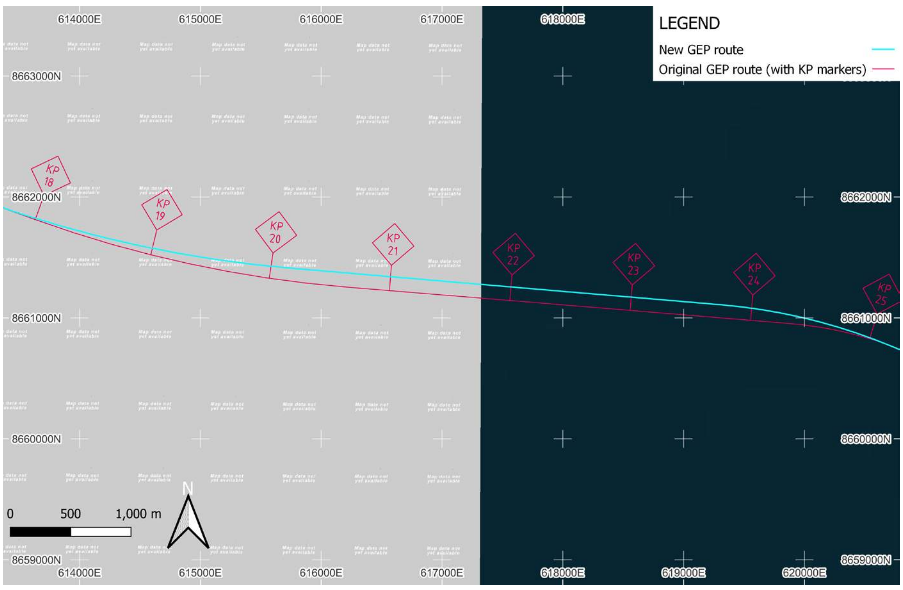
1.1 Background

Santos Pty Ltd is proposing to install a gas export pipeline (GEP) off the northwest coast of the Northern Territory (NT). The proposed GEP begins at the Barossa gas field, north of the Tiwi Islands, and extends south to feed the Darwin LNG plant, located in Middle Arm, Darwin Harbour. Two stages are proposed for the GEP. The first stage is a GEP from the Barossa gas field to a point at the existing Bayu-Undan to Darwin pipeline southwest of Bathurst Island. The second stage is to extend the GEP from this point to the Darwin LNG plant. The maritime cultural heritage of the second stage has been presented in a previous report.[1]

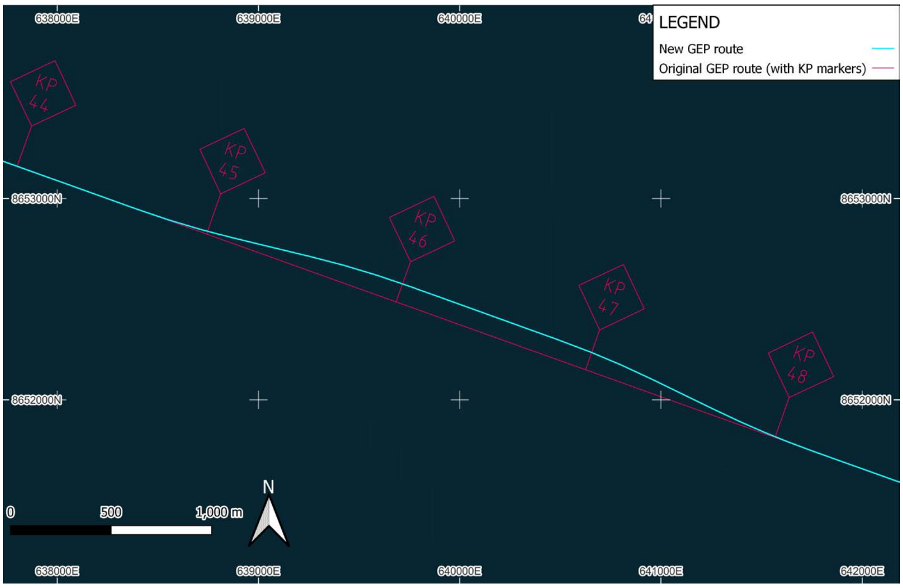
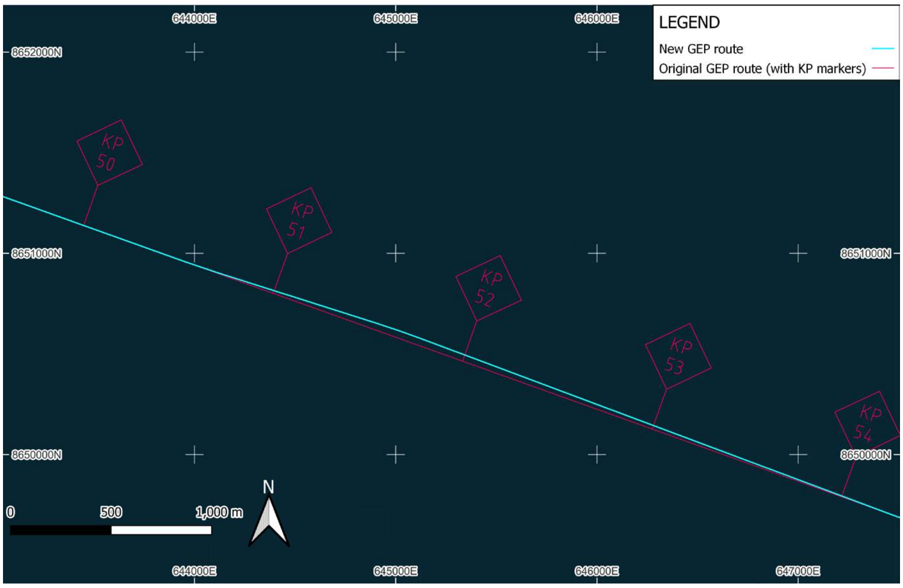
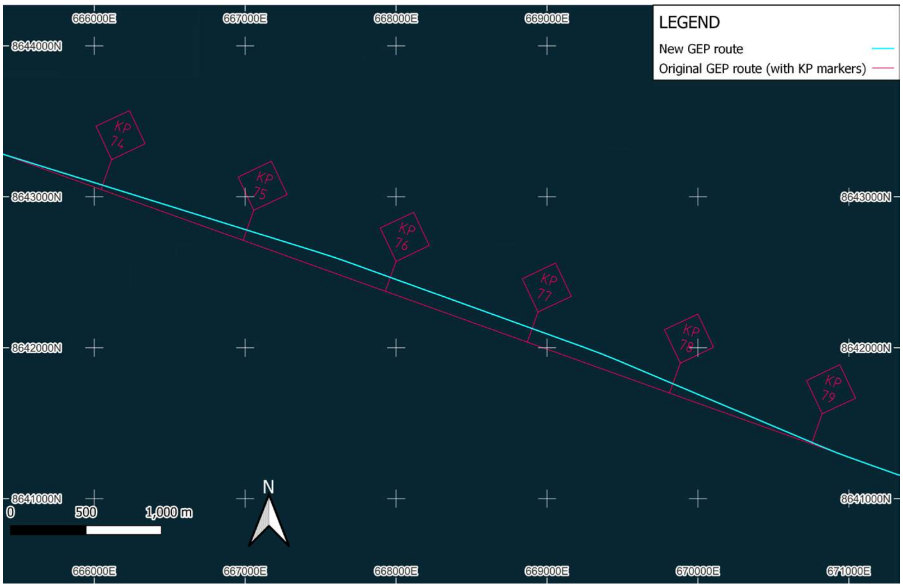
On 20 March 2023, Santos informed CA that minor route changes within the second stage GEP alignments had been required through consultation with the Darwin Harbour Master office. Under the recommendations of the previous report, any new route changes would need to be properly assessed by a qualified maritime archaeologist.[2] No new targets have been identified, as the assessment of the currently available geophysical survey data is considered complete and the GEP realignment remains within the area of the previous geophysical survey corridor.

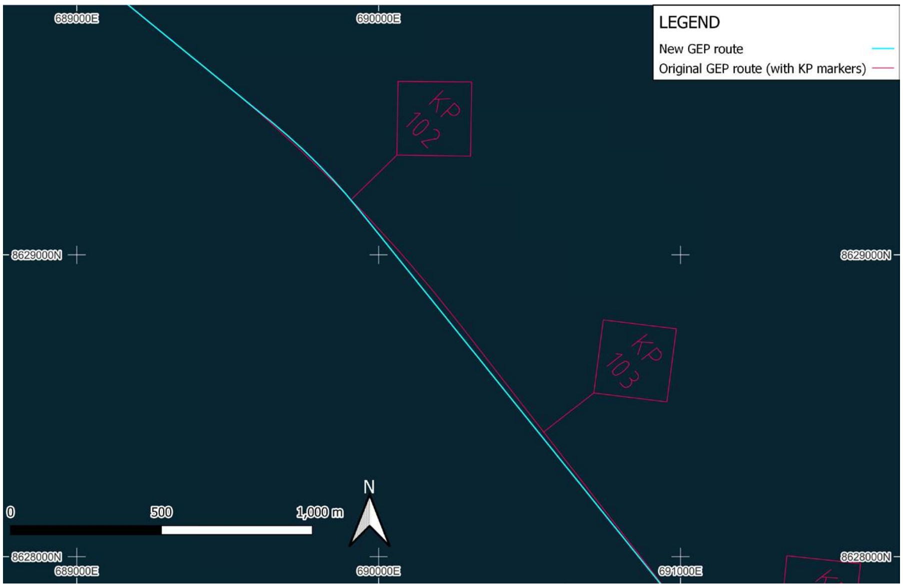
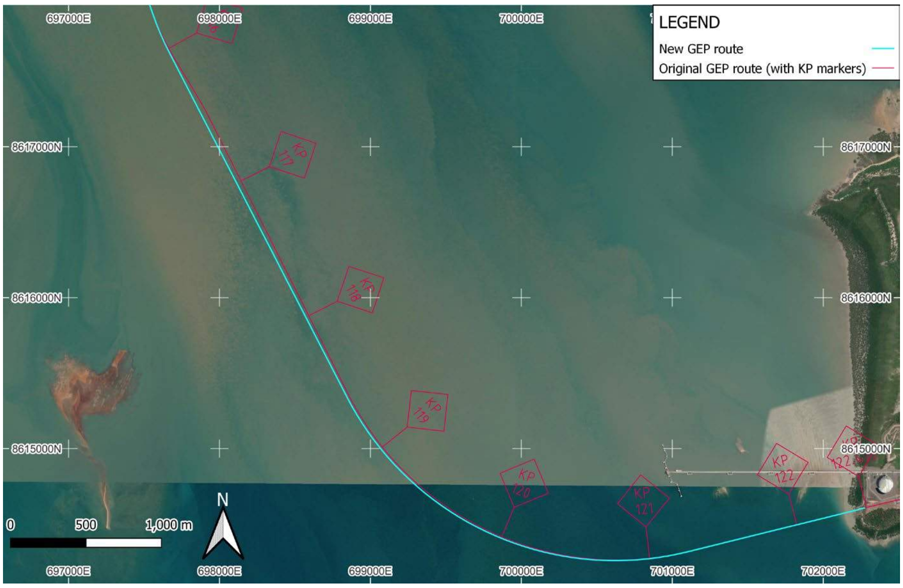
The new route largely follows the original proposed GEP route, with seven small deviations in course, two of which avoid the shipping channel in Darwin Harbour. The realignment shifts the proposed pipeline centreline up to 115 metres in sections in Darwin Harbour, crossing the existing Bayu-Undan pipeline to avoid the shipping channel (Table 1).

Table 1: Location of GEP route deviations and deviation distance.

<table>
<tr><th>KP location of route change</th><th>Approximate maximum deviation from original GEP (m)</th><th>Image of deviation</th></tr>
<tr><td>18-25</td><td>115</td><td>
</td></tr>
</table>

[1] **Cosmos Archaeology, 2022,** Santos (Barossa) Gas Export Pipeline, Additional and Nearshore Barossa GEP Stage (Beagle Gulf and Darwin Harbour), Maritime Heritage Assessment, report prepared for Santos Ltd.
[2] Op. Cit., **Cosmos Archaeology, 2022.**

45-48	100	
51-53	35	
73-79	100	

102-104	25	
110-114	110	
116-121	30	

2 IMPACT ASSESSMENT OF NEW GEP ROUTE

2.1 Previously identified impacts

The previous maritime heritage assessment (CA, December 2022) for the original GEP route noted several items identified through geophysical survey data review and ROV surveys that could be potentially impacted by pipeline installation. Three targets, MA_007, NCL_SC_016 and 174 were determined to be within 35 metres of the proposed original GEP alignment. All three targets were observed during ROV surveys in June 2022 and determined to be cultural in origin. The heritage significance of these objects could not be fully assessed; however, they were provisionally assessed to be of minimal to moderate heritage significance.

The previous report assessed that only target MA_007 and the potential remains of anti-submarine net mooring trot 17 were likely to be impacted by the pipeline installation. While the realignment of the proposed GEP route has not changed its proximity to trot 17 or targets 174 and NCL_SC_016, the new route places target MA_007 outside of the range of likely impact.

2.2 Targets with altered distance to GEP

Analysis of the realigned GEP alignment shows 33 targets and anomalies with altered distances from the proposed GEP (Table 2). Of these 33 targets, 18 are now located further away from the GEP route. Included among these 18 is target MA_007, which is now located 83 metres from the GEP route, previously 6 metres. Of the 15 targets that have a closer distance to the realigned GEP route, 10 of these still have distances beyond 100 metres. Two targets, ID 192 and 609, are located within 50 metres at 47 and 42 metres respectively.

Target ID	Distance to original GEP	Distance to realigned GEP	Target in closer proximity?
MA_031	146	117	yes
192	158	47	yes
501	854	772	yes
502	831	721	yes
503	730	617	yes
504	700	589	yes
576	268	251	yes
595	849	844	yes
603	740	704	yes
604	808	768	yes
605	845	800	yes
606	832	792	yes
607	502	491	yes
609	132	42	yes
610	244	154	yes
MA_001	35	39	no
MA_007	6	83	no
NCL_SC_002	12	40	no
141	141	158	no

Target ID	Distance to original GEP	Distance to realigned GEP	Target in closer proximity?
191	77	188	no
196	59	60	no
233	40	56	no
238	88	195	no
239	98	104	no
577	263	265	no
587	853	876	no
589	453	542	no
590	470	559	no
591	727	818	no
592	344	449	no
593	400	499	no
594	520	572	no
597	443	449	no

Table 2: Targets with altered distances to new GEP alignment.

2.3 Adjusted trenching locations

The location of proposed trenching for pipeline installation has been adjusted with the GEP realignment (Figure 1). Previously trenching had been planned between KP 101-107, 110-114, 119-121, and 121 to terminus. The trench between 101-107 has been shortened to 103-107 and the trench from 110-114 has been eliminated. The remaining trenches have not had their lengths altered. Furthermore, a new trenching location has been added between KP 92-95 outside of Darwin Harbour in Beagle Gulf (Figure 2).

Previously one target, MA_007, had been located within an area of proposed trenching works. The adjustment of the trenching locations avoids the impact of trenching on this target.

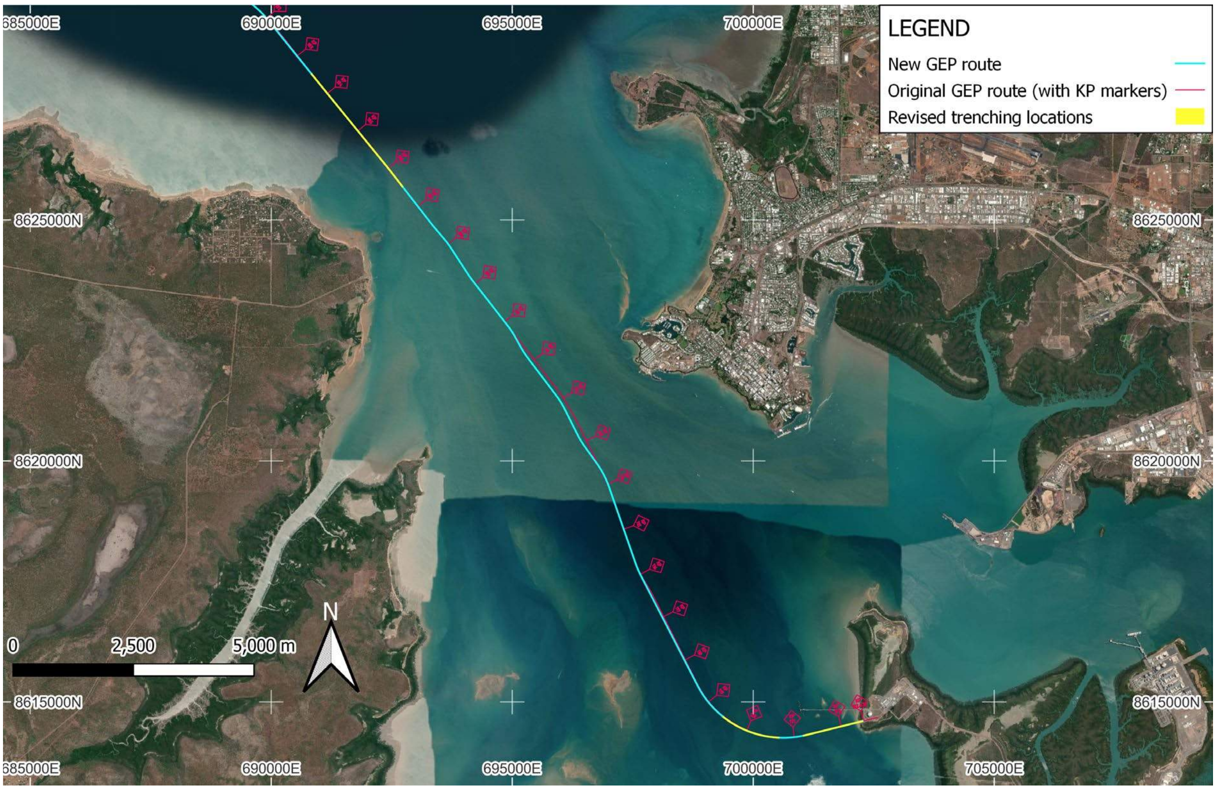


Figure 1: Revised trenching locations in Darwin Harbour.

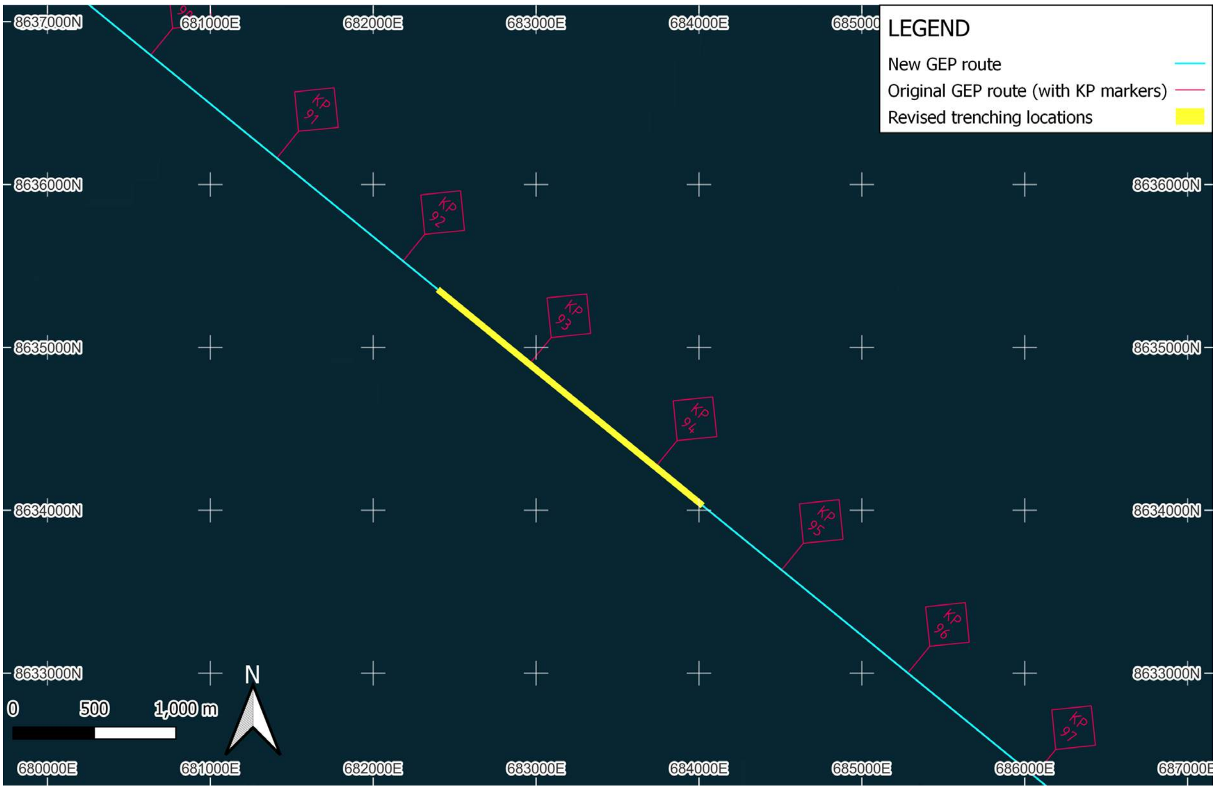


Figure 2: Additional trenching location in Beagle Gulf.

3 UPDATED RECOMMENDATIONS

Realignment of the GEP and proposed trenching locations has altered the potential for identified maritime cultural heritage objects and unverified geophysical anomalies.

3.1 Previous recommendations

Recommendation 1 If feasible, the proposed GEP alignment should be altered to avoid the WWII anti-submarine net mooring Trot 17 as well as cultural heritage objects identified at Target MA_007.

The altered route of the GEP realignment will avoid impacts to Target MA_007. No realignment has been proposed within the area of Trot 17.

Therefore recommendation 1 changed to

Recommendation 1 If feasible, the proposed GEP alignment should be altered to avoid the WWII anti-submarine net mooring Trot 17.

Recommendation 2 If potentially cultural anomalies objects identified in this assessment are likely to be impacted, undertake a detailed heritage impact assessment by a qualified maritime archaeologist.

No further impact assessment recommended for Target MA_007. This recommendation remains for Trot 17.

Recommendation 3 Establish no-anchoring zones around shipwreck locations, the anti-submarine net moorings, and unverified geophysical anomalies within the anchoring corridor.

No change for this recommendation.

Recommendation 4 If additional remote sensing data is collected for the proposed GEP it should be reviewed by a qualified maritime archaeologist.

No change for this recommendation.

Recommendation 5 Prepare and implement an Unexpected Maritime Archaeological Finds Protocol.

No change for this recommendation. Note this protocol has been established in a separate report and been delivered to Santos as part of a heritage induction package for contractors.

Recommendation 6 Review of this assessment if proposed alignment of pipeline changes.

This technical memo satisfies Recommendation 6 in this case, however, further adjustments and changes to the GEP alignment and proposed works should be likewise reviewed by a qualified maritime archaeologist.

3.2 Conclusion

- Realignment of the GEP route has altered the proximity of 33 targets from the pipeline route.
- 18 of these targets are now located further from the proposed alignment, including Target MA_007. No further mitigation beyond the previous recommendations is required for these targets.
- 15 targets are now located closer to the proposed alignment. Two of these targets, ID 192 and 609 are now within 50 metres of the proposed GEP route at 47 and 42 metres distance respectively. This is still considered an acceptable buffer or safety distance to avoid impacts. No further mitigation beyond the previous recommendations is required for these targets.
- The realigned GEP route has not been altered in the location of WWII anti-submarine net mooring trot 17. As this object has been previously assessed as having **High** heritage significance and **Certain** probability of being impacted by proposed works, Trot 17 still requires further mitigation as proposed in CA, December 2022.
- Further alterations to GEP alignment or proposed works should be reviewed by a qualified maritime archaeologist.
- Further remote sensing data collected as part of this development should be reviewed by a qualified maritime archaeologist.
- No-anchoring zones should be established for maritime cultural heritage and unverified geophysical survey anomalies within the proposed anchoring corridor.
- Implementation of the unexpected finds protocol and heritage induction to contractors should be maintained.

4 ANNEX A: UPDATED TARGET TABLE

The table below is a consolidated list of all targets identified as potentially cultural from geophysical survey data review. Additionally, several known shipwrecks within the study area and anchoring corridor are included, as well as targets surveyed during ROV surveys (see main report, Section 7, and Annex A).

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
B	MA_001*	697,628.20	8,617,803.70	Likely buoy mooring and cable	1	1	0.25	20	39
A	MA_007*	695,763.20	8,621,695.50	Metal frame and debris	5	2	0.25	24	83
B	MA_028	693,130.70	8,624,923.90	Buried ferrous object near anti-sub net moorings	N/A	N/A	N/A	21	151
B	MA_031	698,180.90	8,616,372.60	Buried ferrous object	N/A	N/A	N/A	13	117
B	MA_037	701,335.50	8,613,704.20	Buried ferrous object	N/A	N/A	N/A	19	651
B	NCL_SC_002*	698 297.94	8 616 489.78	Debris	1	0.4	N/A	17	40
B	NCL_SC_010	694 982.00	8 622 822.59	Linear debris, likely cable remains.	17	0.5	N/A	20	70
A	NCL_SC_016*	694 168.64	8 623 820.49	Cable, possible telegraph	3.5	1.6	N/A	24	39
B	NCL_SC_031*	691 780.61	8 626 909.95	Single isolated non-ferrous object, likely debris.	1.4	0.7	N/A	16	26
A	112	623 013.42	8 659 220.00	Single object of high relief. Possible debris related to I-124.	8	6	N/A	46	71
B	115	649 361.40	8 649 116.46	Shallow depressions with low relief object.	8	4	N/A	44	89
B	130	665 465.07	8 643 481.67	Possible debris scatter.	18	8	N/A	29	211
B	135	621 286.34	8 660 259.37	Likely natural feature, closest proximity target to I-124	62	58	N/A	48	194
B	136	622 455.26	8 659 969.89	Possible debris scatter or natural feature.	98	32	N/A	49	227

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	138	686 407.37	8 632 159.33	Mound associated with anchor scars	13	16	N/A	17	61
B	141	690 574.96	8 628 606.67	Debris or rocks FUGRO ID: NCL_SC_043, 044, 045, 046	53	20	N/A	30	158
A	149	691 670.76	8 626 677.01	Unknown, may be related to pipeline or another cultural feature.	Total length: 258m Ind. Diameter: 5m	19	N/A	19	206
A	164*	693 038.56	8 625 231.53	Part of anti-submarine net mooring trot 18 FUGRO ID: NCL_SC_026	209	2	N/A	16	35
A	166*	693 399.74	8 624 898.55	Part of anti-submarine net mooring trot 16 FUGRO ID: NCL_SC_017, 018, 019	73	5	N/A	21	45
A	167*	693 085.69	8 625 121.75	Part of anti-submarine net mooring trot 17 Likely connected to Target ID: 164	3	3	N/A	16	65
A	174*	694 194.43	8 623 696.01	Winch or windlass with rope FUGRO ID: NCL_SC_013	5	4	N/A	24	15
A	191	696 438.36	8 620 800.13	Single object of high relief. Possible small boat.	8	3	N/A	19	188
B	192	696 253.89	8 620 643.48	Possible debris	24	22	N/A	14	47
B	196	696 859.94	8 619 902.39	Debris or rocks	9	6	N/A	19	60
A	210	701 140.90	8 613 958.61	Possible aircraft wreck or natural feature.	12	7	N/A	17	358
B	233*	639 844.98	8 652 470.81	Triangular depression, Likely natural feature.	39	8	N/A	41	56

Target ID		Datum: GDA94 CRS: UTM Zone 52S Easting	Northing	Interpretation	Dimensions (m) Length	Width	Height	Depth (m)	Distance from pipeline (m)
A	234	647 746.21	8 649 692.16	Single mound, indicating lone discarded object.	5	4	N/A	43	87
A	238	696 581.70	8 620 537.67	Possible scattered debris.	70	10	N/A	21	195
A	239	697 710.77	8 617 774.90	USAT *Mauna Loa*	124.97	16.46	N/A	19	104
A	240	691 578.22	8 626 925.25	Possible mooring block for anti-submarine defences	4	2	N/A	16	121
A	242	691 589.94	8 626 799.20	Steel wire rope and chain associated with anti-submarine defences. (boom net), UXO including mechanical fuses and fuse cones. (See Section 6.4)	23	13	N/A	17	192
A	243	693 188.00	8 624 746.00	Possible mooring block related to anti-submarine defences.	2	2	N/A	15	216
A	244*	693 196.00	8 625 167.00	Part of anti-submarine net mooring trot 18 FUGRO ID: NCL_SC_022, 023, 024, 025	120	5	N/A	22	50
A	248	693 131.66	8 624 925.53	Debris scatter, or possible anti-submarine net remains	Var.	Var.	N/A	16	149
A	500	697,615.17	8,618,840.23	USAT Meigs	121.00	20.00	3.30	20	369
A	501	695,875.84	8,619,850.01	Medkhanun 3	25.00	8.00	7.00	19	772
A	502	695,698.81	8,620,246.53	Ham Luong	18.00	5.00	3.00	25	721
A	503	695,794.02	8,620,287.72	Song Saigon	40.00	10.00	5.00	24	617
A	504	695,778.93	8,620,381.31	John Holland Barge	38.00	15.00	5.00	25	589
A	505	693,287.42	8,623,844.84	Mandorah Queen	12.00	5.00	2.00	20	683
A	506	691,938.35	8,625,657.51	NR Diemen	29.00	5.00	0.00	8	642
A	573	692,508.78	8,625,489.01	Debris	26.00	15.00	0.50	17	295

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	574	691,574.41	8,626,791.47	WWII anti-sub boom net	41.00	21.00	1.00	21	209
A	575	691,518.71	8,626,801.77	Debris	10.00	6.00	0.75	20	245
B	576	689,856.12	8,628,847.08	Mound	7.00	6.50	0.40	25	251
B	577	689,412.76	8,629,288.62	Isolated object	4.00	4.50	0.50	24	265
B	578	685,439.11	8,632,096.37	Mound associated with trawl scar	8.00	4.50	0.40	17	602
A	579	689,314.84	8,630,473.13	Debris	20.00	9.00	1.30	31	592
B	580	689,842.70	8,630,171.05	Mound	5.00	4.00	1.50	30	692
A	581	691,692.88	8,627,659.36	Possible cable	312.00	2.50	1.40	31	431
A	583	692,918.80	8,626,550.93	Linear debris	11.00	2.00	1.50	39	682
A	584	692,936.90	8,626,417.56	Debris or boulder	7.00	6.00	3.50	39	613
A	588	693,982.49	8,624,331.38	Debris	8.00	4.00	2.50	35	165
A	585	694,508.35	8,624,088.70	Debris	9.00	3.00	0.50	32	472
B	586	694,770.88	8,624,269.65	Possible small boat or natural feature	17.00	4.00	1.25	35	791
A	587	695,753.15	8,623,106.77	Mooring block	3.00	2.50	0.80	33	876
A	589	696,110.51	8,621,995.74	Debris	17.00	7.00	2.50	33	542
A	590	696,133.59	8,621,994.69	Debris	4.50	2.50	2.00	33	559
A	591	696,472.78	8,621,975.02	Debris	6.40	6.20	1.50	32	818
A	592	696,535.45	8,621,187.11	Debris	8.50	2.70	1.30	25	449
A	593	696,548.46	8,621,272.90	Mooring block	1.40	1.40	0.75	25	499
A	594	697,090.00	8,620,464.24	Debris	3.50	3.00	1.75	25	572
A	595	697,563.09	8,620,256.32	Debris	6.50	4.20	1.75	32	844
A	597	698,035.82	8,617,894.98	Debris	3.00	3.00	2.00	20	449
B	598	697,030.36	8,617,864.23	Linear feature	59.00	2.00	0.75	12	504
B	599	697,055.70	8,617,918.12	Linear feature	24.00	2.00	0.75	13	462
B	600	697,036.34	8,618,057.64	Linear feature	33.00	2.00	1.00	16	434
A	601	696,815.85	8,619,144.52	Debris	40.00	8.00	0.50	19	286
A	602	696,751.52	8,619,156.36	Debris	24.00	11.00	0.75	16	343
A	603	696,112.03	8,619,639.40	Debris	8.00	6.60	3.00	14	704
B	604	696,043.52	8,619,624.92	Linear feature, log	18.70	2.40	1.00	13	768

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
B	605	696,000.91	8,619,629.09	Linear feature, log	15.80	2.40	0.50	13	800
B	606	696,032.94	8,619,598.74	Linear feature, log	13.00	2.40	0.75	13	792
B	607	696,362.60	8,619,654.65	Debris	7.00	6.50	1.00	12	491
A	609	696,003.49	8,621,145.27	Debris	16.00	7.50	3.00	21	42
B	610	695,614.51	8,621,498.95	Isolated object	3.30	1.50	0.60	18	154
A	611	693,064.64	8,624,298.00	Mooring block	1.70	1.70	0.50	17	599
A	612	693,132.32	8,624,265.69	Debris	3.00	2.50	0.90	18	568
A	620	692,571.44	8,624,809.47	Ant-sub net mooring	1.00	1.00	1.00	12	663
A	621	692,539.74	8,624,860.74	Ant-sub net mooring	1.00	1.00	1.00	15	656
A	622	692,523.80	8,624,892.44	Ant-sub net mooring	1.00	1.00	1.00	15	649
A	623	692,599.70	8,624,754.58	Ant-sub net mooring	1.00	1.00	1.00	11	674
A	624	692,709.75	8,624,594.89	Ant-sub net mooring	1.00	1.00	1.00	15	685
A	625	692,769.99	8,624,467.63	Ant-sub net mooring	1.00	1.00	1.00	10	716
A	626	692,749.61	8,624,525.87	Ant-sub net mooring	1.00	1.00	1.00	10	696
A	627	692,726.33	8,624,548.70	Ant-sub net mooring	1.00	1.00	1.00	11	700
A	628	692,147.90	8,624,971.06	Ant-sub net mooring	1.00	1.00	1.00	12	898
A	629	692,431.95	8,624,717.81	Ant-sub net mooring	1.00	1.00	1.00	7	829
A	630	692,412.02	8,624,771.61	Ant-sub net mooring	1.00	1.00	1.00	7	812
A	631	692,453.33	8,624,625.24	Ant-sub net mooring	1.00	1.00	1.00	9	869
A	632	692,922.97	8,624,532.76	Ant-sub net mooring	1.00	1.00	1.00	16	556
A	633	692,914.46	8,624,593.08	Ant-sub net mooring	1.00	1.00	1.00	16	525
A	634	692,897.79	8,624,648.33	Ant-sub net mooring	1.00	1.00	1.00	18	504
A	635	692,876.05	8,624,702.14	Ant-sub net mooring	1.00	1.00	1.00	15	488

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	636	692,763.55	8,624,903.58	Ant-sub net mooring	1.00	1.00	1.00	11	453
A	637	692,729.14	8,624,950.23	Ant-sub net mooring	1.00	1.00	1.00	11	452
A	638	692,816.54	8,624,826.14	Ant-sub net mooring	1.00	1.00	1.00	17	459
A	639	693,066.90	8,624,638.82	Ant-sub net mooring	1.00	1.00	1.00	20	377
A	640	693,040.27	8,624,691.00	Ant-sub net mooring	1.00	1.00	1.00	18	365
A	641	693,020.88	8,624,746.07	Ant-sub net mooring	1.00	1.00	1.00	19	347
A	642	692,944.62	8,625,014.99	Ant-sub net mooring	1.00	1.00	1.00	22	242
A	643	692,919.53	8,625,081.20	Ant-sub net mooring	1.00	1.00	1.00	15	221
A	644	692,908.66	8,625,150.86	Ant-sub net mooring	1.00	1.00	1.00	15	187
A	645	692,905.94	8,625,190.98	Ant-sub net mooring	1.00	1.00	1.00	16	164
A	646	693,039.04	8,625,225.45	Ant-sub net mooring	1.00	1.00	1.00	19	38
A	647	693,058.79	8,625,182.69	Ant-sub net mooring	1.00	1.00	1.00	18	49
A	648	693,076.54	8,625,127.44	Ant-sub net mooring	1.00	1.00	1.00	19	69
A	649	693,093.03	8,625,071.10	Ant-sub net mooring	1.00	1.00	1.00	18	90
A	650	693,205.80	8,624,728.36	Ant-sub net mooring	1.00	1.00	1.00	17	213
A	651	693,234.87	8,624,680.26	Ant-sub net mooring	1.00	1.00	1.00	18	222
A	652	693,144.21	8,624,841.13	Ant-sub net mooring	1.00	1.00	1.00	18	191
A	653	693,182.07	8,624,784.25	Ant-sub net mooring	1.00	1.00	1.00	19	196
A	654	693,311.23	8,624,817.58	Ant-sub net mooring	1.00	1.00	1.00	27	75
A	655	693,293.93	8,624,874.10	Ant-sub net mooring	1.00	1.00	1.00	26	53
A	656	693,197.83	8,625,161.77	Ant-sub net mooring	1.00	1.00	1.00	26	48
A	657	693,162.23	8,625,272.64	Ant-sub net mooring	1.00	1.00	1.00	21	88

Target ID		Datum: GDA94 CRS: UTM Zone 52S Easting	Northing	Interpretation	Dimensions (m) Length	Width	Height	Depth (m)	Distance from pipeline (m)
A	658	693,173.46	8,625,217.02	Ant-sub net mooring	1.00	1.00	1.00	21	63
A	659	693,400.45	8,624,893.93	Ant-sub net mooring	1.00	1.00	1.00	24	42
A	660	693,420.92	8,624,841.76	Ant-sub net mooring	1.00	1.00	1.00	22	24
A	661	693,376.72	8,624,944.02	Ant-sub net mooring	1.00	1.00	1.00	24	56
A	662	693,282.43	8,625,202.62	Ant-sub net mooring	1.00	1.00	1.00	28	140
A	663	693,307.79	8,625,145.38	Ant-sub net mooring	1.00	1.00	1.00	25	125
A	664	693,254.26	8,625,282.33	Ant-sub net mooring	1.00	1.00	1.00	27	167
A	665	693,362.50	8,625,014.22	Ant-sub net mooring	1.00	1.00	1.00	26	88
A	666	693,460.95	8,625,089.13	Ant-sub net mooring	1.00	1.00	1.00	26	211
A	667	693,555.33	8,624,959.96	Ant-sub net mooring	1.00	1.00	1.00	25	203
A	668	693,650.62	8,624,848.92	Ant-sub net mooring	1.00	1.00	1.00	27	204
A	669	693,506.97	8,624,814.32	Ant-sub net mooring	1.00	1.00	1.00	21	72
A	670	693,465.48	8,624,923.37	Ant-sub net mooring	1.00	1.00	1.00	25	111
A	671	693,643.69	8,624,929.98	Ant-sub net mooring	1.00	1.00	1.00	26	251
A	672	693,469.78	8,625,242.93	Ant-sub net mooring	1.00	1.00	1.00	28	313
A	673	693,711.60	8,625,070.97	Ant-sub net mooring	1.00	1.00	1.00	32	394
A	674	694,135.50	8,625,135.19	Ant-sub net mooring	1.00	1.00	1.00	36	759
A	675	694,161.68	8,625,283.10	Ant-sub net mooring	1.00	1.00	1.00	36	875
A	676	694,183.69	8,625,228.03	Ant-sub net mooring	1.00	1.00	1.00	36	856
A	677	694,250.36	8,625,094.43	Ant-sub net mooring	1.00	1.00	1.00	34	821
A	678	693,923.28	8,625,184.46	Ant-sub net mooring	1.00	1.00	1.00	34	629
A	679	693,952.90	8,625,141.07	Ant-sub net mooring	1.00	1.00	1.00	28	624

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	680	693,970.93	8,625,083.92	Ant-sub net mooring	1.00	1.00	1.00	28	601
A	681	693,751.64	8,625,475.17	Ant-sub net mooring	1.00	1.00	1.00	35	678
A	682	693,775.01	8,625,422.23	Ant-sub net mooring	1.00	1.00	1.00	35	664
A	683	693,794.64	8,625,355.29	Ant-sub net mooring	1.00	1.00	1.00	35	638
A	684	693,902.95	8,625,554.38	Ant-sub net mooring	1.00	1.00	1.00	36	846
A	685	694,101.63	8,625,224.18	Ant-sub net mooring	1.00	1.00	1.00	35	791
A	686	693,979.35	8,625,516.11	Ant-sub net mooring	1.00	1.00	1.00	34	883
A	687	693,951.72	8,625,500.98	Ant-sub net mooring	1.00	1.00	1.00	33	852
A	688	693,595.12	8,625,397.09	Ant-sub net mooring	1.00	1.00	1.00	36	506
A	689	693,625.83	8,625,262.22	Ant-sub net mooring	1.00	1.00	1.00	34	448
A	690	693,861.92	8,624,914.00	Ant-sub net mooring	1.00	1.00	1.00	33	408
A	691	694,235.64	8,625,020.33	Ant-sub net mooring	1.00	1.00	1.00	35	763
A	692	694,004.85	8,624,910.74	Ant-sub net mooring	1.00	1.00	1.00	34	515
A	693	693,790.27	8,625,076.31	Ant-sub net mooring	1.00	1.00	1.00	33	458
A	694	692,680.70	8,625,066.80	Ant-sub net mooring	1.00	1.00	1.00	16	418
A	695	692,486.05	8,624,972.60	Ant-sub net mooring	1.00	1.00	1.00	16	630
A	696	692,274.19	8,624,850.32	Ant-sub net mooring	1.00	1.00	1.00	7	872
A	697	692,370.93	8,624,932.20	Ant-sub net mooring	1.00	1.00	1.00	10	746
A	698	692,376.54	8,624,652.46	Ant-sub net mooring	1.00	1.00	1.00	6	913
A	699	693,479.77	8,625,162.13	Ant-sub net mooring	1.00	1.00	1.00	26	271
A	700	693,373.52	8,625,219.83	Ant-sub net mooring	1.00	1.00	1.00	25	222
A	701	692,476.81	8,624,552.19	Ant-sub net mooring	1.00	1.00	1.00	9	895

Target ID		Datum: GDA94 CRS: UTM Zone 52S		Interpretation	Dimensions (m)			Depth (m)	Distance from pipeline (m)
		Easting	Northing		Length	Width	Height		
A	702	692,545.01	8,624,451.33	Ant-sub net mooring	1.00	1.00	1.00	13	903
A	703	692,536.68	8,624,530.67	Ant-sub net mooring	1.00	1.00	1.00	14	861
A	704	692,512.14	8,624,583.21	Ant-sub net mooring	1.00	1.00	1.00	10	848
A	705	692,731.65	8,624,460.66	Ant-sub net mooring	1.00	1.00	1.00	10	750
A	706	693,612.40	8,625,501.30	Ant-sub net mooring	1.00	1.00	1.00	37	584
A	707	693,639.40	8,625,450.30	Ant-sub net mooring	1.00	1.00	1.00	37	574
A	708	693,667.30	8,625,396.10	Ant-sub net mooring	1.00	1.00	1.00	36	563
A	709	693,801.20	8,625,027.90	Ant-sub net mooring	1.00	1.00	1.00	33	435
A	710	693,812.30	8,624,981.60	Ant-sub net mooring	1.00	1.00	1.00	32	413

*Targets with starred ID's have been visually inspected during ROV surveys (see Section 7 of nearshore maritime heritage assessment). Target proximities to GEP that have been altered with the realignment are highlighted red (closer to new alignment) and green (further from new alignment).

Santos

Appendix 17: Threatened and Migratory Species Likelihood of Occurrence Assessment

Threatened and Migratory Species – Likelihood of Occurrence Assessment

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Reptiles					
Flatback Turtle	*Natator depressus*	VU/M	VU/M	The Project Area overlaps habitat critical to the survival of Flatback turtles and a Flatback turtle Biological Important Area (BIA) (inter-nesting).	**Likely** - No important habitat (foraging or nesting) for the species occurs within the Project Area. Individuals are likely to be sighted transiting through the area as they move through foraging areas.
Green Turtle	*Chelonia mydas*	Not listed	VU/M	The Green turtle utilises Darwin Harbour regularly (Whiting 2003).	**Likely** - Species is known to occur in the Darwin Harbour and surrounding waters.
Hawksbill Turtle	*Eretmochelys imbricata*	VU	VU/M	The Hawksbill turtle utilises Darwin Harbour regularly (Whiting 2003).	**Likely** - Species is known to occur in the Darwin Harbour and surrounding waters.
Leatherback Turtle	*Dermochelys coriacea*	CE	EN/M	The leatherback turtle is considered to be an oceanic species, which is unlikely to occur within the Darwin Harbour (Whiting 2001). The species is likely to occur in oceanic waters outside the Darwin Harbour.	**Potential** - Species unlikely to occur within the Darwin Harbour, but potentially occurs in surrounding waters.
Loggerhead Turtle	*Careta Caretta*	VU	EN/M	Loggerhead turtles are expected to be infrequent users of the Darwin Harbour (Whiting 2003). The Loggerhead turtle is more likely to occur in oceanic areas outside the Darwin Harbour.	**Potential** - Species may occur within the Darwin Harbour, but potentially occurs in surrounding waters.
Olive Ridley Turtle	*Lepidochelys olivacea*	EN/M	EN/M	Habitat critical to the survival of the Olive Ridley Turtles and a BIA (Inter-nesting) occur outside to the north and south of the Project Area respectively.	**Likely** - No important habitat (foraging or nesting) for the species occurs within the Project Area. Individuals are likely to be sighted transiting through the area as they move through foraging areas.
Plains Death Adder	*Acanthophsis hawkei*	VU	VU	Prefers flat, treeless, cracking soil riverine floodplains. Neither this species nor preferred habitat occurs within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the preferred route alignment for the Project Area, there is no suitable habitat within the Project Area
Mammals					
Bare-rumped Sheath-tailed Bat	*Saccolaimus saccolaimus*	VU	VU	Open Pandanus woodland fringing the and eucalypt tall open forests. It roosts in tree hollows and caves. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - No suitable habitat within the Project Area.
Black-footed Tree-rat	*Mesembriomys gouldii*	EN	EN	Occurs in the Top End of the Northern Territory (NT) in tropical woodlands and open forests in coastal areas. . Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - No suitable habitat within the Project Area.
Brush-tailed Rabbit-rat	*Conilurus penicillatus*	VU	VU	The preferred habitat is eucalypt tall open forest, has been known to also occur on coastal grasslands with scattered large *Casuarina equisetifolia* trees, beaches, and stunted eucalypt woodlands on stony slopes. It shelters in tree hollows, hollow logs and, less frequently, in the crowns of pandanus or sand palms.	**Unlikely** – No suitable habitat is within the Project area.
Fawn Antechinus	*Antechinus bellus*	VU	VU	Occurs in savannah woodland and tall open forest of the Top End of the NT, shelters in tree hollows and fallen logs, shows a preference for areas exposed to cooler and less frequent fires. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - No suitable habitat within the Project Area.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Ghost Bat	*Macroderma gigas*	VU	VU	The distribution of this species is influenced by the availability of suitable caves and mines for roost sites. Daytime roosts may change seasonally. One of the largest known colonies occurs in a series of gold mine workings at Pine Creek in the NT.	**Unlikely** - no suitable habitat within the Project Area.
Golden Bandicoot	*Isoodon auratus*	EN	VU	The Golden Bandicoot has historically occupied a range of habitats across the Northern Territory, although the species favours heathland and shrubland habitats without greater tree cover. The species has declined significantly since European habitation, with the only population being on Marchinbar Island. A relocation program has also established populations on Raragala and Guluwuru islands.	**Unlikely –** As the species has disappeared from mainland distribution in the Northern territory, it is unlikely to be affected by the project.
Nabarlek (Top End)	*Petrogale concinna*	EN	EN	Nabarleks are restricted to rocky areas, especially on steep slopes, with large boulders, caves and crevices. They may move from these to forage in adjacent flat areas. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - No suitable habitat within the Project Area.
Northern Brush-tailed Possum	*Trichosurus vulpecula arnhemensis*	Not listed	VU	Most records are from tall open forests dominated by *Eucalyptus miniata and E. tetrodonta.* The species is unlikely to be present in light of recent reductions in the species range. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** –No suitable habitat within the Project Area.
Northern Brush-tailed Phascogale	*Phascogale pirata*	EN	VU	The Northern Brush-tailed Phascogale is restricted to eucalypt forests in the top end of the NT. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species occurs in eucalypt forests which are not present in proximity to the Project Area
Northern Quoll	*Dasyurus hallucatus*	EN	EN	This species formerly occurred across much of northern Australia, from south-eastern Queensland to the south-west Kimberley, with a disjunct population in the Pilbara. The most suitable habitats appear to be rocky areas. Neither this species nor preferred habitat occurs within the Project Area.	**Unlikely** – whilst the species has historically been recorded within 5 km of the Project Area there is no suitable habitat within the Project Area.
Water Mouse / False Water Rat	*Xeromys myoides*	VU	VU	Mangrove forests, freshwater swamps and floodplain saline grasslands.	**Unlikely** – the species has not been recorded within 5 km of the Project Area and there is no suitable habitat within the Project Area.
Marine Mammals					
Blue Whale	*Balaenoptera musculus*	Not listed	EN/M	The blue whale is found in every ocean except the arctic, with a range that extends from the periphery of drift-ice in polar seas to the tropics. It follows seasonal migration pattern between summering and wintering areas although some individuals may remain in certain areas year-round.. The Project Area does not contain any known feeding, breeding, calving, aggregation or migratory routes. The closest known recorded blue whales was hundreds of kilometres north of the Project Area.	**Unlikely** - The species is unlikely to occur within the Project Area as its preferred habitat is open ocean.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Fin Whale	*Balaenoptera physalus*	Not listed	VU/M	The North Atlantic fin whale has an extensive distribution. In general, fin whales are more common north of approximately 30°N latitude, but considerable confusion arises about their occurrence south of 30°N latitude because of the difficulty in distinguishing fin whales from Bryde's whales. Fin whale is not known to occur even infrequently in the North Marine Region (CoA 2012); however, the species is likely to occur in deeper offshore waters. The Project Area does not contain any known feeding, breeding, calving, aggregation or migratory routes.	**Unlikely** - The species is unlikely to occur within the Project Area as its preferred habitat is open ocean. It is seen to occur further offshore within Commonwealth waters. A 2018 study of whale strikes globally showed there has been no confirmed observations of Fin Whales within the NT waters. Their preference for deep water habitat also puts them outside the vast majority of Australian shipping lanes, including those of the NT. Overall Fin Whales are rarely seen in the Southern Hemisphere, thought to be driven by extensive Japanese exploitation of the species for whaling purposes, combined with a slow recovery rate.
Sei Whale	*Balaenoptera borealis*	Not listed	VU/M	Sei whales have been infrequently recorded in Australian waters. Typically occur within deeper offshore waters. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur within the Project Area as its preferred habitat is open ocean. While Sei Whales are occasionally observed in Northern Territory waters, they are more common further south towards Antarctica. The species is unlikely to habit the Darwin Harbour as it requires deep water habitat. An updated map of the species extent also shows the species potential habitat being outside the project area.
Birds					
Australian Painted Snipe	*Rostratula australis*	VU	EN	Shallow, vegetated, freshwater swamps, claypans or inundated grassland. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – No suitable habitat within the Project Area
Curlew Sandpiper	*Calidris ferruginea*	CE	CE/M	Fresh and brackish water can include ephemeral and permanent lakes, dams, waterholes and bore drains, usually with bare edges of mud or sand. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area
Eastern Curlew	*Numenius madagascariensis*	CE	CE/M	They are most common in mangrove areas but will also forage on intertidal flats and saltmarshes. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area
Gouldian Finch	*Erythrura gouldiae*	EN	EN	The species forages in open woodland with groundcover of *Sorghum* and other annual and perennial grasses. Nests in hollows in *Eucalyptus tintinnans.* Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area
Great Knot	*Calidris tenuirostris*	CR	CE/M	Migratory species. In the NT birds settle on large sheltered intertidal mudflats and sandflats, especially in mangrove areas. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area
Greater Sand Plover	*Charadrius leschenaultii*	VU	VU/M	In the NT, Greater Sand Plovers have been recorded from most of the coastline. In the NT they forage along sandy beaches and sheltered mudflats and have been reported them occasionally also using inland saline wetlands but always close to the coast. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Grey Falcon	*Falco hypoleucos*	VU	VU	Occurs in lightly timbered lowland plains, typically on inland drainage systems, where the average annual rainfall is less than 500 mm. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Has not been recorded within 5 km of the project area and suitable habitat does not occur within the Project Area.
Lesser Sand Plover	*Charadrius mongolus*	EN	EN/M	Migratory species. In the NT the birds forage on sheltered mudflats, sandy beaches, estuaries and mangroves. They have also been reported to use inland saline wetlands occasionally but always close to the coast. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area
Masked Owl (mainland Top End)	*Tyto novaehollandiae kimberli*	VU	VU	Occurs mainly in eucalypt tall open forests (especially those dominated by Darwin woollybutt *Eucalyptus miniata* and Darwin stringybark E. *tetrodonta*), but also roosts in monsoon rainforests, and forages in more open vegetation types, including grasslands. Although it may roost in dense foliage, it more typically roosts, and nests, in tree hollows. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - no suitable habitat within the Project Area
Nunivak Bar-tailed Godwit, Western Alaskan Bar-tailed Godwit	*Limosa lapponica baueri*	VU	VU	Widespread in coastal areas such as wetlands, however predominantly found in New Zealand during breeding season. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - no suitable habitat within the Project Area
Partridge Pigeon	*Geophaps smithii*	VU	VU	Occurs in open forest and woodland dominated by *Eucalyptus tetrodonta* and *E. miniata* with a structurally diverse understorey. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - no suitable habitat within the Project Area
Red Gosshawk	*Erythrotriorchis radiatus*	VU	VU	Forest and woodland with a mosaic of vegetation types, including eucalypt woodland, open forest, gallery rainforest, swamp sclerophyll forest and rainforest margins. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - no suitable habitat within the Project Area
Red Knot	*Calidris canutus*	EN	EN/M	Migratory species. In the NT birds settle on large sheltered intertidal mudflats and sandflats and are rarely encountered far from the coast. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – Whilst the species has been recorded within 5 km of the Project Area, there is no suitable habitat within the Project Area
Sharks					
Dwarf Sawfish	*Pristis clavata*	VU	VU/M	The species' Australian distribution is considered to extend north from Cairns around the Cape York Peninsula in QLD, across northern Australian waters to the Pilbara coast in Western Australia. The species usually inhabits shallow (2–3 m) coastal waters and estuarine habitats. The species does not utilise any purely freshwater areas, as its range is restricted to brackish and salt water. Dwarf sawfish are considered unlikely to occur in the Darwin Harbour area although an individual has been reported from Buffalo Creek (ALA 2022a) approximately 10 km east of the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area based on previous records

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Freshwater Sawfish	*Pristis pristis*	VU	VU/M	The Freshwater Sawfish is a marine/estuarine species that spends its first 3-4 years in freshwater then the larger mature animals tend to occur more often in coastal and offshore waters up to 25 m depth. In the NT, Freshwater Sawfish have been recorded from the Adelaide, Victoria, Daly, East Alligator, South Alligator, Goomadeer, Roper, McArthur, Wearyan and Robinson Rivers (CoA 2015). The Project Area does not contain key habitat resources for this species for foraging or breeding. The closest known record is over 20 km away from the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area based on previous records.
Great White Shark	*Carcharodon carcharias*	Not Listed	VU/M	In Australia, Great White Sharks have been recorded from central QLD around the south coast to north-west WA but may occur further north on both coasts. It has been sighted in all coastal areas except in the NT.	**Unlikely** - The species is unlikely to occur within the Project Area as its preferred habitat is open ocean and is not typically off the Northern Territory coast.
Green Sawfish	*Pristis zijsron*	VU	VU/M	The Green Sawfish was once widely distributed but it is now thought that northern Australia may be the last region where significant populations of Green Sawfish exist. They inhabit muddy bottom habitats and also enter estuaries where they can be found in shallow water. Individuals of this species have been recorded in the region e.g. reported from Buffalo Creek (ALA 2022b) approximately 10 km east of the Project Area. The Project Area does not contain key habitat resources for this species such as foraging or breeding.	**Unlikely** - The species is unlikely to occur in the Project Area based on previous records.
Northern River Shark	*Glyphis garricki*	EN	EN	Since its discovery in 1986, only 36 specimens have been recorded. Little is known of the ecology of the northern river shark but it is probably restricted to shallow, brackish reaches of large rivers. This conclusion is based on the fact that it has not yet been caught in the coastal marine areas despite considerable fishing and collecting activity in these habitats. In the NT this species is only known within the from the Adelaide and East and South Alligator River systems. Individuals of this species of have been recorded in the broader Darwin area, these records are located well away from the Project Area in different habitat then what is found in the Project Area. This species is not known in the Darwin Harbour area.	**Unlikely** - The species is unlikely to occur in the Project Area based on previous records.
Scalloped Hammerhead	*Sphyrna lewini*	Not Listed	Conservation Dependent	The Scalloped Hammerhead has a circum-global distribution in tropical and sub-tropical waters. The scalloped hammerhead shows strong genetic population structuring across ocean basins as it rarely ventures into or across deep ocean waters but ranges quite widely over shallow coastal shelf waters. One individual of this species has been recorded in the Darwin Harbour Region. The Project Area does not contain key habitat resources for this species such as foraging or breeding.	**Unlikely** – The species is unlikely to occur in the Project Area based on previous records and there is no suitable habitat within the Project.
Speartooth Shark	*Glyphis glyphis*	Not Listed	CE	Predominantly occurs within tidal rivers and estuaries within the NT. There are records in the Adelaide River which reflects is likely distribution in tidal rivers and estuaries. No individuals have been recorded in the Darwin Harbour region.	**Unlikely** - The species is unlikely to occur in the Project Area based on previous records.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Whale Shark	*Rhincodon typus*	Not Listed	VU/M	In Australia, the Whale Shark is most commonly seen in waters off northern WA, NT and QLD. The Whale Shark seasonally aggregates in coastal waters off Ningaloo Reef between March and July each year, at Christmas Island between December and January, and in the Coral Sea between November and December. The Whale Shark is an oceanic and coastal, tropical to warm-temperate pelagic shark. The Project Area does not contain any known feeding, breeding, aggregation or migratory routes.	**Unlikely** - The species is unlikely to occur within the Project Area as its preferred habitat is open ocean.
Migratory Marine Birds					
Common Noddy, Brown Noddy	*Anous stolidus*	Not Listed	M	Tropical seabird with worldwide distribution. They breed on tropical and subtropical inshore or oceanic islands, which have rocky cliffs and coral or sand beaches. It nests on the ground, in trees or shrubs, and on cliffs or man-made structures, such as docks and jetties. During the non-breeding season, they will spend most of its time at sea and may roost on water, rocks, islets, flotsam and even the backs of sea turtles. The species may only be seen transiting the area, but is unlikely to land onshore with no suitable foraging habitat present.	**Unlikely** - Species is unlikely to occur given the onshore component of the Project is located within the existing DLNG facility disturbance envelope and suitable habitat is not available for this species
Fork-tailed swift	*Apus pacificus*	Not Listed	M	They spend most of the year relatively high in the air column, only coming down to near ground level at times of bad weather. Seen over open country from semi deserts to coasts, islands and sometimes over forests and cities. Species may be observed as an overhead visitor.	**Unlikely** - Species is aerial and unlikely to be found within the Project Area.
Great Frigatebird, Great Frigatebird	*Fregata minor*	Not Listed	M	It is a widespread seabird, with major colonies in the Indian Ocean, West and Central Pacific and Southern Atlantic. They inhabit remote islands in tropical and sub-tropical seas, where it breeds in small bushes, mangroves and even on the ground. . The species has not been recorded in the Darwin region in the last 30 years.	**Unlikely** - Species unlikely to occur in the Project Area and limited suitable habitat is present in the Project Area.
Lesser Frigatebird, Least Frigatebird	*Fregata ariel*	Not Listed	M	It is a widespread seabird, with major colonies in the Indian Ocean, West and Central Pacific and Southern Atlantic. They inhabit remote islands in tropical and sub-tropical seas, where it breeds in small bushes, mangroves and even on the ground. Outside the breeding season it is sedentary, with immature and non-breeding individuals dispersing throughout tropical seas. . The species has not been recorded in the Darwin region in the last 15 years. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - Species unlikely to occur in the Project Area and limited suitable habitat is present in the Project Area.
Little Tern	*Sternula albifrons*	Not Listed	M	Inhabits coastal waters, bays, inlets, saline or brackish lakes, salt fields and sewage ponds near coast throughout northwest, north, east and southeast Australia. It can also be found further inland, sometimes up to several kilometres from the sea. The species has not been recorded in the Darwin region in the last 15 years. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - Species unlikely to occur in the Project Area and limited suitable habitat is present in the Project Area.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Streaked Shearwater	*Calonectris leucomelas*	Not Listed	M	This species is pelagic and abundant off the north coasts of Australia from November to May. Occurs -on the west and east coasts in summer. Species is abundant off northern Australian coasts. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - Species unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species.
White-tailed Tropicbird	*Phaethon lepturus*	Not listed	M	Tropicbirds are predominantly pelagic species, rarely coming to shore except to breed. The White-tailed Tropicbird forages in warm waters and over long distances, moving up to 1500 kilometres from breeding sites. The main breeding site is Christmas Island. Species may be observed as an overhead visitor.	**Unlikely –** Species unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species
Migratory Marine Species					
Australian Snubfin Dolphin	*Orcaella brevirostris*	Not Listed	M	They occur in inshore coastal areas and some rivers from eastern India to north-eastern Australia and through southeast Asia to Vietnam. Inhabits coastal, brackish and freshwaters of the tropical and subtropical Indo-Pacific. A substantial population was located in the western Gulf of Carpentaria, and another in Blue Mud Bay. The species lives in brackish waters near coasts, river mouths and in estuaries. The Project area intersects the Australian Snubfin dolphin BIA for breeding. This species has been recorded within the Darwin Harbour.	**Likely** - Suitable habitat for the species is present. Individuals of the species have previously been recorded near Catalina Island, located to the east on the Project Area.
Dugong	*Dugong dugon*	Not Listed	M	Generally occurs in wide shallow protected bays and mangrove channels that support extensive sea grass meadows. Reported to use shallow waters such as tidal sandbanks and estuaries for calving. Australian range from Shark Bay, WA to Moreton Bay, QLD.	**Likely** – Suitable habitat for the species is present. The species is widely known from the Darwin harbour.
Indo-Pacific Humpback Dolphin	*Sousa chinensis*	Not Listed	M	The Indo-Pacific hump-backed dolphin, is found in tropical and temperate coastal waters of the Indian and Pacific Oceans from northern Australia and southern China in the east, through Indonesia, and around the coastal rim of the Indian Ocean to southern Africa. They are known to enter rivers, estuaries, and mangroves, particularly the latter. They prefer shallow waters <20 m in depth with warm temperatures between 15-36°C. The species is mostly recorded within 10 km of the coast and are on average recorded 2.8 km from the coast. The Project area intersects the Indo-Pacific Humpback dolphin BIA for breeding. This species has been recorded within the Darwin Harbour.	**Likely** - Suitable habitat for the species is present. The species is widely known from the Darwin Harbour.
Salt-water Crocodile	*Crocodylus porosus*	Not Listed	M	The Salt-water crocodile is commonly recorded in the Darwin Harbour. Nesting within Darwin Harbour is limited. As its common name implies, the saltwater crocodile has a high tolerance for saltwater, aided by salt-excreting glands on the tongue. It may be found in brackish water around coastal areas and rivers, often amongst mangrove forest, as well as occurring further out to sea, and also occurs in freshwater rivers, lakes, swamps and marshes, up to 200 kilometres inland	**Likely** - There is no important habitat for the species located within the Pproject Area. Individuals of the species have previously been sighted on boat ramps near the Project Area.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Spotted Bottlenose Dolphin	*Tursiops aduncus*	Not Listed	M	The Project area intersects the Spotted Bottlenose dolphin BIA for breeding. This species has been recorded within the Darwin Harbour. In Australia, the species is restricted to inshore areas such as bays and estuaries, nearshore waters, open coast environments, and shallow offshore waters including coastal areas around oceanic islands east and west of Australia including the Red Sea. Its habitat varies depending on the tides and the season but includes estuaries, coral reefs and surface waters at high seas, so it tolerates both saltwater and brackish water.	**Likely** - Suitable habitat for the species is present. The species is widely known from the Darwin Harbour.
Bryde's Whale	*Balaenoptera edeni*	Not Listed	M	The Bryde's whale can be found in tropical and sub-tropical waters throughout the Atlantic, Pacific and Indian Oceans. There appear to be two distinct habitat preferences amongst Bryde's whales, with some populations, usually comprising smaller-bodied individuals, occurring in coastal waters, while other populations can be found in the open ocean, however all Bryde's whales have a preference for warmer water above 16.3 Degrees Celsius. The Project Area does not contain any known feeding, breeding, calving, aggregation or migratory routes.	**Unlikely** - No suitable habitat is present within the Project Area and the species is unlikely to occur in the Project Area.
Giant Manta Ray	*Manta birostris*	Not Listed	M	This species is believed to have a wider distribution than the closely related reef manta ray, and is more migratory in its behaviour. It appears to be a seasonal visitor to coastal and offshore sites, and is commonly seen along productive coastlines with regular upwellings, as well as around oceanic islands, offshore pinnacles and seamounts. The south coast of Bathurst Island but are not expected to be present in large numbers. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - No suitable habitat is present within the Project Area and the species is unlikely to occur in the Project Area.
Humpback Whale	*Megaptera novaeangliae*	Not listed	M	Australia has two distinct Humpback Whale populations which throughout all coastal waters surrounding Australia; east coast and west coast. . Within the North Marine Region there are relatively few humpback whales known to travel north of their calving grounds located in Camden Sound (Jenner et al. 2001). No humpback whales were recorded during the 12 months of noise monitoring undertaken as part of the Barossa marine studies program (JASCO Applied Sciences 2016; McPherson et al. 2015). The Project Area does not contain any known feeding, breeding, calving, aggregation or migratory routes.	**Unlikely** - The species is unlikely to occur within the Project Area as its preferred habitat is open ocean. It is seen to occur further offshore within Commonwealth waters. A 2021 study by AECOM for the NT government confirmed there was no suitable habitat for Humpback Whales within the Darwin Harbour. The species occasionally travel through the harbour as part of migration for feeding and breeding, however the harbour is outside the main migration routes. In 2021, three humpbacks travelled 20 km inland up the alligator river. This had never been recorded before and marine scientists are still investigating the cause. It is suspected the Whales either got lost or were chased by a predator into the river mouth. All three individuals eventually made it back to open waters and there has been no further observations of Humpbacks in the river since.
Killer Whale, Orca	*Orcinus orca*	Not Listed	M	The Orca is found throughout all the world's oceans. The Orca occurs in virtually every marine region, from polar waters to the equator, and has even been known to enter bays, estuaries and rivers, as well as ice floes. However, it is most commonly recorded in coastal, temperate waters and in areas of high productivity. Its preferred habitat is open ocean. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur within the Project Area.
Longfin Mako	*Isurus pacus*	Not Listed	M	Widely scattered records suggest that the Longfin Mako shark has a worldwide distribution in tropical and warm-temperate oceans; the extent of its range is difficult to determine due to confusion with the Shortfin Mako. In the Indian Ocean, it has been reported from the Mozambique Channel. Its preferred habitat is open ocean likely in Commonwealth waters outside of the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely -** The species is unlikely to occur within the Project Area.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Narrow Sawfish	*Anoxypristis cuspidata*	Not Listed	M	The Narrow Sawfish is found mainly in inshore coastal waters, to depths of around 40 m, where it is thought to spend most of its time on or near the bottom. It may also enter estuaries and river deltas, and has been reported to move upstream into rivers in some areas, although its occurrence in freshwater has yet to be verified Its preferred habitat is open ocean likely in Commonwealth waters outside of the Project Area. Neither this species nor preferred habitat occurs within the Project Area.	**Unlikely** - No suitable habitat is present within the Project Area.
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Not Listed	M	The Oceanic Whitetip is found globally in deep, open oceans. Its preferred habitat is open ocean likely in the Commonwealth waters outside of the Project Area. Neither this species nor preferred habitat occurs within the Project Area.	**Unlikely** – The species is unlikely to occur within the Project Area.
Reef Manta Ray	*Manta alfredi*	Not Listed	M	The Reef Manta Ray is found in tropical and sub-tropical waters in the Pacific and Indian Oceans. Within this widespread range its populations appear to be quite patchy. It is more commonly found in shallow inshore waters and typically occurs around coastal reefs, tropical island groups, atolls, bays and productive coastlines.	**Unlikely** - The species is unlikely to occur within the Project Area and no suitable habitat is present within the Project Area.
Shortfin Mako	*Isurus oxyrinchus*	Not Listed	M	The Shortfin Mako inhabits offshore temperate and tropical seas worldwide. The closely related Longfin Mako Shark is found in the Gulf Stream or warmer offshore waters (for example, New Zealand and Maine). Its preferred habitat is open ocean likely in the Commonwealth waters outside of the Project Area. Neither this species not preferred habitat occur within the Project Area.	**Unlikely** – The species is unlikely to occur within the Project Area.
Migratory Terrestrial/Wetland Species					
Asian Dowitcher	*Limnodromus semipalmatus*	Not listed	M	In the NT the Asian Dowitcher is found in Darwin and Arnhem Land. The Asian Dowitcher occurs in sheltered coastal environments, such as embayments, coastal lagoons, estuaries and tidal creeks. They are known to frequent shallow water and exposed mudflats or sandflats.	**Potential** – Some species recorded in proximity to the Project Area. Potential habitat in the Darwin Harbour.
Common Sandpiper	*Actitis hypoleucos*	Not Listed	M	Shallow, pebbly, muddy or sandy edges of rivers and streams, coastal to far inland; dams, lakes, sewage ponds; margins of tidal rivers; waterways in mangroves or saltmarsh; mudflats; rocky or sandy beaches; causeways, riverside lawns, drains and street gutters.	**Potential** - The Project Area does not contain suitable habitat for nesting/roosting however there is suitable habitat for foraging on either side of the Project Area which may result in this species traversing the Project Area.
Grey Plover	*Pluvialis squatarola*	Not listed	M	Grey Plovers occur almost entirely in coastal areas, where they usually inhabit sheltered embayments, estuaries and lagoons with mudflats and sandflats, and occasionally on rocky coasts with wave-cut platforms or reef-flats, or on reefs within muddy lagoons. They also occur around terrestrial wetlands such as near-coastal lakes and swamps, or saltlakes.	**Potential** - The Project Area does not contain suitable habitat for nesting/roosting however there is suitable habitat for foraging on either side of the Project Area which may result in this species traversing the Project Area.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Oriental Plover	*Charadrius veredus*	Not listed	M	Oriental Plovers usually forage among short grass or on hard stony bare ground but also on mudflats or among beachcast seaweed on beaches. Oriental Plovers sometimes roost on soft wet mud or in shallow water of beaches and tidal mudflats. The species does not breed in Australia.	**Potential –** Some species recorded in proximity to the Project Area. Potential habitat in the Darwin Harbour and offshore of Wagait Beach.
Osprey	*Pandion haliaetus*	Not Listed	M	Treated as conspecific with *P. Cristatus*. The Osprey is thinly distributed around the coast of Australia where they forage for fish in fresh, brackish, or saline waters of rivers, lakes, estuaries and inshore coastal waters. Nests are usually located near a suitable area of foraging habitat and are a bulky structure made from piled sticks, often positioned in a tall dead tree or artificial structures such as telecommunication towers or poles. Breeding pairs defend breeding territory against other Ospreys, and active nests are usually more than 1 km apart.	**Potential** - The Project Area and surrounds contain suitable foraging habitat for the species. It is noted that there is an Osprey nest on the DLNG site (atop an artificial pole).
Bar-tailed Godwit	*Limodsa lapponica*	Not Listed	M	The Bar-tailed Godwit has been recorded in the coastal areas of all Australian states. It is widespread in the Torres Strait and along the east and south-east coasts of Queensland, NSW and Victoria, including the offshore islands. Populations have also been recorded in the Top End, from Darwin and Melville Island, east to the Alligator River and Croker Island. The Bar-tailed Godwit is found mainly in coastal habitats such as large intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays. It is found often around beds of seagrass and, sometimes, in nearby saltmarsh. Species has been recorded in the Darwin Harbour. Neither this species nor preferred habitat occur within the Project Area	**Unlikely** - The species is unlikely to occur within the Project Area and the Project Area does not contain suitable habitat for this species.
Barn Swallow	*Hirundo rustica*	Not Listed	M	Species if found sporadically throughout northern Australia during non-breeding season. The barn swallow is found in vegetated areas including farmland, sports grounds, native grasslands and airstrips as well as over open water such as billabongs, lagoons, creeks and sewage treatment plants. The closest known record is over 5 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur within the Project Area and the Project Area does not contain suitable habitat for this species.
Clack-tailed Godwit	*Limosa limosa*	Not Listed	M	The Black-tailed Godwit is found in all states and territories of Australia; however, it prefers coastal regions, and the largest populations are found on the north coast between Darwin and Weipa. In Australia the Black-tailed Godwit has a primarily coastal habitat environment. The species is commonly found in sheltered bays, estuaries and lagoons with large intertidal mudflats or sandflats, or spits and banks of mud, sand or shell-grit; occasionally recorded on rocky coasts or coral islets. Species has been recorded in the Darwin Harbour. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur within the Project Area and the Project Area does not contain suitable habitat for this species.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Broad-billed sandpiper	*Limicola falcinellus*	Not Listed	M	Shallow, pebbly, muddy or sandy edges of rivers and streams, coastal to far inland; dams, lakes, sewage ponds; margins of tidal rivers; waterways in mangroves or saltmarsh; mudflats; rocky or sandy beaches; causeways, riverside lawns, drains and street gutters. The closest known record is over 5 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur within the Project Area and the Project Area does not contain suitable habitat for this species.
Common Greenshank	*Tringa nebularia*	Not Listed	M	Species is common throughout Australia from August till March. Found in mudflats, estuaries, saltmarshes, margins of lakes, wetlands, clay pans, fresh and salines, commercial salt fields, sewage ponds. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Grey-tailed Tattler	*Tringa brevipes*	Not Listed	M	Found in estuaries, tidal mudflats, mangroves, wave-washed rocks and reefs, shallow river margins, coastal or inland. In Australia adults arrive in the north coast from late Aug to early Sep. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Grey Wagtail	*Motacilla cinerea*	Not Listed	M	Found near running water, disused quarries, sandy rocky streams in escarpments and rainforests, sewage ponds, ploughed fields and airfields. Visitor to Australia from November to April. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Little Curlew	*Numenius minutus*	Not Listed	M	The Little Curlew is most often found feeding in short, dry grassland and sedgeland, including dry floodplains and black soil plains, which have scattered, shallow freshwater pools or areas seasonally inundated. Open woodlands with a grassy or burnt understorey, dry saltmarshes, coastal swamps, mudflats or sandflats of estuaries or beaches on sheltered coasts, mown lawns, gardens, recreational areas, ovals, racecourses and verges of roads and airstrips are also used. The closest known record of this species is over 5 km from the Project Area and was recorded 10 years ago. While the Project Area does contain some attributes which are known to be utilised by this species (i.e. mudflats), they typically prefer to forage in short grasses which are not present at the site.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Little Ringed Plover	*Charadrius dubius*	Not Listed	M	This species is associated with open plains; bare rolling country, often far from water; ploughed land; muddy or sandy wastes near inland swamps or tidal mudflats; bare clay pans; margins of coastal marshes; grassy airfields, sports fields, and lawns. They are a regular summer migrant to Australia from Sep-Mar. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Long-toed Stint	*Calirdirs subminuta*	Not Listed	M	The long-toed stint breeds in Siberia during the Northern Hemisphere summer. It is a visitor to New Guinea and Australia and a vagrant to Sweden, South Africa, Melanesia, Hawaii, the northwestern USA and the vicinity of the Bering Sea. In its over-wintering range it visits a variety of wetland habitats including shallow freshwater or brackish areas, lakes, swamps, floodplains, marshes, lagoons, muddy shores and sewage ponds. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Marsh Sandpiper	*Tringa stagnatilis*	Not Listed	M	It is a migratory species, with majority of birds wintering in Africa, and India with fewer migrating to Southeast Asia and Australia. They prefer to winter on freshwater wetlands such as swamps and lakes and are usually seen singly or in small groups. These birds forage by probing in shallow water or on wet mud. They mainly eat insects, and similar small prey. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Oriental, Horsfield's Cuckoo	*Cuculus optatus*	Not Listed	M	Treated as conspecific with *C. saturatus* (Himalayan Cuckoo). Inhabits monsoon forests and rainforest edges; leafy trees in paddocks; river flats, roadsides, mangroves and islands. The closest known record is over 5 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for this species.
Oriental Pratincole	*Glareola maldivarum*	Not Listed	M	Usually inhabits open plains, floodplains or short grassland, often with extensive bare areas. Often occur near terrestrial and artificial wetlands, especially around the margins. This species also occurs along the coast, inhabiting beaches, mudflats and islands, or around coastal lagoons. Does not breed in Australia. The closest known record is over 10 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for this species
Oriental Reedwarbler	*Acrocephalus orientalis*	Not Listed	M	Rare migrant to coastal North and eastern Australia. Found in dense reeds, cumbungi, over and near water. It breeds mainly in reed beds and can also be found in marshes, paddy fields, grassland and scrub where it forages for insects and other invertebrates. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Pacific golden Plover-	*Pluvialis fulva*	Not Listed	M	This species usually inhabits coastal habitats, though it occasionally occurs around inland wetlands. Usually occur on beaches, mudflats and sandflats in sheltered areas including harbours, estuaries and lagoons, and also in evaporation ponds in saltworks. The species is also sometimes recorded on islands, sand and coral cays and exposed reefs and rocks. Breeding occurs in dry areas of tundra away from the coast, usually on slopes of low hills, knolls or foothills vegetated with lichen and moss, or in bare, stony areas. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Pectoral Sandpiper	*Calidris melanotos*	Not Listed	M	Species has patchy distribution around Australia's coastline. Found in shallow fresh waters, often with low grass and other herbage; swamp margins, flooded pastures, sewage ponds; occasionally tidal areas and saltmarshes. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species.
Pin-tailed Snipe	*Gallinago stenura*	Not Listed	M	Pin-tailed Snipe occurs most often in or at the edges of shallow freshwater swamps, ponds and lakes with emergent, sparse to dense cover of grass/sedge or other vegetation. The species is also found in drier, more open wetlands such as clay pans in more arid parts of species' range. It is also commonly seen at sewage ponds; not normally in saline or inter-tidal wetlands. The closest known record is over 10 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species.
Red-necked Stint	*Calidris ruficollis*	Not Listed	M	Species are found in tidal mudflats, saltmarshes; sandy or shelly beaches; saline and freshwater wetlands, coastal and inland; salt fields and sewage ponds. They are often in dense flocks, feeding or roosting. Spends the southern summer months in Australia and is found widely except in the arid inland. The closest known record is over 10 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species.
Red-rumped Swallow	*Cecropis daurica*	Not Listed	M	Migratory bird that spends the winter months in northern Australia. This species is found in open hilly country and mountains, river gorges, valleys, sea cliffs, as well as in cultivated areas and human habitations, including towns. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Ruddy Turnstone	*Arenaria interpres*	Not Listed	M	Winters on Australian coastlines. Tidal reefs and pools, weed covered rocks, pebbly shelly and sandy shores with stranded seaweed, mudflats, occasionally inland on shallow waters, sewage ponds, commercial salt fields, open or ploughed ground. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** – The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Rufous Fantail	*Rufous rufifrons*	Not Listed	M	The rufous fantail inhabits moist and moderately dense habitats. Within these areas, it has astonishingly large variations in habitat requirements. They can be found in eucalyptus forests, mangroves, rainforests and woodlands (usually near a river or swamp). Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Sanderling	*Calidris alba*	Not Listed	M	Broad ocean beaches of firm sand 'where waves ebb and flow', depositing strands and heaps of seaweed; often near river mouths; also inlets, tidal mudflats and coastal lagoons. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Sharp-tailed Sandpiper	*Calidris acuminata*	Not Listed	M	The sharp-tailed sandpiper breeds in northern Siberia but migrates south to winter in Australia and New Zealand. In the non-breeding season they can be found in tidal mudflats, saltmarshes, mangroves; shallow fresh, brackish or saline inland wetlands; floodwaters, irrigated pastures and crops; sewage ponds and salt fields. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Swinhoe's Snipe	*Gallinago megala*	Not Listed	M	Found on northern Australian coastlines. Non-breeding habitats include shallow freshwater wetlands of various kinds including paddy fields and sewage farms, with bare mud or shallow water for feeding, with nearby vegetation cover.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species
Terek Sandpiper	*Xenus cinereus*	Not Listed	M	In Australia, the Terek Sandpiper has been recorded on coastal mudflats, lagoons, creeks and estuaries. Records indicate that the species favours muddy beaches near mangroves but may also be observed on rocky pools and coral reefs and occasionally up to 10 km inland around brackish pools. The closest known record is over 10 km from the Project Area. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Wandering Tattler	*Tringa incana*	Not Listed	M	Non-breeding habitats include shallow freshwater wetlands of various kinds including paddy fields and sewage farms, with bare mud or shallow water for feeding, with nearby vegetation cover. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Whimbrel	*Numenius phaeopus*	Not Listed	M	Estuaries, mangroves, tidal flats, coral cays, exposed reefs, flooded paddocks, sewage ponds, bare grasslands, sports grounds and lawns. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.

Common Name	Scientific Name	TPWC Act	EPBC Act	Description/Habitat	Likelihood of Occurrence
Wood Sandpiper	*Tringa glareola*	Not Listed	M	In Australia, the Terek Sandpiper has been recorded on coastal mudflats, lagoons, creeks and estuaries. Records indicate that the species favours muddy beaches near mangroves but may also be observed on rocky pools and coral reefs and occasionally up to 10 km inland around brackish pools. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat.
Yellow Wagtail	*Motacilla flava*	Not Listed	M	Regular summer migrant to coastal Australia, especially Darwin to Broome, but also north-eastern Queensland from November to April. Found in short grass and bare ground, swamp margins, sewage ponds, saltmarshes, playing fields, airfields, ploughed land and town lands. The closest known record over 10 km from the Project Area. This observation was recorded 30 years ago. Neither this species nor preferred habitat occur within the Project Area.	**Unlikely** - The species is unlikely to occur in the Project Area and the Project Area does not contain suitable habitat for the species.

CE – Critically Endangered
EN – Endangered
VU – Vulnerable
NT – Near Threatened
M - Migratory

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Appendix 18: Offshore Construction Environmental Management Plan (CEMP)

BAS-210 0024

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Darwin Pipeline Duplication (DPD) Project – Offshore Pipeline Construction Environmental Management Plan (CEMP)

PROJECT / FACILITY	Barossa DPD Project
REVIEW INTERVAL (MONTHS)	No review required
SAFETY CRITICAL DOCUMENT	NO

Rev	Owner	Reviewer/s Managerial / Technical / Site	Approver
	Project Environmental Lead	Project HSE Manager	Project Director
E			

Any hard copy of this document, other than those identified above, are uncontrolled. Please refer to the Barossa Document Management System for the latest revision.

Rev	Rev Date	Author / Editor	Amendment
A	31/08/2022	RPS	Issued for Santos review
B	18/10/2022	RPS	Issued for Santos review
C	01/02/2023	RPS	Issued for Santos review
D	09/03/2023	RPS	Issued for Santos review
E	26/04/2023	RPS	Issued for NT EPA review

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Contents

Abbreviations, acronyms, glossary and units of measurements 10

1 Introduction 18

1.1 Project overview 18

1.2 Purpose 20

1.3 Scope 20

1.4 Plan structure 24

1.5 Proponent 25

1.5.1 Details of the proponent 25

1.5.2 Details of nominated liaison person 26

1.5.3 Notification procedure in the event of changed details 26

1.6 Document review, revision and availability 26

2 Detailed activity description 28

2.1 Overview 28

2.2 Offshore Project Area 30

2.3 General detail of construction 33

2.3.1 Pre-lay works 33

2.3.2 Pipeline installation and pre-commissioning 41

2.3.3 Summary of vessel and support activities 47

2.3.4 Resource requirements and access 49

2.3.5 Fuels and chemicals 49

2.3.6 Atmospheric Emissions 49

2.3.7 Discharges 49

2.4 Indicative construction schedule 51

3 Legal and other obligations 52

3.1 Commonwealth Environmental Approval 52

3.2 Northern Territory Environmental Approvals 52

3.3 Aboriginal Areas Protection Authority certificates 53

3.4 Legislative framework 53

3.5 Key Legislation 53

3.5.1 Environment Protection and Biodiversity Conservation Act 1999 (Cth) 53

3.5.2 Environmental Protection Act 2019 (NT) 54

3.5.3 Energy Pipelines Act 1981 54

3.5.4 Petroleum (Submerged Lands) Act 1981 (NT). 54

3.6 Other relevant legislation 55

3.6.1 Commonwealth legislation 55

3.6.2 Northern Territory legislation 56

3.7	International conventions and agreements	58
3.8	Standards, codes and guidelines	59
4	**Environmental management framework**	**61**
4.1	Santos Management System	61
4.2	Santos' environment, health, and safety policy	61
4.3	DPD Project environmental management plans	61
4.4	Supporting Management Processes and Procedures	62
4.4.1	Contractor Health, Safety and Environment requirements	62
4.4.2	Chemical selection and assessment procedure	62
4.4.3	Santos marine vessel vetting process	63
4.4.4	Santos waste management process	63
4.4.5	Biofouling management	64
5	**Existing environment**	**68**
5.1	Coastal processes	68
5.1.1	Physical environment	68
5.1.2	Coastal morphology	69
5.1.3	Oceanography	70
5.2	Marine environmental quality	71
5.2.1	Water quality	71
5.2.2	Sediment quality	72
5.2.3	Underwater noise	73
5.3	Marine ecosystems	73
5.3.1	Benthic habitats	73
5.4	Terrestrial ecosystems	81
5.4.1	Flora	81
5.4.2	Mangroves	81
5.5	Fauna	81
5.6	Community and economy	92
5.6.1	Socio-economic environment	92
5.6.2	Culture and heritage	105
5.7	Windows of sensitivity	109
6	**Impact and risk assessment**	**110**
6.1	Conceptual site model	110
6.2	Impact and risk assessment methods	110
6.2.1	Identification of environmental hazard	110
6.2.2	Standard controls	110
6.2.3	Impact and risk assessment	110
6.3	Residual consequences and risks	115
6.3.1	Planned events	115

6.3.2	Unplanned events	116
6.4	Impact/risk assessment summary	117
6.5	Assessment of potential for cumulative impacts	134
6.5.1	Cumulative assessment methodology	134
6.5.2	Cumulative impacts to marine environmental quality	134
6.5.3	Cumulative impacts to marine ecosystems	134
6.5.4	Cumulative impacts to atmospheric processes	135
6.5.5	Cumulative impacts to coastal processes	135
6.5.6	Cumulative impacts to community and economy	135
6.5.7	Cumulative impacts to culture and heritage	135
7	**Environmental management strategies**	**136**
7.1	NT EPA hierarchy	136
7.2	Environmental performance objectives	137
7.3	Performance criteria	137
7.4	Management actions	137
7.5	Adaptive management mechanism	137
7.6	Planned event - impact management strategies	137
7.6.1	Interaction with other marine users	137
7.6.2	Seabed and benthic habitat disturbance	141
7.6.3	Onshore ground disturbance	148
7.6.4	Noise Emissions	152
7.6.5	Light emissions	160
7.6.6	Routine vessel discharges	163
7.6.7	Pre-commissioning water extraction and discharges	166
7.6.8	Atmospheric emissions	169
7.6.9	Contingency pipeline discharges	172
7.7	Unplanned event - risk management strategies	176
7.7.1	Dropped objects	176
7.7.2	Introduction of invasive marine species	179
7.7.3	Unplanned marine fauna interaction	181
7.7.4	Release of liquid hazardous materials	185
7.7.5	Release of hydrocarbon (offshore vessel bunkering or vessel tank rupture)	188
7.7.6	Release of dry natural gas	193
8	**Implementation strategy**	**197**
8.1	Leadership, accountability and responsibility	197
8.2	Workforce training and competency	201
8.2.1	Inductions	201
8.2.2	Training and competency	202
8.2.3	Workforce involvement and communication	202
8.3	Audits and inspections	202
8.3.1	Environmental Incident Reporting	203

8.3.2 Reportable incident – Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth) 203
8.3.3 Reportable incident – Waste Management and Pollution Control Act 1998 (NT) 204
8.3.4 Wildlife incident reporting 204
8.3.5 Hydrocarbon/ hazardous substance spill reporting 205
8.3.6 Corrective actions 205
8.3.7 Continuous improvement 205
8.4 Emergency preparedness and response 205
8.4.1 Contractor emergency and oil spill response plans 206
8.4.2 Santos incident management and oil spill response arrangements 206
8.5 Reporting and notifications 206
8.6 Document management 211
8.6.1 Information management and document control 211
8.6.2 Management of change 211
8.6.3 Reviews 211

9 Stakeholder consultation 212

10 References 213

Attachment 1 Santos Environment, Health and Safety Policies 219

Attachment 2 Summary of management actions 220

Figures

Figure 1-1: DPD Project Location 19
Figure 1-2: Conceptual model of management plan geographical scopes 24
Figure 2-1: DPD Project Area 31
Figure 2-2: Shore crossing and indicative onshore layout within the Project Area 32
Figure 2-3: Indicative trench locations 34
Figure 2-4: Indicative trench designs for the DPD Project 35
Figure 2-5: Onshore construction site layout 38
Figure 2-6: Location of causeway 39
Figure 2-7: Example of pipelaying vessel (offshore) 42
Figure 2-8: Example of pipelaying vessel (nearshore) 42
Figure 4-1: Generic biofouling risk assessment process (from Department of Agriculture, Fisheries and Forestry, 2009) 67
Figure 5-1: RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021) 76
Figure 5-2: RPS survey habitat mapping against mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021) 77
Figure 5-3: RPS surveys habitat mapping along offshore pipeline route 78
Figure 5-4: Northern Territory Aquatic Reserves and Reef Fish Protection Areas 80
Figure 5-5: Flatback turtle BIA and Habitats Critical to survival 85
Figure 5-6: Olive ridley turtle BIA and Habitats Critical to survival 86
Figure 5-7: Australian snubfin dolphin BIA 87
Figure 5-8: Indo-Pacific humpback dolphin BIA 88

Figure 5-9: Spotted bottlenose dolphin BIA 89
Figure 5-10: Commonwealth managed Northern Prawn Fishery 98
Figure 5-11: Northern Territory managed commercial fisheries 99
Figure 5-12: Commercial shipping traffic 101
Figure 5-13: Defence areas – maritime 104
Figure 5-14: Authority Certificate C2022/098 subject land area in Darwin Harbour 107
Figure 5-15: Shipwreck locations within and adjacent to Darwin Harbour 108

Tables

Table 1-1: DPD Project Activities within the Project Area covered by the CEMPs 22
Table 1-2: Construction Environmental Management Plan Structure 24
Table 1-3: Proponent details for Barossa DPD Project's pipeline licences 26
Table 2-1: Attributes of the Activity 28
Table 2-2: DPD Pipeline start and end locations 30
Table 2-3 Projected and contingency construction discharge volumes for the DPD Project in NT jurisdiction 51
Table 2-4: Preliminary pre-lay, construction, installation, and pre-commissioning schedule for DPD 51
Table 3-1: Other Commonwealth legislation relevant to DPD offshore construction activities 55
Table 3-2: Other Northern Territory legislation relevant to DPD offshore construction 56
Table 3-3: International agreements and conventions relevant to the activity 59
Table 4-1: Biofouling mitigation measures 66
Table 5-1: Average monthly and annual mean, max and min rainfall (mm) from 1941 to 2022 for Darwin International Airport (BOM, 2022) 69
Table 5-2: Protected areas near or overlapping the Project Area 79
Table 5-3: Summary of EPBC Act Listed Threatened (LTS) and Listed Migratory Species (LMS) identified by the Protected Matters Search Tool 82
Table 5-4: EPBC Act listed threatened and migratory marine fauna within the Project Area 83
Table 5-5: Biological Important Areas (BIAs) identified within 5 km of the Project Area 84
Table 5-6: Threats from recovery plans, conservation advice and wildlife conservation plans relevant to the activity 90
Table 5-7: Summary of socio-economic activities that occur within the Project Area 94
Table 5-8: Windows of sensitivity in the vicinity of the Project Area 109
Table 6-1: NT EPA Consequence Descriptors 112
Table 6-2: Summary environmental consequence level descriptions 114
Table 6-3: Likelihood descriptions 114
Table 6-4: Risk assessment matrix 115
Table 6-5: Summary of the residual consequence levels associated with planned impacts 115
Table 6-6: Summary of the residual risk level associated with unplanned risks 117
Table 6-7: Summary of impact and risk assessment outcomes 118
Table 7-1: Environmental management strategy template 136
Table 7-2: Interaction with other marine users (including construction activities and Project infrastructure) EPOs and associated performance criteria 138
Table 7-3: Management actions for interaction with other marine users 139

Santos

Table 7-4: Additional management actions not adopted for interaction with other marine users. 140
Table 7-5: Seabed and benthic habitat disturbance EPOs and associated performance criteria 141
Table 7-6: Management actions for seabed and benthic habitat disturbance 143
Table 7-7: Additional management actions not adopted for seabed and benthic habitat disturbance 146
Table 7-8: Ground disturbance and clearing EPOs and associated performance criteria 149
Table 7-9: Management actions for onshore ground disturbance during offshore DPD construction activities 150
Table 7-10: Noise emissions EPOs and associated performance criteria 152
Table 7-11: Management actions for noise emissions during routine construction including the use of an Xcentric Ripper tool 154
Table 7-12: Additional environmental management actions for contingency rock breaking using hydraulic hammer 156
Table 7-13: Additional (ALARP) management actions not adopted for noise emissions 157
Table 7-14: Light emissions EPOs and associated performance criteria 160
Table 7-15: Management actions for light emissions 161
Table 7-16: Additional management actions not adopted for light emissions 161
Table 7-17: Routine vessel discharges EPOs and associated performance criteria 164
Table 7-18: Management actions for routine vessel discharges 165
Table 7-19: Additional management actions not adopted for routine vessel discharges 165
Table 7-20: Pre-commissioning discharges EPOs and associated performance criteria 166
Table 7-21: Management actions for pre-commissioning water extraction and discharges 168
Table 7-22: Additional management action not adopted for pre-commissioning water extraction and discharges 168
Table 7-23: Atmospheric emissions EPOs and associated performance criteria 169
Table 7-24: Management actions for atmospheric emissions 171
Table 7-25: Contingency construction and pre-commissioning pipeline discharges EPOs and associated performance criteria 173
Table 7-26: Management actions for contingency construction and pre-commissioning pipeline discharge 174
Table 7-27: Additional management actions not adopted for contingency pipeline discharges 175
Table 7-28: Dropped objects (including accidental release of non-hazardous waste) EPOs and associated performance criteria 176
Table 7-29: Management actions for dropped objects 177
Table 7-30: Introduction of invasive marine species EPOs and associated performance criteria 179
Table 7-31: Management actions for introduction of invasive marine species 180
Table 7-32: Additional management actions not adopted for the introduction of invasive marine species 180
Table 7-33: Unplanned marine fauna interactions EPOs and associated performance criteria 181
Table 7-34: Management actions for marine fauna interaction 183
Table 7-35: Additional management actions not adopted for unplanned marine fauna interactions 184
Table 7-36: Release of liquid hazardous materials EPOs and associated performance criteria 186
Table 7-37: Management actions for release of hazardous material 187

Table 7-38: Hydrocarbon release (offshore vessel bunkering or vessel tank rupture) EPOs and associated performance criteria 189

Table 7-39: Management actions for hydrocarbon release (offshore bunkering incident or vessel fuel tank rupture) 190

Table 7-40: Additional management actions not adopted for release of hydrocarbon (offshore bunkering incident or vessel fuel tank rupture) 192

Table 7-41: Release of dry natural gas EPOs and associated performance criteria 194

Table 7-42: Management actions for release of dry natural gas 195

Table 8-1: Chain of command, key leadership roles and responsibilities 198

Table 8-2: Summary of reporting requirements 207

Abbreviations, acronyms, glossary and units of measurements

Abbreviations and acronyms

Abbreviation/acronym	Definition
AAPA	Aboriginal Areas Protection Authority
ABN	Australian business number
ABWM	Australian Ballast Water Management Requirements
AFANT	Amateur Fishers Association of Northern Territory
AFZ	Australian Fishing Zone
AHT	Anchor Handling Tugs
AIMS	Australian Institute of Marine Science
ALARP	As low as reasonably practicable
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid sulphate soils
ASSDMP	Acid Sulphate Soils and Dewatering Management Plan
AUV	Autonomous underwater vehicle
AWR	Darwin air weapons range
AWTI	Above water tie-in
BHD	Backhoe dredge
BIA	Biologically important area
BOM	Bureau of Meteorology
BWMS	Ballast water management system
CAMBA	China-Australia Migratory Bird Agreement
CCS	Carbon capture and storage
CHARM	Chemical hazard assessment and risk management
CEMP	Construction Environment Management Plan
CMID	Common Marine Inspection Document
CMT	Crisis Management Team

Abbreviation/acronym	Definition
COLREGs	Convention on the International Regulations for Preventing Collisions at Sea, 1972
CPRFPA	Charles Point Reef Fish Protection Area
CSD	Cutter suction dredge
CSV	Construction support vessel
DAFF	Department of Agriculture, Fisheries and Forestry
DAWE	Department of Agriculture, Water and the Environment
DCA	Department of Communications and the Arts
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DEPWS	Northern Territory Department of Environment, Parks and Water Security
DEWHA	Commonwealth Department of the Environment, Heritage, Water and the Arts
DGPS	Differential global positioning system
DGV	Default guideline value
DHAC	Darwin Harbour Advisory Committee
DIPL	Northern Territory Department of Infrastructure, Planning and Logistics
DITT	Northern Territory Department of Industry, Tourism and Trade
DLNG	Darwin Liquefied Natural Gas
DLRM	Department of Land Resource Management
DNRETAS	Department of Natural Resources and Environment Tasmania
DP	Dynamic positioning
DPA	Darwin Port Authority
DPD	Darwin Pipeline Duplication
DPIR	Department of Primary Industry and Resources
DPIRD	Department of Primary Industries and Regional Development
DoAWR	Department of Agriculture and Water Resources
ECAP	Environmental Compliance Assurance Plan
ECNT	Environment Centre Northern Territory
EDP	Exceptional Development Permits
EIS	Environmental impact statement

Abbreviation/acronym	Definition
ENVID	Environmental impact identification
EPA	Environmental Protection Authority
EP Act	Environmental Protection Act 2019
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPO	Environmental performance objective
EPS	Environmental performance standard
EMP	Environmental management plan
EMS	Environmental management strategy
ESD	Ecologically sustainable development
FCGT	Flood, clean, gauge and testing
FPSO	Floating production, storage and offloading
FPV	Fall pipe vessel
GEP	Gas export pipeline
GOMO	Guide for Offshore Marine Operations
GHG	Greenhouse gas
HAT	Highest astronomical tide
HFO	Heavy fuel oil
HSE	Health, safety and environment
HSEQ	Health, safety, environment and quality
HSEQ-MS	Health, safety, environment and quality management system
IACS	International Association of Classification Society
IFO	Intermediate fuel oil
ILT	Inline tee
IMCA	International Maritime Contractors Association
IMCRA	Interim Marine and Coastal Regionalisation of Australia
IMDG	International Maritime Dangerous Goods
IMS	Introduced marine species
IMR	Inspection, maintenance and repair activities
ITF	Indonesian Through Flow
JAMBA	Japan-Australia Migratory Bird Agreement
KEF	Key ecological feature

Abbreviation/acronym	Definition
KP	Kilometre point
LAT	Lowest astronomical tide
LBL	Long baseline acoustic positioning system
LoR	Limit of reporting
LMS	Listed migratory species
LNG	Liquified natural gas
LTS	Listed threatened species
MA	Management actions
MARPOL	International Convention for the Prevention of Pollution from Ships
MARS	Maritime Arrival Reporting System
MBES	Multibeam echosounder
MDO	Marine diesel oil
MFO	Marine fauna observer
MGO	Marine gas oil
MMNMP	Marine Megafauna Noise Management Plan
MNES	Matters of National Environmental Significance
MoC	Management of change
MSL	Mean Sea Level
NAGD	National Assessment Guidelines for Dredging
NAXA	North Australian Exercise Area
NEMP	Nearshore Environmental Monitoring Plan
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NLC	Northern Land Council
NMR	North Marine Region
NOEC	No Observable Effect Concentration
NSPMMPI	National System for the Prevention and Management of Marine Pest Incursions
NT	Northern Territory
NT EPA	Northern Territory Environmental Protection Agency
OCIMF	Oil Companies International Marine Forum
OCNS	Offshore Chemical Notification Scheme

Abbreviation/acronym	Definition
ODS	Ozone depleting substances
OHS	Occupational Health and Safety
OPEP	Oil pollution emergency plan
OVID	Offshore Vessel Inspection Database
OVMSA	Offshore Vessel Management and Self-Assessment
PASS	Potential acid sulphate soils
PIG	Pipeline inspection gauge
PLET	Pipeline end termination
PLR	Pig launcher/receiver
PMP	Pipeline Management Plan
PMST	Protected Matters Search Tool
POLREP	Marine Pollution Report
PSV	Platform supply vessel
PTS	Permanent threshold shift
Q1, Q2, Q3 and Q4	Quarter 1, 2, 3 and 4
RFPA	Reef Fish Protection Area
RO	Reverse osmosis
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
ROV	Remote Operated Vehicle
SDS	Safety data sheet
SDV	Side dump vessel
SER	Supplementary Environmental Report
SHB	Split Hopper Barges
SMPEP	Shipboard marine pollution emergency plan
SMS	Santos Management System
SOLAS	Safety of Life at Sea
SOPEP	Shipboard oil pollution emergency plan
SSC	Suspended sediment concentration
SSS	Side-scan sonar
SWPLB	Shallow Water Pipelay Barge
TPWC Act 1976	Territory Parks and Wildlife Conservation Act 1976

Abbreviation/acronym	Definition
TSDMMP	Trenching and Spoil Disposal Management and Monitoring Plan
TSHD	Trailer Suction Hopper Dredge
TSS	Total Suspended Soils
TTS	Temporary threshold shift
USAT	United States Army Transport ship
USBL	Ultra-short baseline system
UXO	Unexploded ordnance
WA	Western Australia
WMPC Act 1998	Waste Management and Pollution Control Act 1998

Glossary

Term	Definition
Biologically important area	Areas spatially defined and mapped by the Commonwealth Department of Environment (DoE) where aggregations of individuals of a species are known to display a biologically important behaviour such as breeding, foraging, resting or migration.
Consequence	Impact of an event or incident e.g. a loss, injury or concern. May be expressed qualitatively or quantitatively.
DLNG team	The DLNG contractors
Environmental Performance Standard	A statement of performance required of a management action.
Environmental Performance Objective	Measurable level of performance required for the management of environmental aspects of an activity to ensure that environmental impacts and risks are of an acceptable level.
Impact	A positive or negative effect the DPD Project would have on the environment (including physical, ecological and socio-economic environments.
Licence	A licence granted under Part III or section 43 of the Energy Pipelines Act 1981 (NT)
Licensees	The registered holder of a licence
Measurement Criteria	A system of measurements that define whether a project is successful.
Non-Indigenous	Refers to heritage artefacts or sites that are not deemed "sacred sites" per the *Northern Territory Aboriginal Sacred Sites Act 1989* or deemed Aboriginal or Macassan archaeological sites or artefacts per the *Heritage Act 2011* (NT).

Term	Definition
Offshore Project Area	Offshore Project Area is the same area as the Project Area, except it extends between the boundary between Commonwealth and NT waters and the onshore termination point.
Onshore Project Area	Onshore Project Area is the same area as the Project Area, except it extends between the onshore termination point and the upstream weld of the beach valve.
Onshore termination point	The point (KP122.484, approximately 2 m above highest astronomical tide) to which the pipeline will be pulled ashore to by the shore pull activity.
Performance Criteria	The standards by which success of management actions is evaluated.
Pipeline	A pipe or system of pipes that has or have a maximum allowable operating pressure greater than 1050 kilopascals or a hoop stress (being a circumferential stress arising from internal pressure) that is, at one or more positions, greater than 20% of the specified minimum yield stress specified in the manufacturing standard with which the pipe complies and that are used or intended to be used for the conveyance of an energy-producing hydro-carbon, and includes: a. all structures for protecting or supporting a pipeline; and b. (b) all loading terminals, works and buildings and all fittings, pumps, tanks, appurtenances, and appliances, c. used in connection with a pipeline, but does not include: d. a pipeline as defined in the *Petroleum (Submerged Lands) Act 1981*; e. a pipeline constructed or to be constructed on land used for residential, business, agricultural, commercial, or industrial purposes, designed for use solely for the residential, business, agricultural, commercial or industrial purposes carried on that land and situated wholly within the boundaries of that land; or f. a pipeline or a pipeline of a class declared under section 4(2) to be a pipeline in respect of which a licence is not required
Pipeline management plan	Pipeline management plan in force, in relation to a pipeline, means: a. a pipeline management plan for the pipeline submitted by or for the pipeline licensee and accepted under these Regulations; or b. if the pipeline management plan is accepted in part – that part of the pipeline management plan that is accepted, as revised from time to time under these Regulations, but does not include a pipeline management plan for which the acceptance has been withdrawn.
Project Area	The Project Area is an area extending 500 m either side of the pipeline, within which the Construction Activity will take place.

Term	Definition
Residual risk	Risk remaining after implementation of mitigation measures.
Risk	A combination of the potential consequence of an event occurring and the likelihood of the consequence occurring.
Sensitive receptor	A receptor that could be subject to adverse impacts from the DPD Project.
Target	Specific and measurable performance requirements to achieve Environmental Performance Objectives.

Units of measurement

Unit	Definition
°	degrees
%	per cent
µS	microSiemens
MA	centimetre
dB	decibels
dB(A)	A-weighted sound pressure level in decibels
kHz	kilohertz
km	kilometre
km2	square kilometre
m	metre
m2	square metre
mg/L	milligrams per litre
nm	nautical mile (1.856 km)
ppt	parts per thousand

1 Introduction

1.1 Project overview

Santos NA Darwin Pipeline Pty Ltd (Santos) is the operator of the existing Bayu-Undan to Darwin Gas Export Pipeline (GEP). The Bayu-Undan to Darwin GEP is a dry natural gas export pipeline transporting gas from the Bayu-Undan field located in Timor-Leste waters to the Darwin Liquefied Natural Gas (DLNG) facility at Wickham Point peninsula near Darwin, Northern Territory (NT), Australia. The Bayu-Undan to Darwin GEP has been operational since 2005. In anticipation of the end of the Bayu-Undan field's commercial production in 2022/2023, the Barossa field is being developed to supply gas to the DLNG facility. The supply of backfill gas to the DLNG facility was originally planned to be achieved through the installation of a 262 kilometre (km) Barossa GEP to a tie-in point on the existing Bayu-Undan to Darwin GEP.

In recognition of potential Carbon Capture and Storage opportunities at the Bayu-Undan field, Santos has approved an alternative solution to transport backfill gas to the DLNG facility through the construction of an additional segment of pipeline to extend the Barossa GEP to the DLNG facility, instead of tying into the Bayu-Undan to Darwin GEP. Construction of this segment of pipeline is referred to as the Darwin Pipeline Duplication (DPD) Project, as it will be installed parallel to the existing Bayu-Undan to Darwin GEP. The effective 'duplication' of the existing Bayu-Undan to Darwin GEP is considered the optimal route to minimise potential environmental and social impacts.

The pipeline will run from a location where the Barossa GEP approaches the existing Bayu-Undan pipeline and continue through Darwin Harbour to the beach valve location at the DLNG facility at Wickham Point (**Figure 1-1**). Santos' DPD Project includes a ~23 km segment in Commonwealth waters and ~100 km segment in NT waters and lands adjacent to the existing Bayu-Undan to Darwin pipeline route. The DPD Project pipeline will be located for the most part 50 – 100 m from the existing Bayu-Undan to Darwin pipeline, to minimise potential environmental and social impacts. The Project Area for the DPD Project includes a 2 km buffer around the pipeline route in NT waters, the onshore construction area at the DLNG facility and an offshore spoil disposal ground, and buffer, for the trench spoil disposal (**Figure 1-1**).

Pre-lay trenching is required to meet a number of objectives, including providing pipeline protection and stability (in combination with rock installation), reducing pipeline spanning and ensuring compliance with shipping channel clear water requirements. Sections of the pipeline route within the harbour, with a combined length of up to ~12.8 km, will be trenched using various equipment with the remainder of the pipeline laid directly on the seabed. Rock sourced from a local quarry will be used to backfill in some areas where anchor protection or additional stabilisation is required.

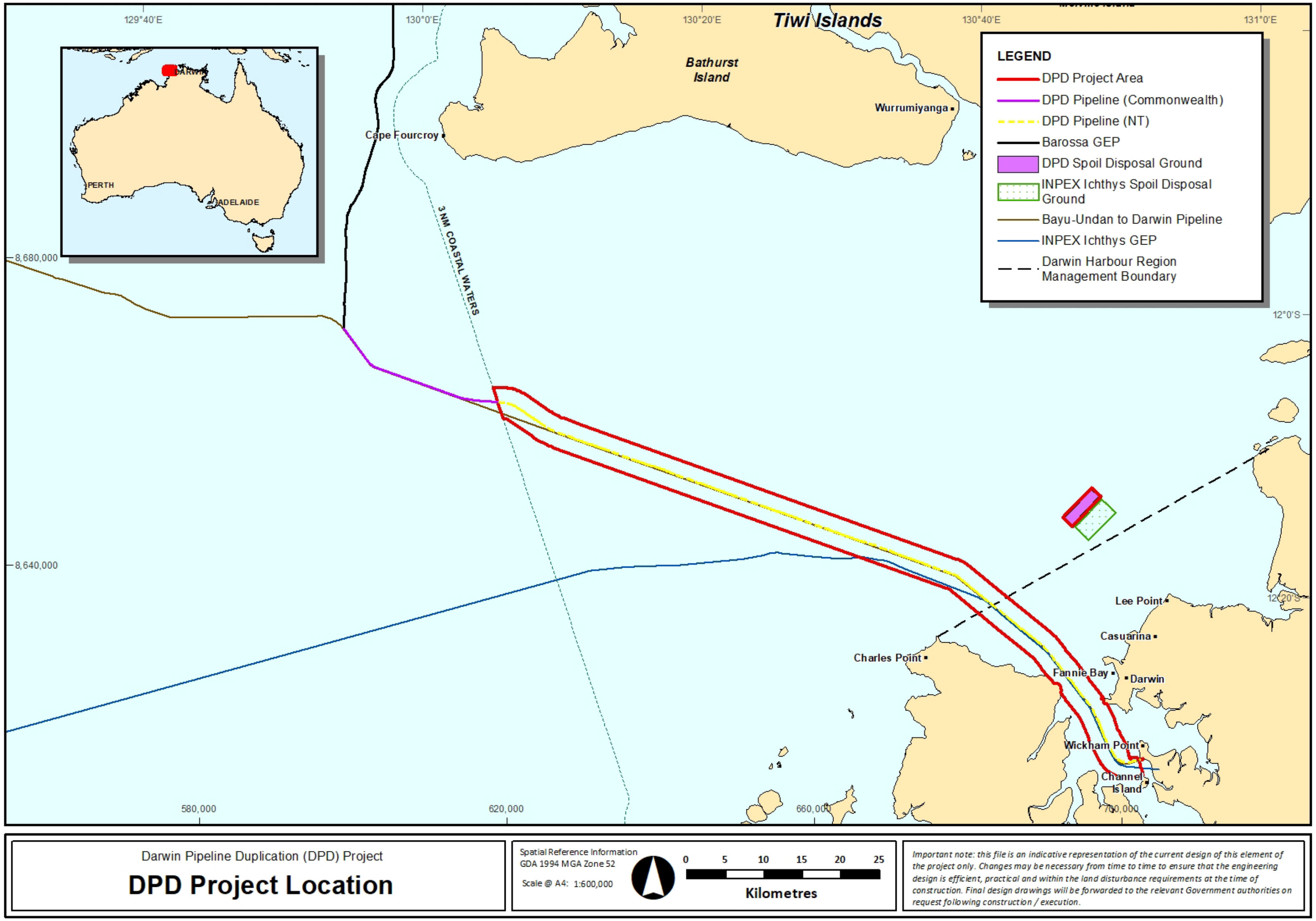

Figure 1-1: DPD Project Location

1.2 Purpose

This CEMP has been prepared to detail and provide guidance on environmental management requirements, to ensure the DPD Project pipeline construction activities in NT jurisdiction and on NT lands are undertaken in an environmentally responsible manner and in line with regulatory requirements.

This CEMP will be submitted with the DPD Project Supplementary Environmental Report (BAS-210 0020) (SER) under the NT *Environment Protection Act 2019* (EP Act) and supporting regulations. This CEMP will be provided to the relevant Minister in support of the Pipeline Management Plan (PMP) required to construct a pipeline under the *Energy Pipelines Act 1981* (NT), *Petroleum (Submerged Lands) Act 1981* (NT) and supporting regulations. This CEMP will also be provided to DCCEEW to support the preliminary documentation submission under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). This CEMP also meets the content requirements for an Environment Plan under the *Petroleum (Submerged Lands) Act 1981* (NT) and supporting regulations, specifically the *(Management of Environment) Regulations 1999*.

The purpose of this CEMP is to meet the relevant requirements of the:

+ *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) as administered by Department of Climate Change, Energy, the Environment and Water (DCCEEW), including relevant management and recovery plans and conservation advice for Matters of National Environmental Significance (MNES) and Commonwealth Marine Reserves Network Management Plans.
+ NT EP Act and Environment Protection Regulations 2020, as administered by the NT EPA (2015).
+ NT Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015)
+ *NT Energy Pipelines Act 1981*, and Energy Pipelines Regulations 2001 as administered by NT Department of Industry, Tourism and Trade (DITT)
+ *NT Petroleum (Submerged Lands) Act 1981* and supporting regulations (NT Petroleum (Submerged Lands) (Application of Commonwealth Laws) Regulations 2004 and Petroleum (Submerged Lands) (Management of Environment) Regulations 1999).

This CEMP details the environmental impacts and risks associated with the activity and demonstrates how these will be managed. The CEMP provides an implementation strategy that will be used to measure and report on environmental performance during planned activities and unplanned events, to ensure impacts and risks are continuously reduced to and maintained at an acceptable level. The environmental management of the activity described in the Offshore CEMP complies with the Santos Environment, Health and Safety Policy (**Attachment 1**) and with all relevant legislation (**Section 3**). All relevant stakeholder consultation performed has been considered in the development of this CEMP (**Section 9**).

1.3 Scope

This CEMP addresses the construction of the section of the DPD pipeline from the shore pull onshore termination point (location described in **Table 2-1**) to the boundary between NT and Commonwealth waters. Spoil disposal activities at the nominated DPD spoil disposal area are also covered under this CEMP. This CEMP is termed the DPD Project Offshore Pipeline CEMP (Offshore CEMP) as it covers primarily activities supporting installation of pipeline in marine waters, with some activities at the shoreline and onshore at the DLNG facility. The construction of the remaining section of pipeline between the onshore termination point and the upstream weld of the beach valve will be subject to the DPD Project Onshore Pipeline CEMP (BAS-210 0025) (Onshore CEMP).

A summary of activities relevant to each CEMP is provided in **Table 1-1**.

This CEMP is an overarching management plan for the Santos Barossa DPD Project team including the DPD Project contractors (Allseas, Deme Van Ord and subcontractors) and covers construction activities from the 3 nm Commonwealth waters boundary to the shore pull onshore termination point. Under this management plan there are three additional management plans that address specific activities during construction (**Figure 1-2**). These are the:

+ Trenching and Spoil Disposal Monitoring and Management Plan (TSDMMP) (BAS-210 0023) that addresses all trenching and spoil disposal activities from the 3 nm Commonwealth waters boundary to the onshore termination point
+ Acid Sulphate Soil and Dewatering Management Plan (ASSDMP) (BAS-210 0049) that addresses all activities associated with acid sulphate soils (ASS) or potential ASS (PASS) from lowest astronomical tide (LAT) to the upstream weld of the beach valve
+ Marine Megafauna Noise Management Plan (MMNMP) (BAS-210 0045) that addresses all activities associated with noise impacts to marine megafauna from the 3 nm Commonwealth/NT waters boundary to the onshore termination point.

Table 1-1: DPD Project Activities within the Project Area covered by the CEMPs

Phases	Activities		
	Offshore CEMP	**Onshore CEMP**	**Outside scope of CEMPs**
Surveys	Offshore Surveying during construction Environmental surveys during construction	Onshore surveying during construction	Low impact pre-construction surveys required to gather information for Project planning and approvals are out of scope for the CEMPs. These surveys include, but are not limited to, environment, heritage, geotechnical, geophysical and unexploded ordinance (UXO) surveys. Any surveys in Commonwealth waters.
Pre-lay works	Installation of offshore pipeline from the onshore termination point to the 3 nm Commonwealth/NT waters boundary Targeted trenching (~12.8 km in total) and spoil disposal from the onshore termination point to the 3 nm Commonwealth/NT waters boundary Spoil disposal at nominated spoil disposal grounds with some in situ placement at the shore-crossing Pre-lay span rectification Cable crossings along the pipeline route Installation of site buildings and generators Construction of the site access road Installation of traffic plates over the existing Bayu-Undan pipeline Preparation of the site pad, including installation of geotextile and site hard stand	Onshore trenching of the onshore pipeline from the upstream weld of the beach valve to the onshore termination point and onshore stockpile of trench material for use as trench backfill. This will involve: Excavation of trench from the upstream weld of the beach valve to site pad Extension of trench to the onshore termination point through the site pad once no longer in use Storage of any identified ASS / PASS on limestone pads and treated with lime prior to reuse or disposal to landfill	Any pre-lay works within Commonwealth waters.

Phases	Activities		
	Offshore CEMP	Onshore CEMP	Outside scope of CEMPs
	areas, installation of holdback anchor, linear winch, trench and shore pull wire.		

Pipeline installation and pre-commissioning	+ Pipelay activities
	+ In-line tee installation
	+ Pipeline shore pull
	+ Rock backfill
	+ Post-lay span rectification
	+ Testing and pre-commissioning the offshore pipeline
	+ Post-lay trenching
	+ Pipelay contingencies
		+ Installation of the onshore pipeline from the upstream weld of the beach valve to the onshore termination point
		+ Testing and pre-commissioning the onshore pipeline
		+ Tie-in onshore pipeline to the offshore pipeline at the onshore termination point
			+ Any installation or pre-commissioning within Commonwealth waters, including:
			  + DPD Project Pipeline end termination (PLET) installation
			  + Spool installation (between DPD Project PLET and Offshore Barossa GEP to PLET)
			+ Installation of the beach valve and the pipeline between the beach valve and the DLNG facility
			+ Installation of the shore crossing CP monitoring system

Demobilisation	+ Removal of the pre-commissioning spread + Removal of the hard stand and geotextile + Re-contouring of the site as applicable + Removal of causeway/s	+ Backfilling onshore pipeline trench + Site returned to pre-construction condition	
Operations	N/A	N/A	+ Operations + Inspection maintenance and repair
Decommissioning	N/A	N/A	+ Decommission pipeline + Removal of subsea infrastructure + Onshore decommissioning and rehabilitation + As-left/ post-surveys

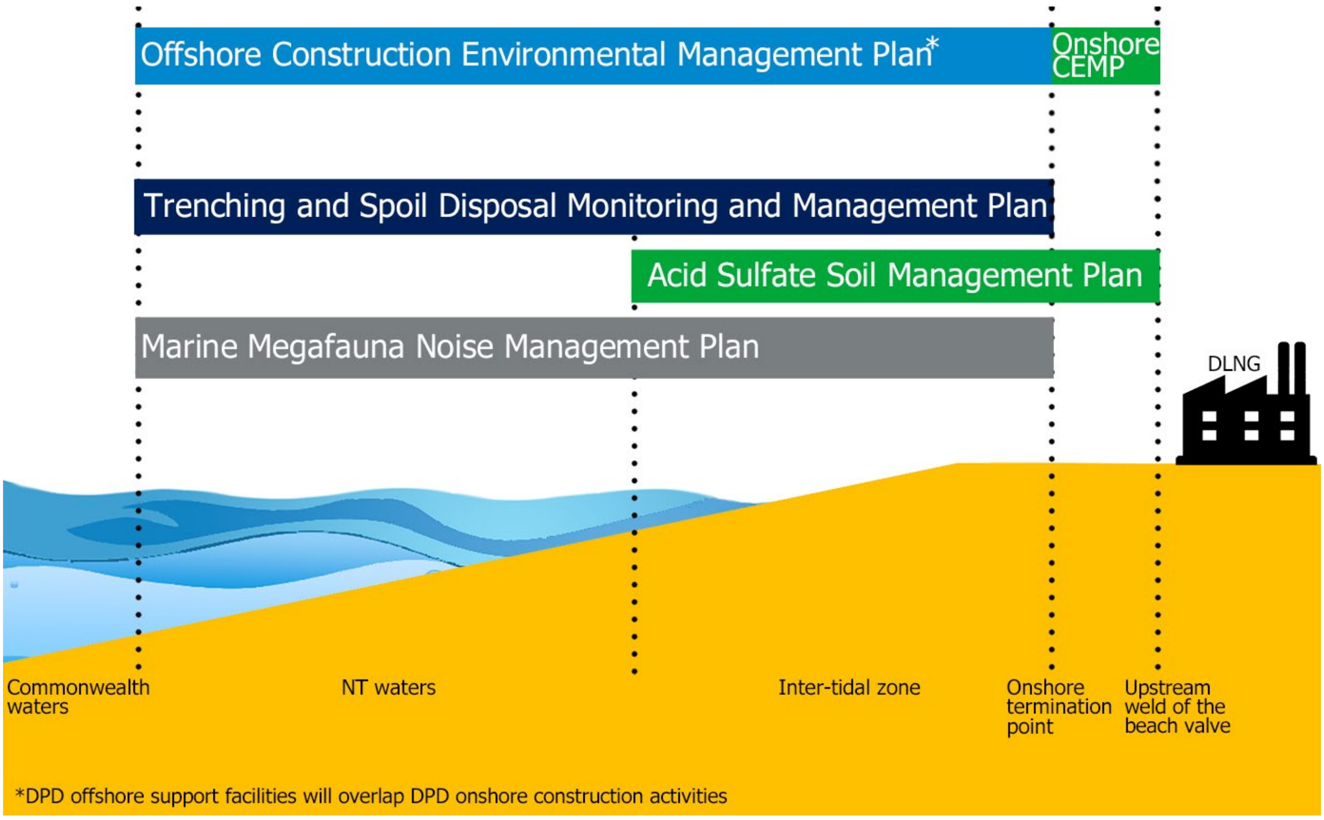

Figure 1-2: Conceptual model of management plan geographical scopes

1.4 Plan structure

This CEMP has been prepared and structured in accordance with the Guideline for the Preparation of an Environmental Management Plan (in draft) (NT EPA, 2015) and the Commonwealth Petroleum (Submerged Lands) (Management of Environment) Regulations (1999). The guideline requirements and where they have been addressed within the CEMP are detailed in **Table 1-2**.

Table 1-2: Construction Environmental Management Plan Structure

Regulatory requirement		Relevant CEMP Section
Petroleum (Submerged Lands) (Management of Environment) Regulations 1999	**NT EPA: Draft Guideline for the Preparation of an Environmental Management Plan 2015**	
-	Project Overview Proponent details Key contacts	**Section 1**: Introduction
Description of the activity	Clear and comprehensive project description	**Section 2**: Detailed Activity Description
-	Legal and other obligations	**Section 3**: Legal and Other Obligation

Regulatory requirement		Relevant CEMP Section
Petroleum (Submerged Lands) (Management of Environment) Regulations 1999	NT EPA: Draft Guideline for the Preparation of an Environmental Management Plan 2015	
-	Environmental management framework	**Section 4**: Environmental Management Framework
Description of the environment	Existing environment	**Section 5**: Existing Environment
Description of environmental effects and risks	Conceptual Site Model Environmental risk assessment	**Section 6**: Risk Assessment The requirement for a Conceptual Site Model is addressed within the risk assessment.
Environmental performance, objectives, and standards	Environmental Management Strategies	**Section 7**: Environmental Management Strategies
Implementation strategy for the environment plan	-	**Section 8**: Implementation Strategy
Reporting etc. arrangements Other information in the environment plan	Corrective actions and contingencies Auditing, Reporting and Review Training and awareness	**Section 8**: Implementation Strategy
-	Communication	**Section 9**: Stakeholder consultation

1.5 Proponent

1.5.1 Details of the proponent

Santos, as the operator of the Barossa Joint Venture, has applied to the DITT for two pipeline licences for the nearshore section of the DPD pipeline:

- Coastal and Territorial Waters Licence for the section of the pipeline under the jurisdiction of the *Petroleum (Submerged Lands) Act 1981* (NT) (i.e. between the NT Coastal Waters Limit and the Territorial Sea Baseline)
- Inland Waters Licence for the section of pipeline under the jurisdiction of the *Energy Pipelines Act 1981* (NT) (i.e. between the Territorial Sea Baseline and the upstream weld of the beach valve).

Both licences are applicable to the section of pipeline within the scope of the Offshore CEMP. The proposed proponent details are provided in **Table 1-3**, with the nominated operator shown in bold.

Table 1-3: Proponent details for Barossa DPD Project's pipeline licences

Title	Proponent (nominated operator in bold)	ABN	Interest	Contact details
Coastal and Territorial Waters Licence Inland waters licence	Santos NA Barossa Pty Ltd	44 109 974 932	25.0%	Business Address: Level 7, 100 St Georges Terrace, Perth, Western Australia, 6000 Telephone number: (08) 6218 7100 Fax number: (08) 6218 7200 Email address: barossa.regulatory@santos.com
	Santos Offshore Pty Ltd	38 005 475 589	25.0%	
	SK E&S Australia Pty Ltd	55 158 702 071	37.5%	Business Address: Level 6, 60 Martin Place, Sydney NSW 2000, Australia Telephone number: (02) 21213304 Fax number: None Email address: hyunjoon-kim@sk.com
	JERA Barossa Pty Ltd	18 654 004 387	12.5%	Business Address: Level 9 Brookfield Place, 125 St Georges Terrace, Perth, Western Australia, 6000

1.5.2 Details of nominated liaison person

Name: Dr Lachlan MacArthur

Title: Environmental Approvals Adviser

Business address: Level 7, 100 St Georges Terrace, Perth, WA 6000

Telephone number: (08) 6218 7100

Email: Barossa.regulatory@santos.com

1.5.3 Notification procedure in the event of changed details

If there is a change in the nominated operator or a change in the contact details for the operator or liaison person, Santos will notify the DITT and provide the updated details.

1.6 Document review, revision and availability

This CEMP has been prepared for submission with the SER (BAS-210 0020) and other supporting documents to the NT EPA, under the EP Act and to DCCEEW under the EPBC Act, and will be updated to reflect any relevant regulatory conditions associated with the DPD Project approvals.

This CEMP will also be provided to the relevant Minister in support of the PMP required to construct a pipeline under the NT *Energy Pipelines Act 1981* (NT) and Energy Pipelines Regulations 2001. A pipeline licensee for a pipeline for which a PMP is in force must submit to the Minister a proposed revision of the PMP in the event of a change, or proposed change, of circumstances or operations under Regulation 33, when requested by the Minister under Regulation 34 or at the end of each five-year period under Regulation 35.

Further, this CEMP will also be provided to the relevant Minister to meet the requirements of an Environmental Plan under the NT *Petroleum (Submerged Lands) Act 1981* and supporting regulations (NT Petroleum (Submerged Lands) (Application of Commonwealth Laws) Regulations 2004 and Petroleum (Submerged Lands) (Management of Environment) Regulations 1999). Under these regulations, a revision is required in the event of a change, or proposed change, of circumstances or operations under Regulation 17, when requested by the Designated Authority under Regulation 18 or at the end of each five-year period under Regulation 19.

Santos will review and update the document as required based on regulatory feedback and any regulatory conditions on the DPD Project approval as applicable. The final CEMP will be made publicly available on an Australian website.

2 Detailed activity description

2.1 Overview

Table 2-1 provides the key attributes of the construction activity covered by this CEMP. A detailed activity description is provided in **Section 2.3.**

Table 2-1: Attributes of the Activity[1]

Attribute	Summary
Activity location	The DPD pipeline will extend from the pipeline end termination at kilometre point 0 in Commonwealth waters to the upstream weld of the beach valve (KP 122.692) onshore at the DLNG facility. The scope of this CEMP is limited to the section of pipeline within NT waters and lands, from ~KP 23 to KP 122.484 (the onshore termination point). The onshore termination point is two metres above highest astronomical tide (HAT). The nominal coordinates of the KPs are provided in **Table 2-2**. The location of the Project Area within which construction activities covered within this plan will occur, is shown in **Figure 2-1** with further detail of the onshore Project Area provided in **Figure 2-2**. Support facilities and activities for the offshore pipeline construction by the offshore pipeline installation contractors will occur in areas overlapping those used by the onshore pipeline installation contractors to manage the installation of the pipeline section from the onshore termination point (KP122.484) to the upstream weld of the beach valve (KP 122.692), which are outside the scope of this CEMP.
Pipeline characteristics	Approximately 100 km of pipeline will be installed under this CEMP from ~KP 23 to the onshore termination point (KP 122.484). The pipeline diameter from the pipeline end termination (KP 0) up to an-inline tee (approximately 60 km offshore) is 26 inches, after which the pipeline increases to 34 inches. Pipeline will be constructed from carbon steel with an external anti-corrosion coating and sacrificial anodes to maintain the pipeline integrity and a concrete coating to provide stability and protection.
Key activities	+ Pre-lay works phase: + Targeted trenching along sections of the pipeline route (~12.8 km in total) from the shore pull onshore termination point to near the outer boundary of the Darwin Harbour Region Management Area (Figure 2-3) + Spoil disposal at nominated spoil disposal ground (Figure 2-3) with some in-situ placement at shore-crossing to reduce ASS Risk + Pre-lay span rectification + Installation of cable crossings along the pipeline route + Pipeline installation and pre-commissioning phase:

[1] The scope of this CEMP is limited to the section of pipeline within NT waters.

Attribute	Summary
	+ Pipelay activities + In-line tee installation + Pipeline shore pull + Trench backfill using rock + Post-lay span rectification + Testing and pre-commissioning the offshore pipeline Tie-in offshore pipeline to the onshore pipeline at the onshore termination point
Vessels	**Trenching**
	+ Backhoe Dredge (BHD) assisted by Split Hopper Barge + Cutter Suction Dredge (CSD)
	Pipelay and Rock Installation
	+ Shallow water pipelay barge (SWPLB) + Deep water pipelay vessel + Pipe supply vessels (PSV) + Construction support vessel/survey (CSV) + Nearshore CSV/survey (Span Rectification) + BHD for rock installation + Fall pipe vessel (FPV) for rock installation
	Support Operations
	+ Multicat (Shallow water anchor handling for SWPLB and CSD) + Anchor handling tugs (AHTs) + Supply boat for all vessels + Crew boat (crew changes) + Survey vessels
Vessel fuel	Vessels will use Group II hydrocarbon fuels such as marine gas oil (MGO) or marine diesel oil (MDO).
Proposed schedule	A probable DPD construction sequence and schedule is discussed in **Section 2.4.** The construction activities will likely span a cumulative period of 15 months in the field.

The locations for activities along the DPD Pipeline are described using ‘kilometre points’ (KP), where KP0 is the beginning of the DPD Project pipeline from the “pipeline end termination point” (PLET C) in Commonwealth waters.

Table 2-2: DPD Pipeline start and end locations

Location	Kilometre point	Easting	Northing
Boundary between Commonwealth and NT waters	~KP23	618,128.53	8,663,104.10
Shore pull onshore termination point	KP122.484	702,272.73	8,614,606.40
Upstream weld of the beach valve	KP122.692	702,472.29	8,614,655.73

*Coordinates in GDA 94, MGA zone 52

2.2 Offshore Project Area

DPD Project construction activities in NT jurisdiction will occur within a Project Area defined in **Figure 2-1**. The Project Area extends 2 km either side of the DPD pipeline route and additionally includes the spoil disposal ground. Activities undertaken within the Project Area that are not associated with the DPD Project are beyond the scope of this CEMP.

The Project Area consists of the three key 'areas', being:

+ Offshore NT waters (i.e., NT waters outside Darwin Harbour Region Management Area). Note this includes the proposed location for spoil disposal;
+ Darwin Harbour (i.e., waters within the Darwin Harbour Management Area); and
+ Shore crossing location including the short onshore section of the pipeline to the upstream weld beach valve. Note activities between the onshore termination point and the upstream weld of the beach valve are not covered under this CEMP (refer to **Section 1.3**) with the exception of DPD offshore support facilities e.g. site offices and laydown area.

The Project Area within the NT waters has not been amended since the Darwin Pipeline Duplication (DPD) Project – NT EPA Referral (BAA-201 0003; Santos, 2021). However, there has been a refinement to the onshore area for the DPD Project to include the temporary access road, part of which previously fell outside of the Project Area. The Project Area is shown in **Figure 2-1** with further detail of the shore crossing at the DLNG facility, including support facilities, shown in **Figure 2-2**.

The locations for activities along the DPD Project pipeline are described using 'kilometre points' (KP), where KP 0 is the beginning of the DPD Project pipeline from the "pipeline end termination point C" (PLET C) in Commonwealth waters.

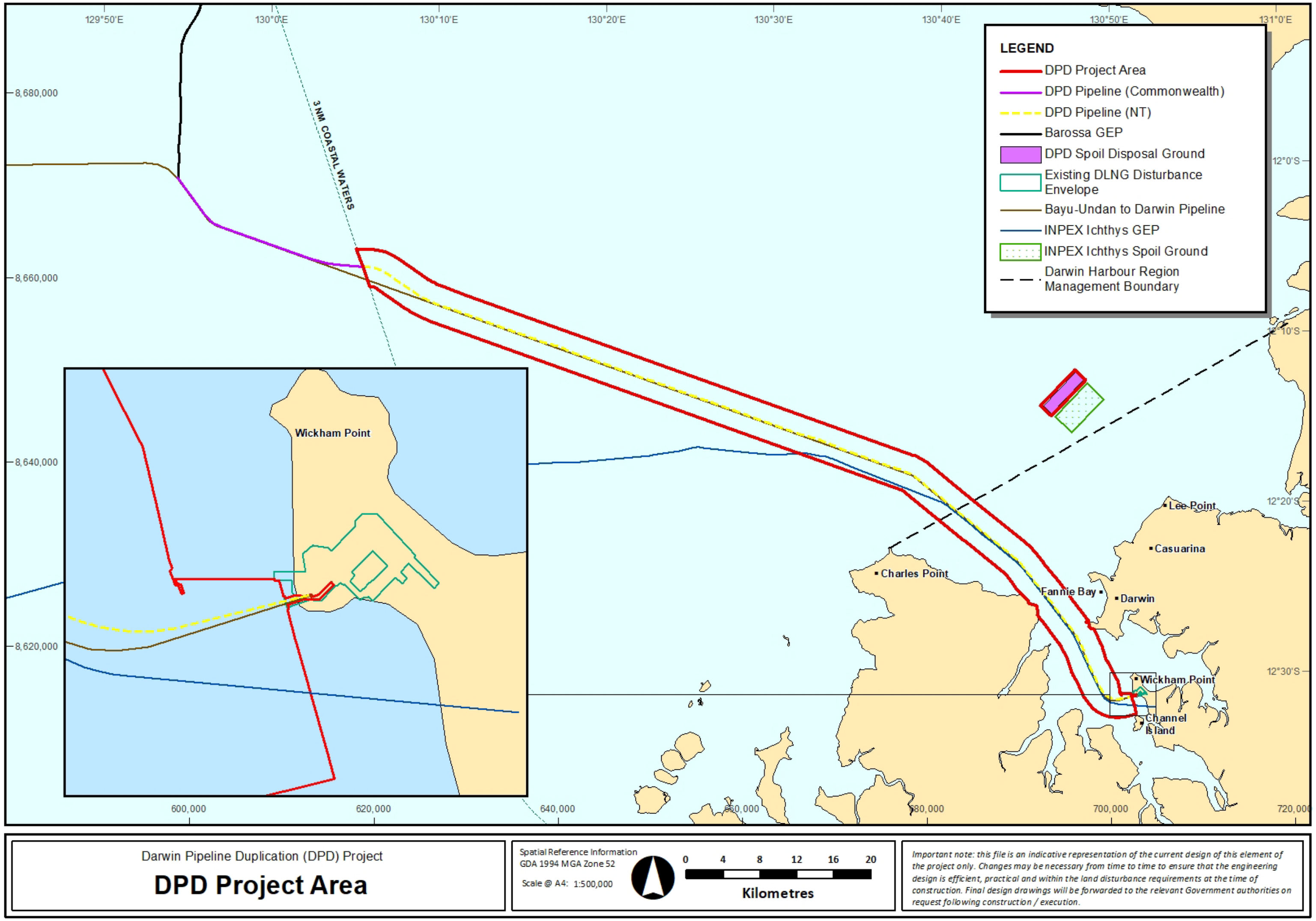

Figure 2-1: DPD Project Area

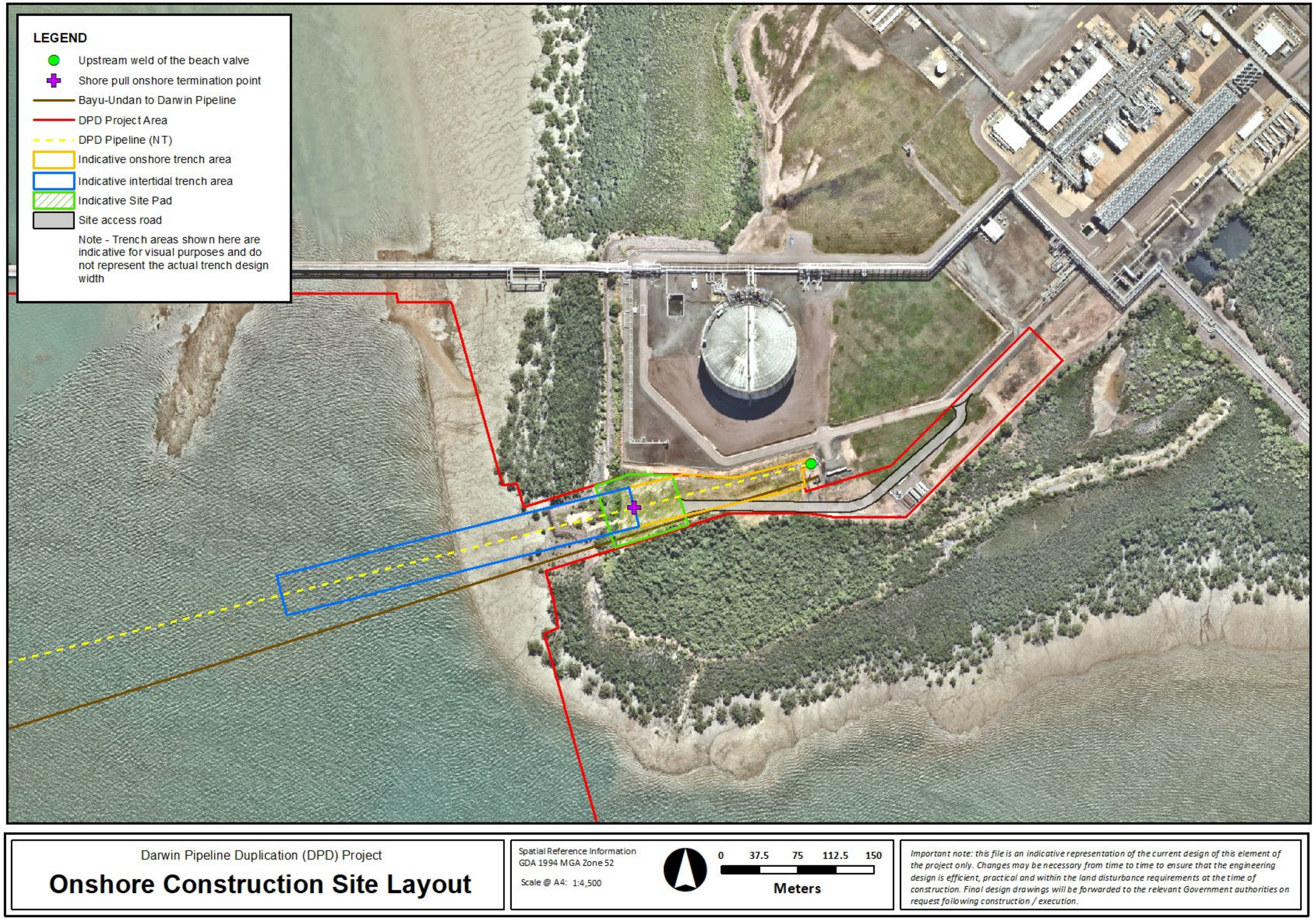

Figure 2-2: Shore crossing and indicative onshore layout within the Project Area

2.3 General detail of construction

2.3.1 Pre-lay works

For the offshore section of the DPD Project pipeline (i.e. from approximately the outer boundary of Darwin Harbour to the NT water limit) the pipeline will be installed directly on the seabed. Route optimisation has been conducted to avoid seabed features. Given pipeline stability is improved when the pipeline can be placed as flat as possible, some seabed intervention will be required as part of pre-lay rectification and/or stabilisation activities.

While carbon steel pipe with concrete coating provides substantial protection to the DPD Project pipeline from external impacts, in shallower waters, including sections within Darwin Harbour, the DPD Project pipeline will require stabilisation due to exposure to waves, currents and tidal movement, and will need further impact protection from third-party activities (i.e. anchors). As such, in some areas the DPD Project pipeline will be installed and buried in a trench on the seafloor for stabilisation and protection.

2.3.1.1 Pipeline pre-lay trenching

Locations of proposed trenching along the pipeline are shown in **Figure 2-3.** There are various trench types that may be used depending on the overall design requirements. Proposed indicative trench designs for the DPD Project are shown in **Figure 2-4**.

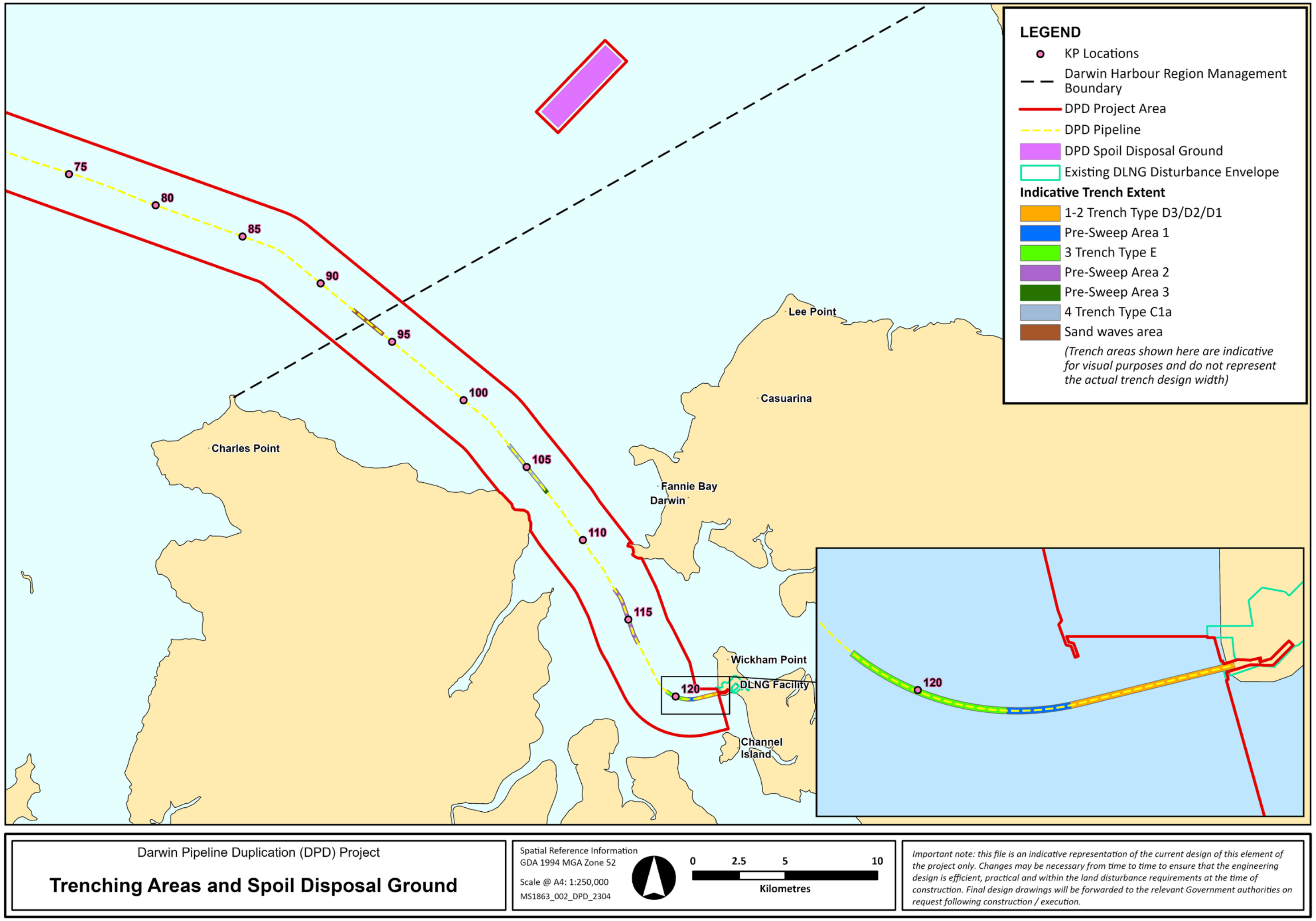

Figure 2-3: Indicative trench locations

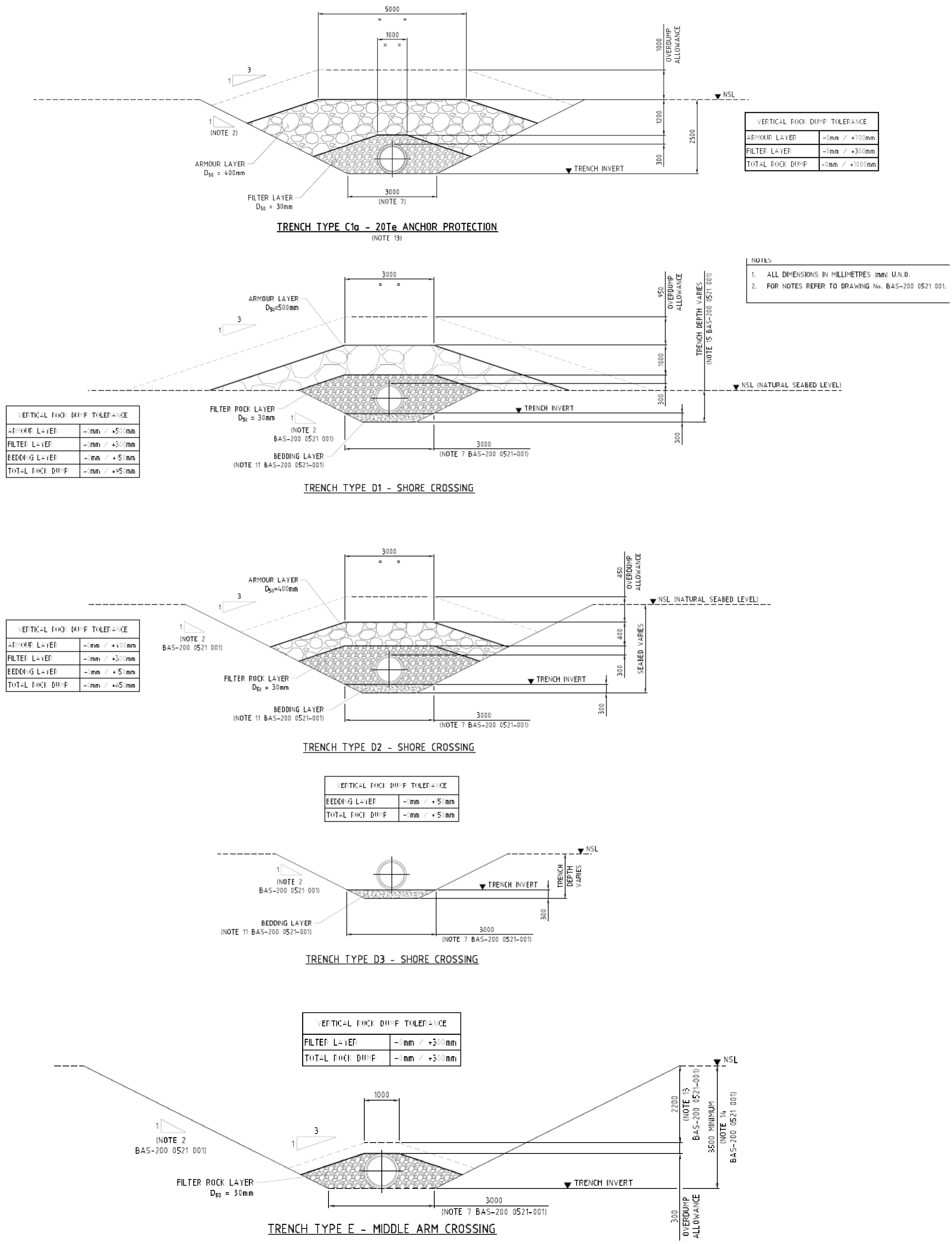

Figure 2-4: Indicative trench designs for the DPD Project

2.3.1.1.1 Darwin Harbour trenching

The pre-lay trenching associated with the DPD Project pipeline installation will involve the excavation of a trench along sections of the pipeline route in Darwin Harbour (**Figure 2-3**) within an indicative trench design width up to 40 m (with a 20 m buffer either side). A Trailer Suction Hopper Dredge (TSHD), Cutter Suction Dredge (CSD) and Backhoe Dredge (BHD) have been proposed for the pre-lay trenching works. Material will be excavated and disposed of at the spoil disposal ground, adjacent to the INPEX spoil disposal ground, as shown in **Figure 2-1**.

Closer to shore a BHD will be used (**Figure 2-3**). Rock breaking tools may be used by the BHD for rock breaking. The BHD will be supported in shallow waters on spuds and will empty spoil onto split hopper barges. These barges are self-propelled or will be towed to the spoil disposal ground, where barges 'split' and spoil is released.

No blasting or rock fragmentation is proposed for the activity, however there may be some requirement for mechanical rock breaking using a BHD mounted hammer or Xcentric ripper at localised rock areas during trenching.

An indicative window for trenching activities is presented in **Section 2.4**. Depending on the final construction schedule, a maintenance dredging campaign may be required to ensure the trench is in specification for pipe lay. It is likely that only isolated pockets along the trench would require maintenance trenching.

Further information on trenching activities, impact assessment and monitoring/management measures is provided in the TSDMMP (BAS-210 0023).

2.3.1.1.2 Shore crossing

A combination of land-based excavators from onshore and a BHD from offshore will be used to dig the trench through the inter-tidal area of the shore crossing at the DLNG facility. To support this, some temporary shoreline modifications may be required, including the construction of a temporary causeway/s so the excavators can operate further from the current shoreline. The temporary causeway/s would be built with rock and fill (**Section 2.3.1.3**).

Experience from the original Bayu-Undan to Darwin pipeline shore crossing works identified that the intertidal zone has potential to contain ASS. Some of the material excavated during the crossing construction was shown to have potential for ASS, which if left exposed to the air would have required treatment with lime. However, the ASS material recovered at the shore crossing was placed below the waterline, so no treatment was ultimately required.

If ASS or potential acid sulphate soils (PASS) are identified during trenching activities, these will be managed by keeping the ASS/PASS material submerged. ASS/PASS material will be placed as close to LAT as possible to keep the material wet under most tidal states which will result in natural dispersion with the tides. PASS in both the intertidal zone and above highest astronomical tide (HAT) is anticipated to have sufficient acid-buffering capacity to avoid the generation of ASS.

Further information on ASS/PASS, impact assessment and monitoring/management measures is provided in the ASSDMP (BAS-210 0049).

2.3.1.1.3 Spoil disposal

Trenching for the DPD Project pipeline installation will result in the requirement to dispose of an estimated 255,000 m³ of spoil however up to750,000 m³ has been considered as a contingency. The proposed spoil disposal ground for trenched material is located to the north of Darwin Harbour, within the Beagle Gulf, approximately 12 km north-west of Lee Point. This location has been selected with consideration of technical, environmental, cost and safety aspects. The selected site is adjacent to the spoil disposal ground approved for use by INPEX for the Ichthys Gas Field Development Project (refer to **Figure 2-1**).

While most of the spoil material will be disposed of within the spoil disposal ground, material excavated at the shore crossing and up to the onshore termination point using land-based excavators will be placed as close to LAT as possible, resulting in the material being saturated across most tidal states. The material will naturally disperse via tidal action and any material remaining at high tide will be removed by BHD and disposed to the offshore DPD spoil disposal ground. This will be done to manage ASS risk and is further detailed in the ASSDMP (BAS-210 0049).

2.3.1.2 Onshore site set-up

Site works within the onshore portion of the Project Area will be required to support the offshore DPD Project construction activities up to the upstream weld of the beach valve (**Figure 2-5**). Earthworks will be required to facilitate the set-up of the onshore site and allow positioning of equipment including removal of rock associated with an existing marine offloading facility (rock groyne), construction of a shore pull and Flood/Clean/Gauge/Testing (FCGT) site pad and the creation of a temporary access road. The construction of the onshore site and onshore component of the shore crossing shall allow for shore pull activities, FCGT activities, onshore trenching and pipelay activities, and equipment layout for contingency operations, including but not limited to allowing for wet buckle dewatering to be performed whilst the pull head is attached to the winch wire.

To facilitate parallel activities at the site pad and shore crossing areas during trenching and pipeline installation of the onshore section, a temporary road will be built through the DLNG site. This will facilitate access to the shore crossing from the south side of the proposed pipeline route.

2.3.1.3 Rock causeway/s

Santos expects that a temporary rock causeway/s will be required to assist with the pre-lay trenching at the shore crossing. In the event these structures are required, they will be located at the shore crossing. Approximately 1600 m^3 of rocks will be required to be imported from the quarry for construction of the causeway. Revetment rocks will mostly be sourced from the location (approximately 1500 m^3). A small layer of gravel or rocks will be applied as a top layer to allow machinery egress. The temporary causeways will cover a footprint of up to approximately 200 m long and 25 m wide either side of the pipeline, with height up to 4 m but an average height of 2 m.

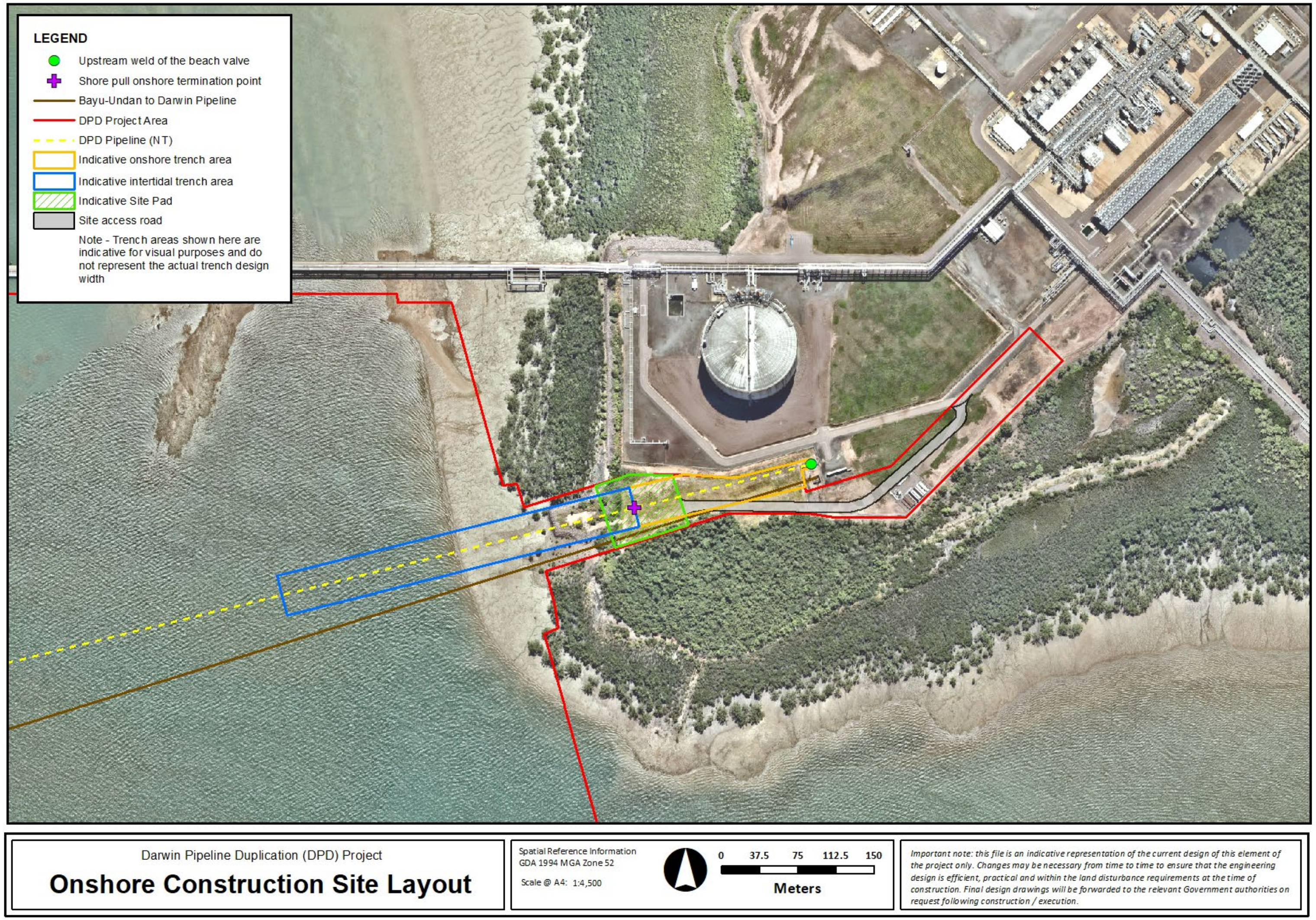

Figure 2-5: Onshore construction site layout

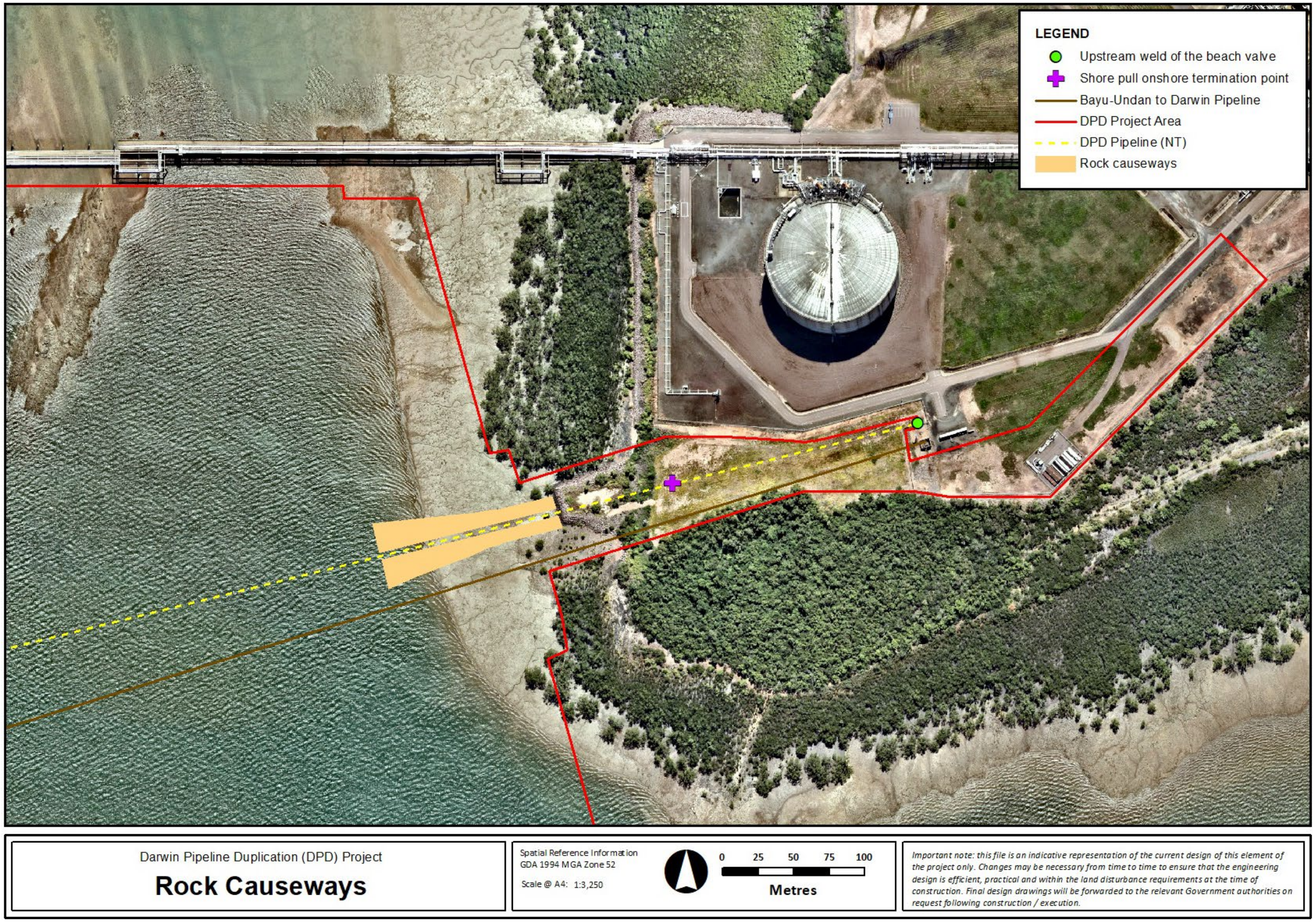

Figure 2-6: Location of causeway

2.3.1.4 Pre-lay span rectification and foundation installation

Pre-lay span rectification will be required in some areas to reduce pipeline spanning. The use of a TSHD to rectify sand waves by removal of sediment between kilometre point (KP) 92.2 and 94.4 is shown in **Figure 2-3**. Otherwise, pre-lay span rectification will occur preferentially through use of mass flow excavation (MFE).

An MFE tool works by accelerating a mass flow of water to blow away sediments within a localised area and can be used to accurately remove sediment high points and reduce pipeline spanning. MFE is an alternative to the installation of numerous concrete mattresses or grout bags. Where concrete mattresses or grout bags aim to support a spanning pipeline, the MFE will remove the span entirely limiting the exposure of the pipeline over its operational life and remove potential integrity concerns. The MFE would be deployed by a construction vessel using dynamic positioning and therefore no additional seabed disturbance is required other than within the localised area where the tool operates.

The use of MFE has been identified as a potential method to reduce sediment high points at 8 locations within two areas along the offshore pipeline route in NT waters. The first area is between KP 51 to 53 (four sites), approximately 40 km offshore from Darwin Harbour boundary and the second area is between KP 72 and 81 (four sites), approximately 12 km from the Darwin Harbour boundary. At each location it is expected that typically less than 100 m of excavation, to a nominal width of 3 m at the bottom of the excavation, would be required along the pipeline route.

The use of MFE would occur during pre-lay activities and is expected to take an indicative 7 – 14 days to complete, with an estimated six hours of operation at each site.

The MFE tool will generate localised turbidity at the seabed during the excavation process. At the locations identified for MFE use, sediment characteristics, as identified by DPD Project sediment sampling (RPS, 2022), indicate a high proportion of sand/gravel (70 – 90 %), with a lesser contribution of fine sediments (silt/clay) (10 – 30 %). Given the localised method and area of operation and the type of sediments observed at the excavation sites, turbidity created by the MFE tool is predicted to be localised and temporary only. The lower fines content will also help mitigate large plume generation and limiting turbidity.

The installation of concrete mattresses or grout bags may be used additional to MFE in instances where MFE proves not suitable (e.g., if consolidated sediments are encountered that cannot be removed by MFE) or as an adjunct to MFE if there is residual spanning requiring further rectification. Each concrete mattress footprint is ~18 m^2 and may be installed in groups and stacked on top of each other to reach the desired height.

In addition, for the in-line tee, a steel pre-lay foundation may be installed, complete with scour protection using mattresses or grout filled mats, with an approximate footprint of 375 m^2.

2.3.1.5 Cable crossings

Telecommunications and power cables in Darwin Harbour will be protected during pipelay operations using concrete mattresses if required. Supports either side of the individual cables will be provided, and it is likely that concrete mattresses will also be used to provide clearance between the DPD Project pipeline and cable.

If concrete mattresses are to be used, it is estimated that the footprint of the mattresses over the four existing cables will each be approximately 12 m × 12 m, or 600 m^2.

For future cables, installation over the DPD Project pipeline will be managed in consultation with the owner/operator of the future cable and Santos.

Detailed surveys will be performed prior to any activities being performed in the vicinity of the power and telecommunication routes. Furthermore, anchoring associated with pipelay activities in this area will include appropriate pull-on and pull-off separation distances to ensure no interaction with the cables present.

2.3.1.6 Pipeline crossings

The DPD pipeline crosses over the Bayu-Undan to Darwin pipeline at two locations (KP ~110.6 and KP ~113.3) in order to avoid encroaching into the Darwin shipping channel. The crossing locations have been selected in regions where the Bayu-Undan to Darwin pipeline is covered by a rock berm. The DPD pipeline is supported by concrete mattresses over the crossings to manage spanning and to ensure a minimum separation between the DPD pipeline and the Bayu-Undan to Darwin pipeline rock berm.

There is the potential to install nominally 30,000 tonnes of rock at the crossing locations subject to pipeline detailed design.

2.3.2 Pipeline installation and pre-commissioning

2.3.2.1 Pipelay activities

The pipeline will be 26/34-inch diameter carbon-steel with an external anti-corrosion coating and anodes to maintain the pipeline integrity and a concrete coating to provide stability and protection.

The DPD Project pipeline will be installed using a continuous assembly pipe-welding installation method, which involves the assembly of the single pipe joints (approximately 12 m in length) in a horizontal working plane on-board the pipelay vessel. The pipe joints are welded together, inspected and then the welded area is coated on-board the vessel before being lowered behind the pipelay vessel. The pipelay uses an ‘S-lay’ method (with the S notation referring to the shape of the pipeline catenary as it is lowered to the seabed). As the pipeline is lowered, it is supported on-board the pipelay vessel using a curved steel structure fitted with rollers known as a ‘stinger’.

The pipelay vessel that will be used is dependent on a range of factors including the availability of vessels, final pipeline parameters and water depth. Both dynamically positioned (DP) and anchored pipelay vessels will be used to perform the installation, dependant on water depth. Examples of pipelay vessels are shown in **Figure 2-7** and **Figure 2-8**.

In the offshore NT waters, the pipeline will be installed at approximately 2 km/day using a deep-water DP pipelay vessel. For this ~65 km extent the installation footprint will be limited to a conservative width of 5 m along the pipeline route.

Figure 2-7: Example of pipelaying vessel (offshore)

Figure 2-8: Example of pipelaying vessel (nearshore)

In shallower waters, predominantly within the Darwin Harbour, anchoring will be required and the speed of pipelay will be reduced to ~300–400 m/day, depending on the coordination of other supporting activities (i.e., pipelay barge and shore pull). For this ~34 km extent, the installation footprint will be limited to 1 m along the pipeline route, plus the footprints required for vessel anchoring. It is estimated that each of the 10 anchors has a footprint of ~10 m^2, including chain sweep. Between 10–20 anchor moves are expected each day, for a period conservatively estimated as 100 days.

When close to the shore crossing, pre-installed onshore anchors may be used. These will be within the proposed shore crossing (i.e., onshore) disturbance footprint. If onshore anchors are used, these anchors have a typical footprint of 5 m × 5 m with an additional 40 m^2 for anchor wire on the seabed.

The base case is for the DPD Project pipeline to be sequentially installed, beginning at the shore crossing, and progressing offshore through NT waters to the PLET in Commonwealth waters. For this to occur the last section of pipe laid by the shallow water pipelay barge will have a recovery head arrangement installed which will include a submersed pennant buoy, allowing this and the pipe to be recovered by the deep water pipelay vessel. Once retrieved the recovery head will be removed and recovered pipe welded to the new section of pipe to commence the deep-water pipelaying process. The base case handover point will be at KP91.5 in approximately 20 m of water, in this case the shallow water pipelay barge will have laid approximately 34 km of pipe and the deep water pipelay vessel will lay approximately 65 km of pipe in NT waters.

An alternative, to pipelaying sequentially from onshore to offshore is to pipelay concurrently with the deep water pipelay vessel and a shallow water pipelay barge. In this scenario, the shallow water vessel would still commence at the shore crossing to facilitate the shore pull and the deepwater vessel would begin lay at KP0. An above water tie-in (AWTI) would be performed where the two sections of pipeline meet. The AWTI would occur using the shallow water pipelay barge and would involve recovery of pipeline end sections using davits and subsequent welding from a temporary work platform. This activity would involve the installation of buoyancy modules on the pipe tails to support the pipeline end sections and facilitate correct alignment for welding. Timing of AWTI operations would be conducted to coincide with neap tides where practicable.

2.3.2.2 Dead-man anchoring

A dead-man anchor may be used during a midline start up with the dynamically positioned pipelay vessel. The dead-man anchor will 'dig' into the seabed to provide stability for the dynamically positioned pipelay vessel during pipelay initiation.

A dead-man anchor will be employed adjacent to the DPD pipeline route, approximately 1500 m towards Darwin on the proposed pipeline route. There is no 'target box' or 'cut-to-length' requirements for the dead-man anchor cable start-up location, as the pipe will be recovered. The pipeline initiation point (for the deep water pipelay vessel) is approximately located at KP91.5, with the dead-man anchor situated adjacent to the pipeline route at approximately KP90.

The expected duration of the dead-man anchor operation from connection of the dead-man anchor wire until head touchdown is approximately seven hours. This includes an allowance for contingency time.

Before the actual pipeline initiation can commence, the anchor will be installed and tested according to the procedure outlined in the Gas Export Pipeline – Audacia 26-inch Pipelay Procedure (BAS-273 5005). This is summarised below:

+ Install the anchor, typically 22 tonne stevshark, fluke angle 32 degrees, at the midline start-up location adjacent to KP90;
+ Move dynamically positioned vessel to the required test location and pay out the 2.5-inch dead-man anchor cable from the dead-man anchor winch;
+ The dead-man anchor will be tested by applying a factored bottom tension, for a duration of 30 minutes. To achieve the required test tension, tension will be increased in a slow and controlled manner to allow the anchor to set firmly into the ground;
+ On successful completion:
+ The dead-man anchor cable will be slackened from the dead-man anchor winch; and

+ The dead-man anchor cable will be transferred outboard, re-routed over the stinger and secured in the firing line. The dead-man anchor start-up rigging will be prepared and Audacia will set up at the start-up position.

A remotely operated vehicle deployed from the dynamically positioned vessel or survey support vessel will perform the following tasks during installation and testing of the anchor:

+ Monitor the correct landing of the dead-man anchor;
+ Take a fix of the position of the dead-man anchor after landing;
+ Monitor the anchor during the tensioning and testing of the dead-man anchor wire; and
+ Take a fix of the dead-man anchor after completion of the test.

2.3.2.3 In-line tee

The in-line tee (ILT) will be installed at KP62.8 during the pipelay activities by the deep-water DP pipelay vessel. If required, a foundation for the ILT will be pre-installed during pre-lay works. The ILT is welded into the DPD Project pipeline on-board the pipelay vessel and is installed as part of normal pipelay. A protection frame, approximately 5 m high, will be installed post-pipelay by crane (guided by ROV).

2.3.2.4 Pipeline shore pull

Shore pull to bring the DPD Project pipeline onshore will use a conventional winch operation. The arrangement for the shore pull consists of a winch spread installed on a winch pad and attached to a hold back anchor located onshore.

The pipeline pull head on the shallow water pipelay vessel is connected to the winch using a pull wire and suitable rigging. The pipe will be pulled ashore from the pipelay vessel using the winch spread located onshore through the pre-constructed trench and winched up to ~2 m above HAT (i.e. the shore pull onshore termination point).

The pulling arrangement will allow for the shore pull to be completed as a continuous operation, which will take approximately two weeks.

2.3.2.5 Trench backfill

The primary method of maintaining pipeline stability on the seabed will be the concrete weighted pipeline coating. It will also be necessary to install localised secondary stabilisation/protection for sections within Darwin Harbour where the concrete weighted coating alone is not considered sufficient to provide stability and/or protection. Backfilling using rock will also be required to protect the pipeline in areas where 21.5 tonne anchors may be used.

Rock sourced from onshore will be used for pipeline stabilisation and protection. The rock will likely be installed via a fall pipe vessel (FPV) or side dump vessel (SDV). Self-propelled DP vessels will be used to install rock on to the seabed, possibly with support barges used to transport rock. The volume of rock required is expected to be 200,000 tonnes and no more than 500,000 tonnes.

2.3.2.6 Post-lay span rectification

To provide pipeline stability, post-lay span rectification may be required and if so, would be undertaken by the installation of grout bags using a remotely operated vehicle (ROV). The likely disturbance footprint for each occasion of post-lay span rectification is 25 m². There will be a requirement to undertake downline flushing of the slurry which will result in a nominal amount of ~1.2 m^3 per fil cycle. It is estimated that there will be ~30 pre- or post-lay grout bags.

The actual locations would not be known until after the DPD Project pipeline is installed and surveyed.

2.3.2.7 Flood/ clean/ gauge/ testing (FCGT) and dewatering/ pre-commissioning

The following section outlines all aspects of the FCGT and dewatering/pre-commissioning processes, however there is no planned discharge of FCGT fluids in NT waters and discharges are limited to Commonwealth waters and will be in accordance with the relevant environmental approvals. Information provided on the FCGT process and discharges within Commonwealth waters has been provided for context as water extraction, filter flushing and pipelay contingencies outlined in **Sections 2.3.2.8** and **2.3.2.9** will occur within the Project Area.

Once installed, the DPD Project pipeline internal surfaces need to be cleaned, tested, and preserved in preparation to carry hydrocarbons. This is conducted through pigging, whereby a series of pipeline inspection gauges (pigs) will be pushed through the pipeline to clean the pipeline, gauge the pipeline, and ensure all air is removed during the flooding process. Pigs are typically bullet shaped instruments which are pushed through the pipeline. Pig launcher/receivers (PLRs) will be installed on the pipeline end termination point (PLET) in Commonwealth waters and at the shore crossing. The pigs will be pushed using chemically treated seawater with seawater sourced from Darwin Harbour. The chemically treated seawater is typically a mixture of biocides (to prevent biofouling and bacterial corrosion on the internal surfaces), an oxygen scavenger (to control corrosion of the pipeline) and a dye (for leak detection during hydrotest). The proposed water treatment chemical is 'Hydrosure' or 'Hydro-3', however there may be a requirement to use other Santos approved chemical packages. The concentration of treated chemical will depend on the required preservation period, which is the period the pipeline will be left filled with the chemically treated seawater before being dewatered for tie-in and commissioning. However, the maximum concentration will be 550 ppm.

Following pigging operations the pipeline will be subjected to a hydrostatic pressure test (hydrotest). Hydrotesting will be completed in line with Santos' specification, Pressure Testing of Process and Utility Piping (1540-120-SPC-0018), and Downer standard, Hydrostatic Testing (SM-QA-ST014) (Downer, 2022). The offshore pipeline installation contractor will source hydrotesting water by water winning from Darwin Harbour, which will be filtered to remove particulates and then chemically treated. A volume of chemically treated seawater will be pushed into the pipeline to raise its pressure. This hydrotest pressure will be held for a period of time as per the relevant standard to test the pipeline integrity. There will be small, localised discharges at the PLET as the pipeline is depressurised.

On completion of FCGT, the flooded pipeline will be dewatered with ~55,000 m^3 of treated seawater discharged at the PLET in Commonwealth waters. The pipeline will be dewatered using a train of dewatering pigs separated by monoethylene glycol (MEG) slugs, driven by nitrogen, which will condition the pipeline. Approximately 1000 m^3 of MEG will be discharged. Dewatering is expected to take one week and discharge will be at the seabed through a diffuser attached to PLET C.

On completion of dewatering, the pipeline will be left packed with nitrogen, ready for hook up.

While the current plan is to dewater the entire DPD Project pipeline in one event as described above, if there is a failure in the pipeline during installation that requires remedial construction work on the pipeline, or if a pipeline wet buckle occurs during pipelay (a wet buckle is when there is a failure in the pipeline during installation which results in the ingress of raw / untreated sea water into the pipeline), contingency plans will be implemented, with associated discharges. Refer to pipelay contingencies below for detail.

2.3.2.8 Water extraction and filter flushing

To provide water for FCGT activities, water will be extracted (water winning) from Darwin Harbour. Water winning will be via a pumping spread comprising four mesh-screened, submersible pumps supported on an anchored pontoon. It is anticipated that the pontoon and extraction hose will be positioned approximately 600 m from shore in approximately 15 m of water at LAT. The total volume of water required will be dependent upon the nature of the FCGT and any contingency requirements (e.g. pipeline filling associated with responding to a wet buckle event). Planned FCGT water winning requirements are expected to require approximately 55,000 m^3 of water. Pumping rates are expected to be approximately 9 – 16 m^3/minute and water winning for FCGT activities is expected to take place over approximately three days (not including any contingency activities).

Water extracted from Darwin Harbour will be filtered prior to chemical treatment. To ensure the effectiveness of filters, regular backflushing is required. While the number of backflushes and volume of water associated with backflushing may vary depending upon the effectiveness of filters and level of clogging by suspended solids, it is estimated that a total of approximately 300 m^3 of backflush water is expected to be discharged. Backflush water will have a higher suspended solids loading compared to water extracted (i.e., higher than ambient Darwin Harbour water suspended solid concentration). The concentration of total suspended solids (TSS) within backflush water will depend upon the ambient concentration within Darwin Harbour, which will vary with tidal state and season. Water during spring tides and over the wet season are expected to be more turbid (higher TSS concentration) than water during neap tides and over the dry season.

Backflush water will be discharged onto the existing disturbed shore crossing construction site, where it will then drain into the intertidal area and solids will disperse with tidal movements. Where possible, and dependent on the progress of shore crossing rock installation at the time of FCGT activities, backflush water will be discharged onto installed rock, to baffle the flow of the discharged backflush water.

2.3.2.9 Pipelay contingencies

While highly unlikely to occur, failures in the DPD Project pipeline and the occurrence of wet buckling can occur during pipelay activities and in these situations, pipelay contingency activities will be required.

A 'wet buckle' event may occur during installation should the pipeline become buckled and fracture during pipelay, resulting in flooding of the pipeline with raw, untreated seawater. If this occurs, the raw seawater will need to be displaced from the pipeline to prevent corrosion to the undamaged section of pipeline. To remove the raw seawater, a contingency pig is launched with treated seawater containing preservation chemicals (biocide, corrosion inhibitor and oxygen scavenger) to flush the pipeline, followed by a second contingency pig which is pushed with compressed dry air. The pipeline end is then recovered and pipelay can continue.

The wet buckle event may occur anywhere along the proposed pipeline between KP0 and KP122.2 and therefore contingency dewatering could occur within this range, treated seawater discharge modelling has been conducted at three locations (KP84, KP102 and KP114) to inform impact assessment of contingency treated seawater of discharge in NT waters. These sites which were specifically selected due to their proximity of pipeline to areas of environmental importance (i.e., reefs, coral, etc) and to be representative of differing metocean conditions along the pipeline route in NT waters.

In the event of an extended period before pipelay can recommence, the pipeline will be flushed and then filled with inhibited seawater to safely preserve the pipeline in the intervening period before pipelay is recommenced. The inhibited seawater will be treated with chemicals to preserve the pipeline (i.e., the same treatment described in **Section 2.3.2.7**). If preservation is required, the entire content of the treated seawater within the pipeline will be discharged (dewatered) prior to pipelay recommencing.

Both overflow and dewatering discharges were modelled at these locations. The volume of treated seawater released as overflow (~600 m^3) was modelled at all three locations. However, during dewatering the volume was varied due to the length of the pipe at the given location, shown below.

- KP84 – 19,958 m^3
- KP102 – 10,623 m^3
- KP114 – 4,400 m^3

2.3.2.10 Demobilisation of onshore support facilities

At the completion of the pipeline installation and pre-commissioning activities, the offshore pipeline installation contractor/ sub-contractors will be responsible for removal the onshore supporting facilities e.g. site pad, access roads (**Figure 2-2**) and demobilising any onshore equipment. Wastes will be disposed of, and site reinstatement undertaken as required.

The causeway/s will be removed upon completion of all activities at the shore crossing site. Excavators will start at the deep end and recover material into dump trucks for temporary storage, with material subsequently disposed offsite. A final survey will be completed to confirm all material brought to site for the causeway has been removed.

2.3.3 Summary of vessel and support activities

Vessel and support activities will include the operation of vessels, vehicles/mobile plant, helicopters and ROVs. Vessel and support activities associated with the DPD Project will be undertaken throughout all phases of the DPD Project.

2.3.3.1 Vessel activities

A number of vessel types will be required to complete the proposed activities, including:

- Marine survey vessels – to support pre-lay and post-lay surveys of the Project pipeline, including verifying trench depth and rock placement, support pipeline and structure placement and monitor spoil ground.
- Environmental monitoring vessel – to conduct environmental monitoring during construction activities;
- Pipelay vessels – A deep water pipelay vessel and shallow water pipelay barge, to install the pipeline and ILT;
- Construction vessels – to support installation of structures (i.e., spool, mattresses for scour protection, mechanical protection, stabilisation and pipeline support) and pre-commissioning activities;
- Rock installation vessels – including fall pipe vessel, side dump vessels and non-propelled barges;
- Trenching and spoil disposal vessels – including a cutter suction dredge (CSD), trailing suction hopper dredge (TSHD), backhoe dredge (BHD) and split hopper barges (SHB);
- Pipe supply vessels – to provide pipe to the pipelay vessel; and
- Supply vessels – to provide general support, crew transfers, material and supplies to all offshore activities.

For trenching and spoil disposal activities, an expected 11 vessels will be required, for deep water and shallow pipelay activities an expected six and seven vessels, respectively, are expected to be involved, for rock installation an expected six vessels will be involved and for pre-commissioning an expected four vessels will be involved.

Supply vessels are expected to operate from local regional ports (i.e. Darwin) to transport fuel, stores, waste and specialist supplies such as rock, pipe etc.

Bunkering (re-fuelling) of the vessels may take place either at sea (i.e. if required for the pipelay vessel) or in port (support and other vessels).

Vessels will vary in length and draft. They may anchor depending on water depth and activity type, with varying anchor requirement and disturbance footprints. Known sensitive areas will be avoided when anchoring.

2.3.3.2 Helicopter activities

Helicopters are the primary means of transporting passengers or urgent freight to and from the pipelay vessel and helideck equipped construction vessel during offshore installation and pre-commissioning activities. They are also the preferred means of evacuating personnel in the event of an emergency. Helicopter support will be principally supplied from Darwin Airport. Helicopter operations will be approximately three days per week, with typically two flights each day. Helicopters will operate during daylight hours unless in the event of an emergency. Helicopters may be required to refuel offshore.

2.3.3.3 Remotely operated vehicle activities

Throughout the DPD Project, offshore activities will be supported by ROVs. The ROV can be fitted with various tools and camera systems that can be used to capture permanent records of the underwater operations and immediate surrounding environment.

2.3.3.4 Onshore facilities and equipment

Constructing onshore facilities will be required to undertake activities up to the shore pull onshore termination point. The activities include:

+ Preparation the site pad and temporary stockpile – this will include a pre-excavation survey to establish a baseline for re-contouring of the site at completion of works. Soil investigations will also be conducted at the locations of the causeway, winch installation area and temporary stockpile area. Excavation will then commence with ~5000 m^3 of material moved to the temporary spoil stockpile or intertidal area (location of spoil dependent on ASS inspection)
+ Temporary road construction, installation of geotextile and site hard stand areas – Compaction of loose soils will be done with vibratory rollers and post compaction geo-fabric to be installed where hardstand material will be applied. The hardstand material shall be placed and compacted to a minimum thickness of 300 mm. Lighting will be provided for safety purposes during night activities.
+ Site installation of the ablution facilities and office buildings. Ablutions will be connected to a septic tank with sludge periodically removed. Office containers will be lifted in via mobile crane and electrical wiring connected to a generator which will be in protective casing.
+ Installation of holdback anchor, linear winch, trench and shore pull wire. The winch will be installed using a crane with lifting capacity of 300/350 tons. Prior to the pipe pull operations an anchor pit will be excavated with ~1608 m^3 of material removed, which will be stored onsite and used as backfill for the pit on completion of activities. The anchor pit is above HAT and as the water table is assumed to be equal with the sea level it is expected that the bottom of the pit will be dry (with the exclusion of rain events).

The types of equipment expected to be used include:

+ Light vehicles;
+ Mobile equipment such as excavators, graders, trucks, fuel trucks, etc.; and
+ Heavy equipment such as cranes

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Facilities to be installed at the project site include:

- Muster point
- Generator
- Contractors offices
- Meeting room
- Stores container
- HV parking area
- LV parking area
- Light towers
- Septic tank with water supply tank
- Ablution facility discharging on septic tank
- Gas detectors

All equipment and facilities are rated for cyclones as per the Cyclone rated design report.

2.3.4 Resource requirements and access

Other resources required for the DPD Project will include:

- Personnel will be required during the construction period. Labour will be recruited from the domestic and local labour market where possible; this is subject to the contractors' resourcing requirements at the time. Accommodation will be provided for the workforce within the Darwin area or onboard vessels.
- Power will likely be supplied by onsite generators to support construction amenities and operation of equipment.
- Water usage for onshore activities including for dust suppression, washdown facilities and ablutions supply will likely be sourced from mains water supply within the DLNG facility or provided as self-sufficient water through containerised water trucks.
- Access to the shore crossing location (i.e. onshore site) will be via the existing DLNG access at the end of Middle Arm Peninsula into Wickham Point.

2.3.5 Fuels and chemicals

Chemical and fuel storage will be stored onsite within the shore crossing location and will include bunded fuel storage/tanks. Fuel trucks will likely be used to supply fuel to construction equipment including excavators, graders, cranes, and generators. Hydrotest chemicals will also be stored onshore within a hydrotest spread (i.e. biocides, oxygen scavenger and dye).

2.3.6 Atmospheric Emissions

A greenhouse gas (GHG) emissions study was conducted to determine the scope 1, 2 and 3 emissions from the DPD Project and the broader Barossa development. The scope 1 emissions within NT jurisdiction are emissions that result directly from the construction DPD Project includes:

- Vessel-based construction activities
- Onshore construction activities from power generating equipment (i.e. engine and generators)

Scope 2 and Scope 3 emissions are associated with the broader Barossa project and comprise electricity use, transport and construction of materials and consumption of Barossa products by customers.

The total scope 1 emissions for DPD Project construction activities in the NT are approximately 50,000 tCO_2-e.

2.3.7 Discharges

The DPD construction activities will produce the following discharges:

+ Vessel wastes including sewage, greywater, food waste, cooling water and reverse osmosis (RO) brine, deck drainage and bilge
+ Contingency pigging resulting discharge of FCGT fluids (in the event of an unplanned wet buckle only)
+ Trench spoil (offshore, intertidal and onshore including PASS)
+ Filter backflush discharges associated with FCGT activities (water extraction).

Approximate volumes of these discharges are presented in **Table 2-3**.

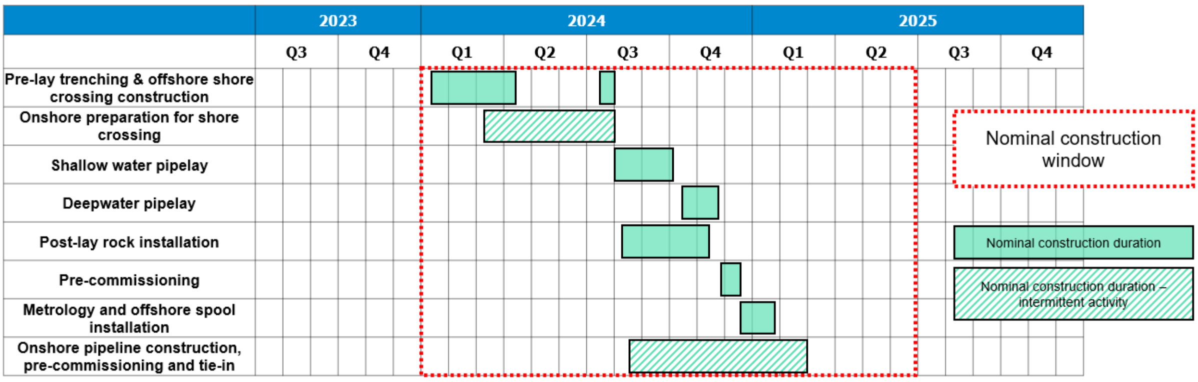
Table 2-3 Projected and contingency construction discharge volumes for the DPD Project in NT jurisdiction

Discharge source	Projected volume (m^3)	Contingency volume (m^3)
Vessel waste	n/a	n/a
Contingency treated seawater discharges	n/a	Dependent upon wet-buckle location. Example discharge volumes are provided below: ~19,958 m^3 (KP84) ~10,623 m^3 (KP102) ~4,400 m^3 (KP114)
Trench spoil	~255,000	750,000
Downline flushing of grout lines	~40	n/a
Filter backflushing	~300 m^3	

2.4 Indicative construction schedule

Santos is targeting to have all DPD regulatory approvals in place by Q1 2024 to ensure construction activities do not delay Barossa first gas in the first half of 2025. A nominal DPD construction sequence and schedule is shown in **Table 2-4** representing a start of construction activities at the beginning of nominal construction window. The construction activities will span a nominal cumulative period of 15-months in the field. The actual construction sequence and schedule will be subject to the timely receipt of all regulatory approvals and drivers such as vessel availability, operational issues, and weather. Santos' regulatory approvals and stakeholder consultation consider construction activities at any time between Q1 2024 to mid-2025.

Table 2-4: Preliminary pre-lay, construction, installation, and pre-commissioning schedule for DPD



3 Legal and other obligations

The following sections describe the legislative framework governing the environmental impacts from the construction of the DPD Pipeline (NT).

3.1 Commonwealth Environmental Approval

The DPD Project including the DPD Pipeline section in Commonwealth Waters was referred to the DCCEEW under the EPBC Act on 7 October 2022 (EPBC 2022-9372). On 6 December 2022 the DPD Project was determined to be a Controlled Action requiring further assessment based on Preliminary Documentation. Further information was requested under section 95A(2) of the EPBC Act on 23 December 2022.

It was determined that the Project may have a significant impact on the following controlling provisions under the EPBC Act:

+ Listed threatened species and communities (sections 18 & 18A)
+ Listed migratory species (sections 20 & 20A)
+ Commonwealth marine areas (sections 23 & 24A)

The Preliminary Documentation is currently being prepared for submission to DCCEEW.

This CEMP will be updated to reflect any relevant regulatory conditions associated with this approval.

3.2 Northern Territory Environmental Approvals

The DPD Project was referred to the NT EPA on 14 January 2022 under Section 55 of the EP Act. The NT EPA determined the DPD proposal required assessment by Supplementary Environmental Report (SER) (Tier 2) in accordance with the Environment Protection Regulations 2020 (EP Regulations). The SER is required to address public submissions and include information additional to the referral document in relation to specific aspects of potential significance.

This CEMP has been prepared for submission with the SER (BAS-210 0020) and other supporting documents to the NT EPA under the EP Act and will be updated to reflect any relevant regulatory conditions associated with the DPD Project approvals. It will also be submitted to DITT for approval under the *Energy Pipelines Act 1981* and the *Petroleum (Submerged Lands) Act 1981 and Energy Pipelines Act 1981*.

The following approvals are also required for construction of the DPD Project under NT legislation:

+ Department of Infrastructure, Planning and Logistics (DIPL) - Development Permit (*Planning Act 1999*) and Occupational License (*Crown Lands Act* (1992))
+ DITT – Energy Division Consent to construct and Consent to Test (*Energy Pipeline Act 1981* and *Petroleum (Submerged Lands) Act 1981*) Pipeline licenses (*Petroleum (Submerged Lands) Act 1981 and Energy Pipeline Act 1981*)
+ Fisheries Permit (*Fisheries Act 1998*)
+ Underwater Heritage Clearance (*Heritage Act 2011*)

Conditions within these permits, where they are relevant to the environmental management of works will be incorporated into future revisions of the CEMP.

3.3 Aboriginal Areas Protection Authority certificates

Aboriginal Areas Protection Authority (AAPA) certificates aim to protect indigenous sacred sites preventing damage from nearby works and outlines conditions to be followed when carrying out works on land and sea near to sacred sites across NT. The AAPA administer these certificates under the *Northern Territory Aboriginal Sacred Sites Act 1989*.

Santos has received an AAPA Authority Certificate (C2022-098) from AAPA on 23 December 2022 and will ensure the requirements of the certificate (including avoidance of restricted work areas) and the *Northern Territory Aboriginal Sacred Sites Act 1989* are met.

3.4 Legislative framework

Environmental legislative requirements governing the DPD Project are described in the following sections. All activities will comply with legislative requirements established under relevant Commonwealth and NT legislation. Key legislation is described below in **Sections 3.5.1**, **3.5.2**, **3.5.3** and **3.6**. Other relevant legislation is described in **Table 3-1** and **Table 3-2**.

3.5 Key Legislation

3.5.1 Environment Protection and Biodiversity Conservation Act 1999 (Cth)

The EPBC Act is administered by DCCEEW. The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities, and heritage places, which are defined in the EPBC Act as matters of national environmental significance. There are nine matters of national environmental significance to which the EPBC Act applies, these are: world heritage properties, national heritage places, wetlands of international importance, nationally threatened species and ecological communities, migratory species, Commonwealth marine areas, the Great Barrier Reef Marine Park, nuclear actions, and water resources (in relation to coal seam gas development and large coal mining development) (DCCEEW, 2022a). When a person proposes to take an action that they consider may need approval under the EPBC Act, they must refer the proposal to the Commonwealth Minister for Environment.

Section 3A of the EPBC Act sets out the principles of ecologically sustainable development (ESD), which are:

+ Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations
+ If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
+ The principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations
+ The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making
+ Improved valuation, pricing and incentive mechanisms should be promoted.

The construction and operation of the DPD Project (including the Commonwealth waters section) has been referred to DCCEEW under the EPBC Act and assessed to be a Controlled Action (referral number EPBC 2022/9372) requiring further assessment based on Preliminary Documentation (in progress).

3.5.2 Environmental Protection Act 2019 (NT)

The EP Act and associated EP Regulations are administered by DEPWS. The EP Act protects the environment and related purposes of the Northern Territory. The Act also:

+ Promotes ecologically sustainable development
+ Recognises the role of environmental impact assessment and environmental approval in promoting the protection and management of the environment of the Territory
+ Provides for broad community involvement during the process of environmental impact assessment and environmental approval
+ Recognises the role that Aboriginal people have as stewards of their country as conferred under their traditions and recognised in law, and the importance of participation by promotion of ecologically sustainable development.

This CEMP has been developed under the guidance of this Act and the NT EPA Draft Guidelines for an Environmental Management Plan (NT EPA, 2015) and will be submitted to NT EPA with the DPD SER (BAS-210 0020) for assessment.

3.5.3 Energy Pipelines Act 1981

The *Energy Pipelines Act 1981* (NT) allows for the creation of provisions for the construction, operation, maintenance and cessation of use or abandonment of pipelines for the conveyance of energy-producing hydrocarbons, and for related purposes. The *Energy Pipelines Act applies* to the DPD pipeline inshore from the NT Territorial Sea Baseline to the upstream weld of the beach valve.

The NT *Energy Pipelines Act 1981* and subsidiary Energy Pipelines Regulations require the proponent to operate licensed pipelines in accordance with an accepted Pipeline Management Plan (PMP). The Energy Pipelines Regulations do not require the PMP to explicitly consider environmental impacts and risks, however it is DITT – Energy Division policy that an environmental management plan (EMP), detailing environmental management, is submitted to with the PMP for approval. This CEMP and supporting plans will constitute the EMP to be provided with the PMP for approval under the *Energy Pipelines Act 1981*.

3.5.4 Petroleum (Submerged Lands) Act 1981 (NT).

The *Petroleum (Submerged Lands) Act 1981* allows for the creation of provisions with respect to the exploration for and the exploitation of the petroleum resources, and certain other resources, of certain submerged lands adjacent to the coasts of the Northern Territory and for other purposes. The *Petroleum (Submerged Lands) Act 1981* applies to the DPD pipeline in NT coastal waters, i.e., between the NT Territorial Sea Baseline and the NT/Commonwealth waters boundary.

3.5.4.1 Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)

The Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 allow for the creation of provisions with respect to the exploration and the production of the petroleum resources, and certain other resources, of certain submerged lands adjacent to the coasts of the Northern Territory and for related purposes*.* The regulations aim to ensure that proponents carry out all petroleum activity in a way that is consistent with the principles of ecologically sustainable development, in accordance with an environment plan that has appropriate environmental performance objectives and standards as well as measurement criteria for determining whether the objectives and standards are met. These Commonwealth regulations are enacted by the Petroleum (Submerged Lands) (Application of Commonwealth Laws) Regulations 2004 and apply between the

Commonwealth/NT waters boundary and the Territorial Sea Baseline. This CEMP has been developed in accordance with the content requirements for an Environment Plan under these regulations, including identifying clear and appropriate environmental performance objectives and standards as well as associated measurement criteria.

3.6 Other relevant legislation

3.6.1 Commonwealth legislation

Other Commonwealth legislative requirements relevant to the DPD offshore construction activities are outlined in **Table 3-1**.

Table 3-1: Other Commonwealth legislation relevant to DPD offshore construction activities

Title	Description
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	The purpose of this act is to preserve and protect places and objects in Australia and in Australian waters from injury or desecration; places or objects in question must be of particular significance to Aboriginal people with Aboriginal tradition.
Biosecurity Act 2015	The Act describes how to manage biosecurity threats to plant, animal and human health in Australia and its external territories, ensuring a very low level of risk.
Industrial Chemicals (Notification and Assessment) Regulations 1990 (Cth) National Industrial Chemicals Notification and Assessment Scheme (NICNAS)	Industrial chemicals are regulated by the Australian Government and administered by NICNAS. NICNAS provides a national notification and assessment scheme to protect the health of the public, workers and the environment from the harmful effect of industrial chemicals. NICNAS also assess all chemicals new to Australia and existing chemicals on a priority basis, in response to concerns about their safety on health and environmental grounds.
National Greenhouse and Energy Reporting Act 2007	Introduces a single national reporting framework for the reporting and dissemination of information about GHG emissions, GHG projects and energy use and production of corporations.
Native Title Act 1993	This Act provides for the recognition and protection of native title and provides or permits for the validation of past acts and intermediate period acts, invalidated because of the existence of native title. It additionally establishes ways in which future dealings affecting native title may proceed and sets standards for those dealings and establishes mechanisms for determining claims to native title.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006	This Act relates to the protection of the sea from the effect of harmful anti-fouling systems. It covers the application or

Title	Description
	use of harmful anti-fouling systems and the issue and endorsement of the required certificates and anti-fouling declarations.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act relates to the prevention of pollution (in any form) from ships and MARPOL requirements are implemented under this Act. MARPOL requirements are implemented under this Act.
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989	This Act, and associated regulations, implements the requirements of the Vienna Convention and Montreal Protocol to avoid using ozone depleting substances.
Underwater Cultural Heritage Act 2018 *Underwater Cultural Heritage (Consequential and Transitional Provisions) Act 2018*	This Act provides for the protection of shipwrecks, sunken aircraft and their associated artefacts that have lain in territorial waters for 75 years or more. It is an offence to interfere with any shipwreck covered by the Act. Some sites also have a protected zone around them.

Notes:

1. The *Environment Protection (Sea Dumping) Act 1981* (Cth) does not apply as spoil disposal will be within NT waters and therefore a sea dumping permit is not required.
2. There will be no trenching of the pipeline route or spoil disposal between the territorial baseline and NT coastal waters limit and therefore the activities included in this TSDMMP do not fall under the jurisdiction of the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999.*

3.6.2 Northern Territory legislation

Other Northern Territory legislative requirements relevant to the DPD Project offshore construction activities are outlined in **Table 3-2**.

Table 3-2: Other Northern Territory legislation relevant to DPD offshore construction

Title	Description
Aboriginal Land Rights (Northern Territory) Act 1976	The Act provides the basis upon which Aboriginal Australian people in the Northern Territory can claim rights to land based on traditional occupation
Aboriginal Land Act 1978	This Act provides for the access to Aboriginal land, certain roads bordered by Aboriginal land and the seas adjacent to Aboriginal land.
Bushfires Management Act 2016 Bushfires Management (General) Regulations 2017	The Act establishes the Bushfires Council and provides for the prevention and control of bushfires in the NT.
Dangerous Goods Act 1998 and Dangerous Goods Regulations 2017	This Act provides for the safe storage, handling, and transport of certain dangerous goods. These being explosives (including fireworks) and fuel gas (including Autogas) (NT WorkSafe, 2021)

Title	Description
Environmental Offences and Penalties Act 2011	This Act defines levels and penalties for environmental offences
Fire and Emergency Act 1996 Fire and Emergency Regulations 1996	This Act provides for the establishment and operation of the NT Fire and Rescue Service and their operational and emergency response activities. The Regulations outline general requirements under the Act, such as storing flammable or combustible material and using cutting, heating and welding equipment.
Fisheries Act 1988	This Act provides for the regulation, conservation and management of fisheries and fishery resources to maintain their sustainable utilisation, to regulate the sale and processing of fish and aquatic life, and for related purposes.
Heritage Act 2011	This Act provides a framework for the identification, assessment, recording, conservation, and protection of the Northern Territory's cultural and natural heritage.
Marine Act 1981	This Act is to regulate shipping within the Northern Territory and to provide for the application to the Northern Territory of the uniform shipping laws code and for related matters.
Marine Pollution Act 1999	This Act protects the marine and coastal environment by minimising intentional and negligent discharges of ship-sourced pollutants into coastal waters, and for related purposes.
Native Title Act 1993	This Act provides for the recognition and protection of native title and provides or permits for the validation of past acts and intermediate period acts, invalidated because of the existence of native title. It additionally establishes ways in which future dealings affecting native title may proceed and sets standards for those dealings and establishes mechanisms for determining claims to native title.
Northern Territory Aboriginal Sacred Sites Act 1989	This Act aims to provide a practical balance between the recognised need to preserve and enhance Aboriginal cultural tradition, in relation to certain land in the Northern Territory and the aspirations of the Aboriginal and all other peoples of the Northern Territory for their economic, cultural, and social advancement; by establishing a procedure for the protection and registration of sacred sites, providing for entry onto sacred sites and the conditions to which such entry is subject, establishing a procedure for the avoidance of sacred sites in the development and use of land and establishing an Authority for the purposes of the Act and a procedure for the review of decisions of the Authority by the Minister.
Northern Territory Environment Protection Authority Act 2012	This act aims to: a) promote ecology sustainable development; b) to protect the environment, having regard to the need to enable ecologically sustainable development; (c) to promote effective waste

Title	Description
	management and waste minimisation strategies; and (d) to enhance community and business confidence in the environmental protection regime of the Territory.
Planning Act 1999 Planning Regulation 2000	The Act provides framework of controls for the orderly use and development of land. The objective of the Act includes ensuring that strategic planning is applied to planning schemes and implemented in individual planning decisions, promotion of sustainable development of land and promotion of the responsible use of land and water resources to limit the adverse effects on development of ecological processes. Division 2 of the Act provides the planning basis for the submission, review, and authorisation of Exceptional Development Permits (EDPs), and related EDP variations. An EDP has been issued for the DLNG Plant. Approval for the DPD Project will be obtained under the Planning Act 1999 (NT), Santos is consulting with DIPL regarding the pathway for this approval.
Ports Management Act 2015	This Act provides for the safe, efficient, and effective control, management, and operation of Northern Territory ports.
Territory Parks and Wildlife Conservation Act 1976	This Act provides for the establishment of Territory Parks and other parks and reserves and for the study, protection, and conservation of wildlife in Northern Territory. This includes provisions on changes and revocation of parks, reserves and sanctuaries, the preparation and implementation of plans of management, the creation and management of sanctuaries and on the management of wildlife, flora, and fauna.
Waste Management and Pollution Control Act 1998 Waste Management and Pollution Control (Administration) Regulations 1998	This Act provides for the protection of the environment through encouragement of effective waste management and pollution prevention and control practices and for related purposes.
Weeds Management Act 2001	This Act allows for the classification of declared weeds or potential weeds, requirements for managing declared weeds or potential weeds and preparing management plans.

3.7 International conventions and agreements

Australia is signatory to numerous international conventions and agreements that obligate the Commonwealth government to prevent pollution and protect specified habitats for flora and fauna. Those which are relevant to the activity re outlined in **Table 3-3**.

Table 3-3: International agreements and conventions relevant to the activity

International agreements and conventions	
Title	**Description**
China-Australia Migratory Bird Agreement (CAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China. Implemented in the EPBC Act.
Japan-Australia Migratory Bird Agreement (JAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan. Implemented in the EPBC Act.
International Convention for the Prevention of Pollution from Ships (MARPOL)	This convention is to eliminate international marine environment pollution through hydrocarbons and other toxic substances and to reduce the accidental discharge of such substances.
Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Korea. Implemented in the EPBC Act.
United Nations Convention on Biological Diversity – 1992	An international treaty to sustain life on earth.
United Nations Framework Convention on Climate Change (1992)	The objective of the convention is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. Australia ratified the convention in December 1992, and it came into force on 21 December 1993.

3.8 Standards, codes and guidelines

There are several Australian Standards, Codes of Practice and Guidelines relevant to this CEMP, which have been identified below.

+ AS2885 Pipelines - Gas and Liquid Petroleum
+ AS/NZS 4801 Occupational Health and Safety (OHS) Management
+ AS/NZS ISO 9001:2008, Quality management systems – Requirements
+ AS/NZS ISO 14001:2004, Environmental management system – Requirements with guidance for use
+ AS/NZS ISO 31000:2009, Risk management – Principles and guidelines
+ HB 203:2006 Environmental Risk Management – Principles and Process
+ Australian Ballast Water Management Requirements. Version 8 (ABWM Requirements; Commonwealth of Australia, 2020a)
+ National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia, 2009a)
+ National Biofouling Management Guidance for Non-trading Vessels (NSPMMPI, Commonwealth of Australia, 2009b)
+ National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC & ARMCANZ, 2000)

+ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
+ Darwin Port Environmental Management Plan (Darwin Port, 2020)
+ Declaration of Beneficial Uses and Objectives, Darwin Harbour Region, Northern Territory Government Gazette No. G27, 7 July 2010
+ Darwin Harbour Water Quality Protection Plan (DLRM, 2014)
+ Darwin Harbour Strategy 2020–2025 (DHAC 2020)
+ Guidelines for Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA, 2013)
+ Draft Guidelines for the Preparation of an Environmental Management Plan (NT EPA, 2015)
+ Guideline for Reporting on Environmental Monitoring (NT EPA, 2016)
+ Water Quality Objectives for the Darwin Harbour Region – Background document (DNRETAS, 2010)
+ Marine Bioregional Plan for the North Marine Region (DSEWPAC, 2012)
+ National Guidance on the Management of Whale and Dolphin Incidents in Australian Waters (DSEWPAC, 2013).

4 Environmental management framework

4.1 Santos Management System

Santos's Management System (known as the SMS) exists to support its moral, professional, and legal obligations to undertake work in a manner that does not cause harm to people or the environment. The framework of policies, standards, processes, procedures, tools, and control measures that, when used together by a properly resourced and competent organisation, result in:

+ A common HSE approach is followed across the organisation.
+ HSE is proactively managed and maintained.
+ The mandatory requirements of HSE management are implemented and are auditable.
+ HSE management performance is measured, and corrective actions are taken.
+ Opportunities for improvement are recognised and implemented.
+ Workforce commitments are understood and demonstrated.

The Implementation Strategy (**Section 8**) and Stakeholder Consultation (**Section 9**) align with the Management System structure and are designed to require that:

+ environmental impacts and risks continue to be identified for the duration of the activity and reduced to ALARP
+ controls are effective in reducing environmental impacts and risks to ALARP and acceptable levels
+ environmental performance objectives (EPOs) and environmental performance standards (EPSs) set out in this CEMP are met
+ consultation with relevant and interested persons is maintained throughout the activity as appropriate.

4.2 Santos' environment, health, and safety policy

Santos' Environment, Health and Safety Policy (**Attachment 1**) clearly sets out its strategic environmental objectives and the commitment of the management team to continuous environmental performance improvement. This CEMP has been prepared in accordance with the fundamentals of this policy. By accepting employment with Santos, each employee and contractor is made aware during the recruitment process that he or she is responsible for the application of this policy.

4.3 DPD Project environmental management plans

This Offshore CEMP is an overarching management plan covers DPD project construction activities (as defined in **Section 2**) from the 3 nm Commonwealth waters boundary to the onshore termination point. The Onshore CEMP (BAS-210 0025), covers the construction of the DPD Project pipeline from the onshore termination point to the upstream weld of the beach valve. Support facilities for activities under the Offshore CEMP may overlap the same areas used for activities covered under the Onshore CEMP. The TSDMMP, ASSDMP and MMNMP sit under these CEMPs and address specific activities and associated management measures requiring further detail and/or requested to be developed by the NT EPA for submission along with the SER. The activities for these management plans are outlined in **Section 6** and **Figure 1-1**.

4.4 Supporting Management Processes and Procedures

4.4.1 Contractor Health, Safety and Environment requirements

The Santos HSE Contractor Management Operating Standard (SMS-HSS-OS08) supports the minimum requirements and expectations for HSE management of Contractors and subcontractors. In addition, the DPD Project has a developed an HSE Exhibit for its scopes of work. The HSE Exhibit forms a part of all contracts and has a detailed environmental requirements section including requirements for:

+ Contractor to develop an environmental implementation plan to demonstrate how applicable environmental legislation and environmental approval requirements and requirements under this CEMP will be implemented
+ Contractor to use an Environmental Management System for managing environmental impacts and risks throughout the activity, demonstrating leadership and accountability, organisational capability, and training/induction processes and performance reporting against environmental requirements
+ Definition of key activities to support continuous environmental improvement
+ Definition of the operational area of the work
+ Chemical selection, approval, and chemical register requirements
+ Prohibited of materials and chemicals
+ Vessel environmental requirements, including trenching and spoil disposal requirements, marine discharge requirements, waste management requirements, unplanned discharge requirements, marine fauna interaction requirements, lighting requirements and invasive marine species requirements

The HSE requirements for contracts/contractor management during pre-contract planning, contracting, contract execution and contract completion and evaluation are outlined in the HSE Contractor Management Operating Standard (SMS-HSS-OS08) and the Contracting and Procurement Operating Standard (SMS-PRC-OS01). These include the following minimum requirements:

+ Contractors to comply with all applicable HSE laws and regulations and any additional guidelines, operating standards and policies provided to the Contractor.
+ A review of the Contractor HSE Management System is completed before being contracted.
+ Provisions for Santos to conduct audits/inspections of the Contractor's operations, equipment and emergency procedures at any time.

4.4.2 Chemical selection and assessment procedure

All chemicals that are planned to be operationally discharged to the environment during the DPD construction activity will be evaluated using a defined framework and set of tools to ensure potential impacts are acceptable, ALARP and met Santos' expectation for environmental performance.

All chemicals that may be discharged to the environment will be detailed in a chemical register that is maintained and updated by the construction contractor. The contractor will submit the chemical application forms, with an SDS, to Santos for approval.

Chemicals that may be discharged to the environment will also require an environmental risk assessment which includes and assessment following principles of the United Kingdom Offshore Chemical Notification Scheme (OCNS) rating system.. The chemical hazard assessment and risk management (CHARM) model under the OCNS is the primary tool to rank offshore chemicals based on assessment of toxicity, biodegradation and bioaccumulation data provided by the chemical supplier.

Santos will approve chemicals planned to be discharge to the environment if they are Gold/Silver (OCNS CHARM) or OCNS group rating D/E (if not CHARM rated) or have an environmental risk assessment submitted by Contractor and approved by Santos.

4.4.3 Santos marine vessel vetting process

Santos manages marine vessel vetting and assurance using a hierarchy of procedures, outlined below. These requirements for vessel acceptance criteria include technical, personnel (e.g. crew competencies) and operational requirements for marine vessels engaged by Santos.

4.4.3.1 Marine assurance

The Marine Offshore Assurance Criteria (1530-045-STN-0001) is a standard that requires all vessels (including MODUs) used by Santos to be vetted. The vetting process is based on industry standards and best practices along with considerations of guidelines and recommendations from recognised industry organisations such as Oil Companies International Marine Forum (OCIMF) and International Maritime Contractors Association (IMCA), and international regulatory agencies like the IMO and vessel Classification Societies. The Marine Offshore Assurance Criteria requires a valid Offshore Vessel Inspection Database (OVID) report or Common Marine Inspection Document (CMID) report as required for vessel operation types. For vessels where the OVID and/or CMID are not valid or available, a Santos Approved Inspection Report is required.

4.4.3.2 Marine standards & compliance

The standards and guidelines that Santos expects the chartered vessels to operate to are:

+ Flag State Legislation
+ Coastal State Legislation for Marine Operations including Biosecurity Compliance
+ MCA Code of Safe Working Practices for Merchant Seamen (2015)
+ IMCA – M117
+ IMCA – M182
+ OCIMF – OVID and OVMSA
+ A.714 (17) Code of Safe Practice for Stowage and Securing (CSS Code) 2011 (IMO)
+ Guide for Offshore Marine Operations (GOMO) (Previously NWES Guidelines)
+ International Convention for the Safety of Life at Sea (SOLAS) 1974, as amended (IMO).
+ International Maritime Dangerous Goods (IMDG) Code (IMO)
+ Guidelines for the Preparation of cargo Securing Manual (MSC.1/Circ.1353 – IMO)
+ IACS - International Association of Classification Societies Rules
+ Safer Together Offshore Vessel Deck Water Management Specification
+ OCIMF Deck-Cargo-Management-Onboard-Offshore-Vessels

Santos performs a risk assessment or HSE Qualification Evaluation process for each vessel to identify any HSE issues or specific management requirements prior to commencing activities.

4.4.4 Santos waste management process

The Santos Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02) requires that for all waste generated by contractors under its influence, the hierarchy of waste management applies whereby wastes are (in order of preference) avoided, reduced, re-used, recycled, treated and/or correctly disposed. A waste inventory must be documented and onshore waste disposal records standardised (Waste Monitoring and Reporting Procedure – SMS-EXA-OS01-PD02-PD01) to allow accurate and consistent waste tracking. Contractors under this CEMP will demonstrate waste management processes will be aligned with regulatory and Santos requirements through the provision of Waste Management Plan for Santos acceptance.

4.4.4.1 Summary of requirements

The Australian ballast water requirements set out the obligation on vessel operators with regards to the management of ballast water and ballast tank sediment when operating within Australian seas. All internationally operating vessels entering Australia will require:

+ An approved Ballast Water Management Plan
+ Maintenance of a complete and accurate record of all ballast water movements including those conducted in Australian waters
+ An international Ballast Water Management Certificate.

Ballast water exchange should be conducted in areas at least 12 nm from the nearest land and in water at least 50 metres deep. Volumetric exchange must be at least 95% of the relevant tank. Records on ballast water exchange shall include the start and finish times and geographic coordinates of the operation.

All ballast water management equipment such as pumps will be maintained as per the vessel preventive maintenance system and regularly tested to ascertain accurate calculations for ballast water exchange operations.

4.4.4.2 Australian pre-arrival report

All international vessels must submit a Ballast Water Report and a Pre-Arrival Report (PAR), 96 to 12 hours prior to arriving in an Australian port through the MNES (MARS), for the Australian Department of Agriculture to review and process.

MARS is the online portal for commercial Vessel Masters and Shipping Agents to submit reports required of all international vessels seeking Australian biosecurity clearance; and request services such as coastal strip, waste removal, ship sanitation certification and crew change.

Department of Agriculture will request evidence from vessels with a ballast water management system of:

+ Valid ballast water management plan specific to the vessel (consistent with the Convention)
+ Valid ballast water management certificate, or certificate of compliance, that is approved by a port state administration, or a recognised survey authority (consistent with the Convention)
+ Ballast water management records that clearly demonstrate the BWMS has been operated consistent with the ballast water management plan.

A Department of Agriculture biosecurity officer will board the vessel to verify the Pre-Arrival Report and Vessel Master must ensure the vessel and personnel are available and able to demonstrate proficiency in the operation and maintenance of the ballast water management system.

4.4.5 Biofouling management

IMS may be present as biofouling on the vessel hull, or within piping, sea chests, etc. The biofouling which may be found on and in a vessel reflects the vessel's design, construction, maintenance, and operations. Each of these aspects introduces biofouling vulnerabilities but also offers opportunities to limit the extent and development of biofouling, with commensurate reduction in biosecurity risks.

4.4.5.1 Vessel risk assessment

Vessels mobilised to the operational area from international or domestic waters will comply with the Australian National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Commonwealth of Australia, 2009c). This includes:

+ Completion of a biofouling risk assessment
+ Implementation of mitigation measures commensurate with the level of risk.

Figure 4-1 presents the risk assessment process. Factors that will inform risk are:

+ Timing of marine pest risk assessment relative to vessels selection and movement to the title area to ensure there is sufficient time to implement control measures in cases where management is warranted
+ History of the vessels including time spent in ports of call since last dry dock and clean to inform whether the facility or vessel may have been exposed to high risk ports/locations
+ Level of biofouling and the presence of species of concern (in particular the presence of marine pests) within biofouling communities on the vessels associated with the activity (often informed by biofouling record books and/or maintenance/cleaning or inspection programs)
+ Operational profile relevant to biosecurity risk such as operating speed, time alongside a facility and the need for ballast exchanges within the title area
+ Receiving environment including the presence of shallow water sensitivities within proximity to the activity and the presence and area of non-biocidal surfaces on facilities that could harbour marine pests
+ Presence and effectiveness of external and internal marine growth prevention systems including effectiveness and integrity of antifouling coatings and functionality of internal treatment systems
+ Qualifications and competency of personnel conducting and reviewing the risk assessment and making management decisions.

4.4.5.2 Vessel risk status

There are three outcomes from the risk assessment which categorise the vessels risk status as outlined below. Vessels are required to have a 'low' risk status to demonstrate to the government that Santos has taken all reasonable measures to minimise the risk of IMS.

+ Low – low risk of introducing IMS; no additional management measures required
+ Uncertain – risk of introducing IMS is not apparent; precautionary approach adopted, additional management measures required to achieve low status
+ High – high risk of introducing IMS; additional management measures will be required.

4.4.5.3 Potential management measures to achieve low risk status

The outcome of the risk assessment will determine management measures required. If the vessel is deemed as 'low' risk status, no other measures are required (providing the vessel does not exceed the seven-day threshold at stationary or slow speed, in waters outside Australia (similar region).

For vessels that present an 'uncertain' or 'high' risk, Contractors will engage a qualified IMS inspector to conduct inspections and/or provide advice on obtaining low status. **Table 4-1** lists mitigation measures that can be applied to achieve 'low' risk status.

Table 4-1: Biofouling mitigation measures

No.	Mitigation Measure	Overview
1	IMS inspection	Visual inspection of submerged surfaces and niche areas by a qualified biosecurity inspector to better understand the actual biosecurity risk. IMS Inspectors will have the qualifications and align inspections and reports with DPIRD guidance in: + Criteria for Suitably Qualified Invasive Marine Pests Experts (DPIRD, 2017a) + Best Practice Guidelines for Invasive Marine Species Inspections (DPIRD, 2017b) + Invasive Marine Species Report Requirements (DPIRD, 2017c)
2	In-water cleaning	The appropriateness of in-water cleaning operations must be a decision made closely with IMS inspector on a case-by-case basis. Many factors will be considered, including: + Degree and type of biofouling; + Location of biofouling on the vessel. Prior to undertaking in-water cleaning within Australia, approval from the relevant state/territory authority must be granted and conditions may be imposed. Application for administering authority (Harbour Master, local government or state environmental protection agency) at least five working days prior to the proposed commencement of the work.
3	Dry docking cleaning	Dry docking and the removal/cleaning of biofouling will include hull surfaces, niche areas such as sea chests, all retractable equipment such as thrusters, intakes and outlets, anodes and voids.
4	Temporal or spatial controls	Temporal or spatial controls to limit vessel exposure to sources of risk.
5	Application of anti-fouling coating	Depending on the age the vessel may require application of new anti-fouling coating. The anti-fouling coating type will be based on technical advice and carried out by professional operators. All vessels greater than 400 gross tonnes will retain Antifouling System Certificate.
6	Treatment of internal seawater systems	In the absence of a marine growth prevention system, cleaning of internal seawater systems may be required, which may include: + Dehydration + Heat

No.	Mitigation Measure	Overview
		+ Physical removal + Chemical treatment. Treatment of Internal Seawater systems will ideally be undertaken prior to mobilisation to Australia. Where chemical treatments are to be undertaken within Australian waters, advice will be sought from the Australian Pesticides and Veterinary Medical Authority (www.apvma.gov.au) in relation to permit and reporting requirements as it is prohibited to clean internal systems without a permit.

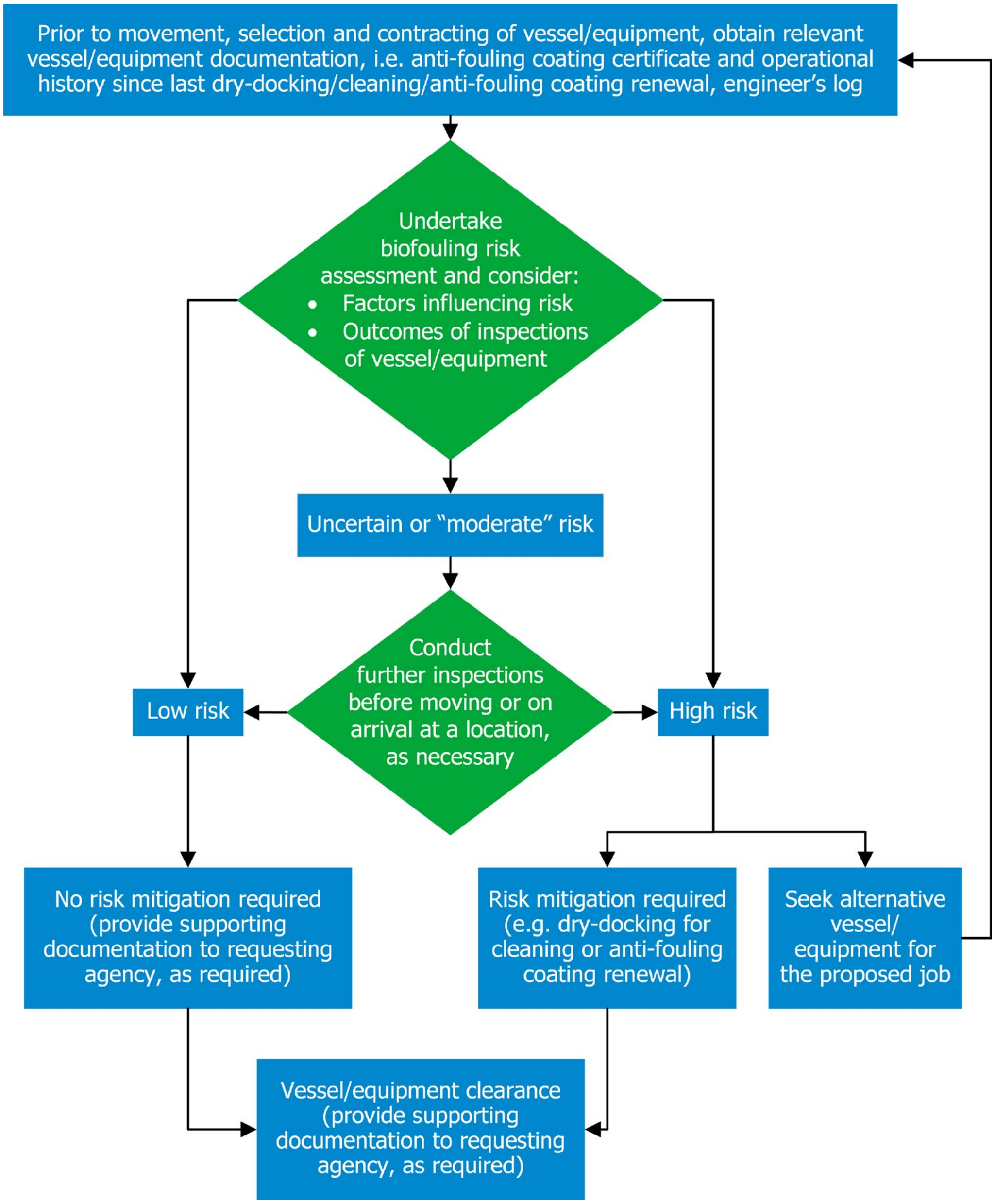


Figure 4-1: Generic biofouling risk assessment process (from Department of Agriculture, Fisheries and Forestry, 2009)

5 Existing environment

This section describes the key physical, biological, socio-economic, and cultural characteristics of the Project Area including the DPD spoil disposal ground. These characteristics have been summarised and grouped into the relevant NT EPA Environmental factors (NT EPA, 2022). Information provided in this section is drawn from the following documents:

+ Darwin Pipeline Duplication (DPD) Project – NT EPA Referral (BAS-201 0003; Santos, 2022)
+ Darwin Pipeline Duplication (DPD) Project – EPBC Referral Supporting Information (BAA-201 0004; Santos, 2022)
+ Santos Barossa DPD – Pipeline Benthic Survey report (BAS-210 0014; RPS, 2022)
+ Ichthys Gas Field Development Project – Draft Environmental Impact Statement (EIS) (INPEX, 2010)
+ INPEX Ichthys GEP Dredging and Spoil Disposal Management Plan (INPEX, 2014)
+ INPEX Ichthys Maintenance Dredging and Spoil Disposal Management Plan (INPEX, 2018)
+ INPEX Draft Maintenance Dredging and Spoil Disposal Management Plan (2023 – 2027) (INPEX, 2022)
+ Darwin Harbour – A Summary of the Ichthys LNG Project Nearshore Environmental Monitoring Program (NEMP) (Cardno, 2014).

5.1 Coastal processes

5.1.1 Physical environment

5.1.1.1 Meteorological conditions

5.1.1.1.1 Climate

The Project Area resides within the monsoonal (wet-dry) tropics of Northern Australia, which is subject to two distinct seasons a hot wet season from November to March and a warm dry season from May to September, with both April and October acting as transitional months between wet and dry seasons, respectively.

Temperatures are hot all year round with mean maximum temperature >30 °C, November is the hottest month of the year ranging from 25 °C mean minimum temperature to 33 °C mean maximum temperature. While June and July are the coolest months in the year ranging from 19 °C mean minimum temperature to 30 °C mean maximum temperature (BOM, 2022).

5.1.1.1.2 Rainfall

The annual mean rainfall for Darwin is 1723.8 mm with the majority of this (87%) rainfall coming in wet season months between November and March. Mean monthly evaporation ranges from 160 mm in February to 245 mm in October, with annual daily evaporation of 6.7 mm. Mean 9 am and 3 pm relative humidity is also higher in the wet season following similar trends to rainfall (BOM, 2022). Monthly and annual mean, max and min rainfall averages from 1941 to 2022 for Darwin International Airport are provided in **Table 5-1**.

Table 5-1: Average monthly and annual mean, max and min rainfall (mm) from 1941 to 2022 for Darwin International Airport (BOM, 2022)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	431	369	311	102	21	2	1	5	17	70	142	252	1724
Max	940	1110	1014	396	296	51	27	84	130	339	371	665	2777
Min	136	103	88	0.6	0	0	0	0	0	0	17	19	1025

5.1.1.1.3 Wind direction and speed

During the wet season winds are predominately light westerly and west–north–west winds, whilst in the dry season winds are varying from the south–east through to the north. Mean wind speeds are generally stronger in the afternoon than in the morning throughout the year. Mean morning wind speeds are typically stronger in the dry season, whilst mean afternoon wind speeds increase during the late dry season and build into the wet season where stronger winds are associated with afternoon storm cells.

5.1.1.1.4 Cyclone activity

The monsoonal tropics are also subject to intermittent cyclone activity usually resulting in the strongest winds and heaviest amount of rainfall. The cyclone season runs from 1 November to 30 April. Cyclones in the Anson-Beagle region are known to occur with low to moderate frequency. Storm surges often result in flooding, raised tidal levels, and increased wave heights resulting in damage, most of the damage caused by cyclones occurs near to the coast within 50 km from the coastline, causing concern for vessels and coastal developments in the area. Storm surges are hard to predict and dependent on the characteristics of the associated cyclone such as speed, intensity and the angle it crosses the coast. Bathymetry also contributes to the risk level of storm surges (BOM, 2022).

5.1.2 Coastal morphology

5.1.2.1 Offshore NT waters

The bathymetry of the Project Area in offshore NT waters has been thoroughly investigated and is well understood. Recent surveys have shown that the seabed along the DPD Project pipeline route in offshore NT waters and within the spoil disposal area is generally flat and featureless and typically less than 30 m in depth.

Within 5 km (north) of the Project Area resides the Carbonate bank and terrace system of the Van Diemen Rise key ecological feature (KEF) of regional significance. The feature consists of banks, terraces, channels, and valleys and the variability in water depth and substrate composition may contribute to the presence of unique ecosystems in the channels. The feature has enhanced biodiversity and productivity relative to surrounding areas and supports relatively high species diversity. This area will not be directly impacted by the DPD Project.

5.1.2.2 Darwin Harbour

Darwin Harbour is a large, drowned river system approximately 500 km^2 in extent. It is comprised of three arms (East Arm, West Arm, and Middle Arm), which along with the smaller Woods Inlet converge into a single unit before opening to the ocean and into Beagle Gulf in the north.

Freshwater inflow from the Elizabeth River into the East Arm and the Blackmore and Darwin rivers into the Middle Arm generally occurs between January and April creating more estuarine conditions.

Port Darwin's main channel is approximately 1525 m wide and 15 – 25 m deep, with a maximum recorded depth of 36 m. The channel is generally deeper on the eastern side of the Harbour, while the western side is broader and shallower areas with intertidal flats and shoal being more extensive.

The channel extends into the East Arm with depths of more than 10 m below LAT, the bathymetry of this area has been modified by dredging associated with the development of East Arm Wharf. A slightly deeper channel can be found in the Middle Arm extending up to the western side of Channel Island.

5.1.3 Oceanography

5.1.3.1 Offshore NT waters

The North Marine Region has no major ocean currents. However, there are tidal currents that play a role in the movement of water, biota, and benthic sediments. There are three recognised large-scale ecological systems in the North Marine Region which are the:

+ Gulf of Carpentaria
+ Arafura
+ Joseph Bonaparte Gulf.

The offshore NT waters Project Area traverses two meso-scale bioregions, the Bonaparte Gulf and Anson-Beagle Bioregions. The Bonaparte Gulf bioregion is predominately within offshore Commonwealth waters, but overlaps with NT coastal waters, south of Bathurst Island.

Oceanic currents within the Bonaparte Gulf are influenced by the Indonesian Through Flow (ITF) and South Equatorial Current. During the dry season (May to September) nearshore currents are generally westerly, whilst in the wet season (November to March) nearshore currents are easterly. Tides are semi-diurnal (two highs and two lows each day) and vary throughout the bioregion from offshore microtidal range (2 to 3 m variation) to inshore mesotidal range (3 to 4 m variation).

The Project Area within the Anson-Beagle Bioregion traverses Beagle Gulf. Due to the extent of the continental shelf ocean currents only have a minor influence on the Beagle Gulf region. Beagle Gulf has limited oceanic interaction and is strongly influenced by strong internal circulation. During the dry season (May to September) there is a south westerly drift due to south-easterly winds, the ITF, and the South Equatorial Current. Whilst during the wet season (November to March) there is a north-easterly drift due to the north westerly monsoonal winds. Tides in the gulf range from 6 to 8 m (IMCRA Technical Group, 1998).

Wave action in Beagle Gulf is seasonal; monsoonal north-westerly winds during the wet season (November to March) increase wave energy within Beagle Gulf and at the entrance to Darwin Harbour, due to the uninterrupted fetch over the Timor Sea. Whilst in the dry season (May to September) south-easterly trade winds generate low wave energy due to limited fetch.

5.1.3.2 Darwin Harbour

Darwin Harbour has a macrotidal (more than four metres) regime with tide range reaching 8 m which is considerable by world standards. Tides are generally semi-diurnal (two highs and two lows each day) with some inequality between successive tides in a single day. Neap tides result in a two-day period where tidal conditions are nearly diurnal (one high and one low each day). There is a great degree of variation in daily tidal range with the presence of spring-neap tide cycle approximately every 15 days. The spring phase of the cycle has an average tidal range of 6 m, while the neap phase average tidal range is 3 m . Large tidal movements and to a lesser extent wind, drives rapid and regular exchange of large volumes of water between Darwin Harbour and Beagle Gulf.

Darwin Harbour is considered sheltered with tsunamis and swell waves unlikely to occur due to the harbour's orientation, shallow bathymetry and protection afforded by the Tiwi Islands. Most waves are generated within Darwin Harbour or Beagle Gulf and are well below 1 m with periods of 2 – 5 seconds, under non-cyclone conditions. Tropical cyclones can cause extreme wave conditions producing significant wave height of 4.5 m and approximate periods of 7.5 seconds at the entrance to Darwin Harbour. Inside the harbour waves heights are reduced by the bathymetry to approximately 0.7 m (GHDM, 1997).

5.2 Marine environmental quality

5.2.1 Water quality

5.2.1.1 Offshore Northern Territory waters

Ichthys NEMP monitoring found that waters in Beagle Gulf were highly turbid in the wet season compared to the dry season likely due to stronger winds, larger waves, greater rainfall, and increased freshwater input (Cardno, 2014).

Environmental surveys to support the Barossa GEP Installation EP investigated water quality within the Barossa field (seasonal through 2015) and along the Barossa Gas Export Pipeline (GEP) (July to August 2017). This included areas close to the Project Area in Offshore NT waters, in which results showed metal concentrations below Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) dissolved metal trigger values (Santos, 2021).

In 2021, water sampling and analysis along the DPD pipeline route and at the spoil disposal ground in the offshore NT waters of the Project Area was completed (RPS, 2022 BAS-210-0014). Concentrations of three metals in water samples were detected above ANZG (2018) default guideline values (DGVs) (for slightly to moderately disturbed marine offshore ecosystems, at the 95% species protection level) Copper concentrations ins samples from three sites at western end of the offshore pipeline route were above the DGV; one of these exceedances was much higher than the DVG with the other two only slightly greater than the DVG, therefore it is likely an outlier and indicative of a potential contaminant. Lead concentrations were found to be much higher in the offshore Darwin Harbour samples than in samples taken at the spoil ground, with one sample above the DGV. Zinc concentrations were found at or above the DGV in 5 samples collected from the western end of the offshore pipeline route and across the proposed spoil disposal ground, with no clear trend in exceedances between surface and bottom waters. Arsenic was recorded below the ANZG (2018) DGV (RPS, 2022).

All nutrient concentrations were below the associated ANZG (2018) DGV (RPS, 2022). Dissolved hydrocarbons were below limits of reporting (LoR) for all samples. Naturally Occurring Radioactive Material (NORMs) were detected in near-seabed samples at two sited along the offshore pipeline route in low concentrations.

Total Suspended Solids (TSS) concentration were all above the limits of reporting LoR and ranged from 1.7 to 8.6 mg/L at offshore sites and 1.4 to 6.2 mg/L at spoil disposal grounds. There was no correlation between depth and TSS at either location.

Water column profiles at sites along the offshore pipeline and at the spoil ground showed no indications of stratification of the water column.

5.2.1.2 Darwin Harbour

Typically, water quality is high in the harbour, although naturally turbid as well. Water quality is highly variable within Darwin Harbour due to tide, sampling location, and season (**Table 5-2**). Darwin Harbour water quality is affected by high levels of surface runoff in the wet season (November to March), which can extend until April or May depending on rainfall received. Tides also influence water quality in the harbour with neap tides promoting water clarity while spring tides carry sediment for fringing mangrove and resuspend fine sediment from the harbour floor (DHAC, 2008).

Water temperatures within Darwin Harbour are predominately high with some seasonal variation, averaging 30.6°C in the wet season and 24.5°C in the dry season. The lowest water temperatures occur in June and July (23°C) while the highest occur in October and November (33°C) (Padovan, 1997).

Salinity within Darwin Harbour is also subject to some seasonal variation, with mean salinity levels in the Harbour being lower during the wet season, due to freshwater influence being greater (**Table 5-3**). Sea water salinity has a global average of 35 ppt (parts per thousand), however salinities throughout the harbour are approximately 37 ppt during the dry season. Salinity is higher in the dry season due to increased evaporation and less freshwater inflow. Areas in the middle of the harbour such as Weed Reef can experience salinity as low as 27 ppt due to monsoonal inflow during February and March (Parry & Munksgaard, 1995). Salinities in the arms are heavily influenced by freshwater inflow in the wet season and can drop to 17 ppt. The water column during this time is heavily stratified with Parry and Munksgaard (1995) reported salinities on the bottom of the harbour to be up to 12 ppt higher than the surface.

Darwin Harbour waters remain well oxygenated throughout the year. Padovan (1997) finding no seasonal effects. Dissolved oxygen levels range from 74% to 96%, averaging approximately 84%. Dissolved oxygen levels are slightly higher at the harbours mouth compared to further into the estuary. Additionally, during spring tide cycles oxygen levels increased by 7% at high tide compared low tide (Padovan, 1997).

Darwin Harbour waters have a narrow pH range of 8.3 – 8.6. Padovan (1997) found no seasonal, spatial, or tidal effect on the pH of the harbour.

Turbidity in the Darwin Harbour is higher in the wet season compared to the dry season, mainly due to influx of terrigenous sediment and somewhat due to surface water sheet flow. Light levels at the bottom of the harbour can be as low as 1% of surface light levels during the wet season (Padovan, 1997). However, the most important factors affecting turbidity are tidal cycle and location (Padovan, 1997). Spring tides are associated with higher current velocities, and therefore higher capacity of water to move sediment, which results is greater turbidity (DHAC, 2005).

5.2.2 Sediment quality

Sediments sampled in the Santos Barossa DPD Pipeline Benthic Survey were found to be represented by slightly gravelly muddy sands to gravelly sands (RPS, 2022) The silt/clay and gravel components indicated a transition in benthic sediments from KP0 to the shore crossing at KP122.5. Sampled areas including the offshore pipeline, the spoil ground, the sand wave dredge area in the northern part of Darwin Harbour and the pipeline route in southern Darwin Harbour (near the shore crossing) were all significantly different in terms of particle size distribution, with clay/silt and gravel per cent contributions highest in Darwin Harbour. Similar transitional patterns were observed for infauna biological assemblage composition along the offshore pipeline route and at the spoil ground. It is likely that other unmeasured factors, e.g. current speeds/site energy, riverine input into Darwin Harbour (e.g. freshwater, silt), salinity profiles up the river and sediment chemistry, also contribute, and that there is likely to be seasonal variability in the distribution and composition of benthic faunal assemblages

Overall, no contaminants of concern were found in the sediments along the pipeline route or at the potential spoil disposal ground, with elevated levels of arsenic considered to be naturally occurring.

Therefore, the sediments along the pipeline route are suitable for unconfined ocean disposal, as per the National Assessment Guidelines for Dredging (NAGD) and NT EPA (2013) guidelines for dredging.

5.2.2.1 Acid sulfate soils

ASS are formed naturally and often occur in low lying coastal areas (BAA-201 0003; Santos, 2021). Coastal estuarine and mangrove environments develop ASS due to its typical waterlogged nature, saltwater influences and anaerobic soils.

ASS mapping over the Darwin region indicates that the Project Area shore crossing has a high potential for ASS to occur (BAA-201 0003; Santos, 2021). However, considering the historical earthworks undertaken as part of the development of the DLNG facility, the natural material has been removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m below ground level. Therefore, ASS associated with the naturally occurring soil material is no longer expected to be present within the onshore zone and the risk has been diminished, however the presence of ASS cannot be completely discounted and may require management. (BAS-210-0049; Santos, 2023).

5.2.3 Underwater noise

Underwater noise, excluding naturally occurring noise, within Darwin Harbour is influenced by the existing shipping traffic, biological sources, and weather. Vessel traffic in Darwin Harbour is a year-round source of noise with the Port of Darwin recording 1,510 trading vessel visits in 2021 – 2022 financial year (Darwin Port Operations, 2022). Further information regarding ambient noise levels in Darwin Harbour including measures is detailed in the MMNMP (BAS-210 0022).

5.3 Marine ecosystems

5.3.1 Benthic habitats

The Darwin region supports several benthic habitats including mangroves, coral, seagrass, macroalgae and soft-bottom benthos described below. Further details of benthic habitats can be found in DPD Project NT EPA Referral and Santos Barossa DPD – Pipeline Benthic Survey Report (Santos, 2021; RPS, 2022 BAS-210-0014).

5.3.1.1 Offshore Northern Territory waters

RPS conducted baseline investigations in October 2021 and June 2022 using drop/towed video at 30 sites and ROV video transects at 42 sites respectively (RPS, 2022). These surveys were used to describe the seabed of the offshore DPD Project pipeline route and to ground truth the results of the Australian Institute for Marine Science (AIMS) 2021 Revised Predicted Benthic Habitat Map for Darwin Harbour. The results are included in full in the NT EPA Referral (Santos, 2021), Santos Barossa DPD – Pipeline Survey Report (RPS, 2022) and are summarised below.

The benthic habitats along the offshore DPD Project pipeline route verified the expectations from the AIMS (2021) Revised Predicted Benthic Habitat Map and were found to be silty shelly sand habitat, with, burrows and polychaete worm tubes. Biota commonly associated with this habitat type were very sparse to sparse, and included hydroids, soft corals (gorgonians, *Junceella* and Alcyoniidae), sea stars and sponges. This soft sediment habitat was also present at the offshore end of the DPD Project pipeline route. Within three of these silty, shelly sand sites, there were sections of sand waves, roughly one metre high, with silty sand in the troughs and coarse shelly sand at the peaks. This substrate was associated with very sparse epibiota. The proposed sand waves dredge area (sand waves) was found to contain rippled coarse sand with very little epibiota (<1% abundance), consisting of some sparse soft corals and crinoids.

The spoil disposal ground sites all consisted of the same soft substrate habitat. This habitat is defined by silty/clay sediment with medium density biota. Biota commonly seen at this habitat were soft corals (gorgonians, *Junceella* and Alcyoniidae), branching and encrusting sponges, Bryozoa (lace coral), invertebrate burrows, polychaete tubes, brown algae and occasional motile crinoids.

5.3.1.2 Darwin Harbour

Benthic habitat surveys were completed in Darwin Harbour in October 2021 and in June 2022 (RPS, 2022). The October 2021 survey was completed systematically to describe habitats along the proposed pipeline route. The June 2022 survey targeted sites which were predicted by the AIMS (2021) Revised Predicted Benthic Habitat Map to have unique habitat or showed features from geophysical surveys, that were considered to potentially represent maritime heritage features. The comparison between the AIMS and survey datasets revealed differences between predicted and observed habitat types, particularly with the level of information provided (approximate densities of biota, substrate types are not available in AIMS data).

Sections 5.3.1.2.1 and **5.3.1.2.2** summarise the findings of the October 2021 and June 2022 surveys respectively.

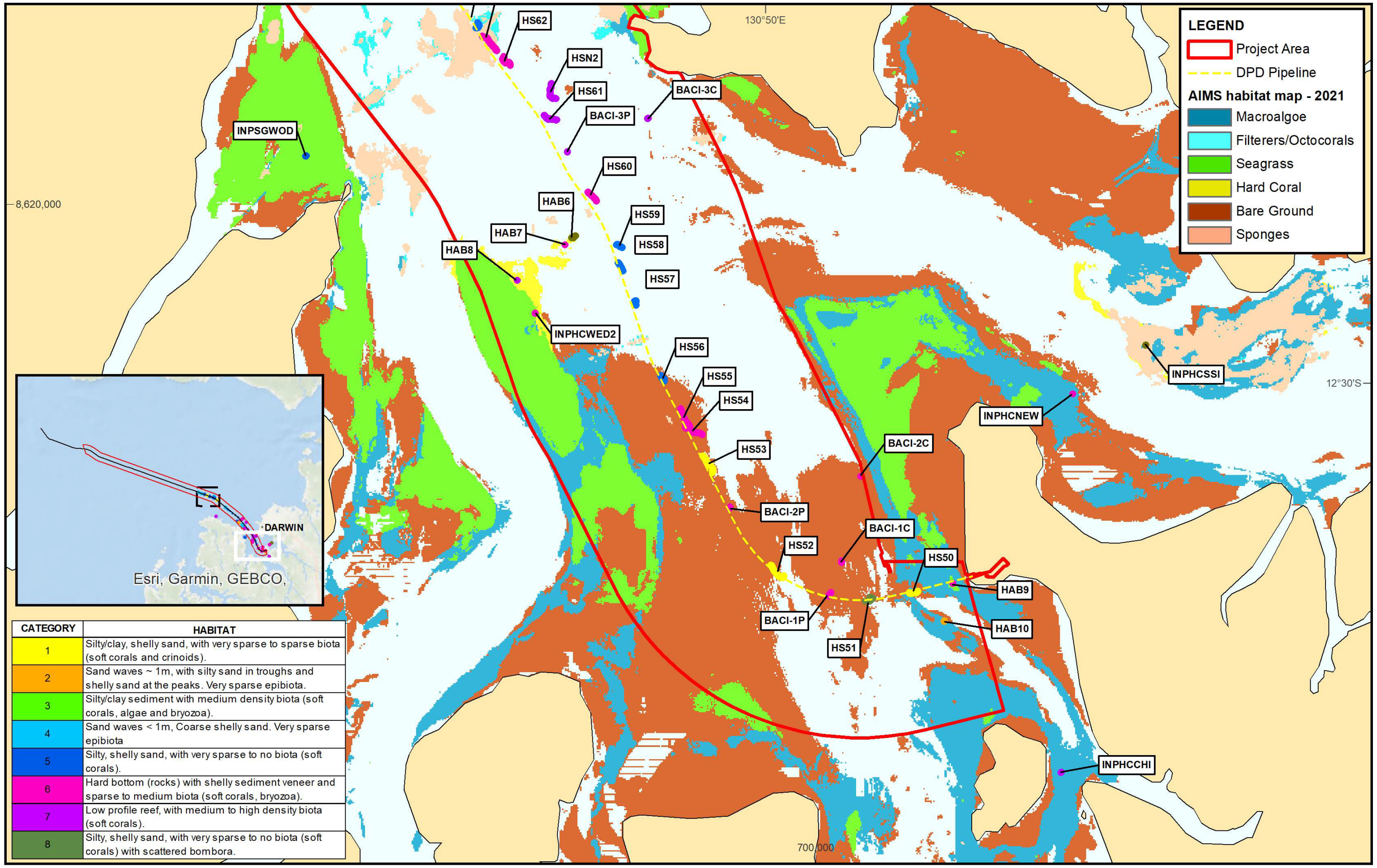
5.3.1.2.1 October 2021 survey

Darwin Harbour benthic habitats comprised soft sediment habitats with two hard substrate habitats recorded during the surveys. Hard substrates were recorded along the section of the pipeline route offshore from Fannie Bay and low profile reef was recorded offshore of Woods Inlet with medium to high density epibiota. The soft substrate habitat adjacent to hard substrate habitats in Darwin Harbour were generally silty, shelly sand with very sparse soft corals to no conspicuous epibiota. As this habitat was recorded both adjacent to and between hard substrate habitats, this soft substrate habitat is potentially a veneer overlying submerged geology. Other recorded soft sediment benthic habitats in Darwin Harbour included:

+ Sand waves <1 m with coarse shelly sand and very sparse epibiota
+ Silt/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids) (at the southern end of the pipeline, near the shore crossing)
+ Silty, shelly sand with sparse epibiota (soft corals) and scattered bombora (at the southern end of the pipeline, near the shore crossing).

5.3.1.2.2 June 2022 Survey

Key objectives of the June 2022 survey were to collect additional samples and benthic habitat imagery during other surveys to augment the benthic dataset and to ground truth the AIMS (2021) Revised Predicted Benthic Habitat Map at selected sites within Darwin Harbour and to increase the number of benthic survey sites along the pipeline route. Ground-truthing within Darwin Harbour focused on sites predicted to be suitable for rarer high-value biota types (e.g., macroalgae, hard corals and seagrass) that were closest to the proposed pipeline route (and therefore had the greatest potential to be influenced by DPD Project construction activities, including trenching). This included an area west of the pipeline route where the route comes closest to the shoreline of Cox Peninsula (including sites HAB 1-4), an area west of the pipeline route where the route comes closest to Weed Reef (including sites HAB 6-8) and sites close to the shore crossing (HAB 9 and 10) (refer to **Figure 5-1**). Results from these surveys showed that the selected sites which were predicted as suitable for macroalgae, seagrass and/or hard coral by the AIMS (2021) Revised Predicted Benthic Habitat Map typically did not show presence of these biota types (BAS 210 0014; RPS 2022, **Figure 5-1** – **Figure 5-3**). Additional to these benthic habitat ground-truthing sites, a number of benthic habitat monitoring sites used by INPEX during the Ichthys project were ground-truthed including hard coral sites (INPHCMAN, INPHCWED, INPHCCHI, INPHCSSI and INPHCNEW) and seagrass sites (INPSGWOD and INPSGCPW) (refer **Figure 5-1** – **Figure 5-3**). Surveys from these sites generally confirmed the presence of seagrass or hard coral as expected, although seagrass was observed at very low densities. The additional sites surveyed along the pipeline route within Darwin Harbour in June 2022 provided results consistent with surveys in October 2021 in that sites comprise a mix of hard substrate and sediments supporting varying densities of filter-feeding biota such as soft corals, hydroids, crinoids and sponges but with an absence of photosynthetic biota such as hard corals, seagrass and algae (BAS 210 0014; RPS, 2022; **Figure 5-1** – **Figure 5-3**).



CATEGORY	HABITAT
1	Silty/clay, shelly sand, with very sparse to sparse biota (soft corals and crinoids).
2	Sand waves ~ 1m, with silty sand in troughs and shelly sand at the peaks. Very sparse epibiota.
3	Silty/clay sediment with medium density biota (soft corals, algae and bryozoa).
4	Sand waves < 1m, Coarse shelly sand. Very sparse epibiota
5	Silty, shelly sand, with very sparse to no biota (soft corals).
6	Hard bottom (rocks) with shelly sediment veneer and sparse to medium biota (soft corals, bryozoa).
7	Low profile reef, with medium to high density biota (soft corals).
8	Silty, shelly sand, with very sparse to no biota (soft corals) with scattered bombora.

Darwin Pipeline Duplication (DPD) Project

SANTOS 2021 HABITAT MAPPING WITH AIMS 2021 HABITAT MAPPING WITHIN DARWIN HARBOUR

Spatial Reference Information
GDA 1994 MGA Zone 52
Scale @ A4: 1:70,000

0 1.25 2.5
Kilometres

Important note: this file is an indicative representation of the current design of this element of the project only. Changes may be necessary from time to time to ensure that the engineering design is efficient, practical and within the land disturbance requirements at the time of construction. Final design drawings will be forwarded to the relevant Government authorities on request following construction / execution.

Figure 5-1: RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021)

Santos

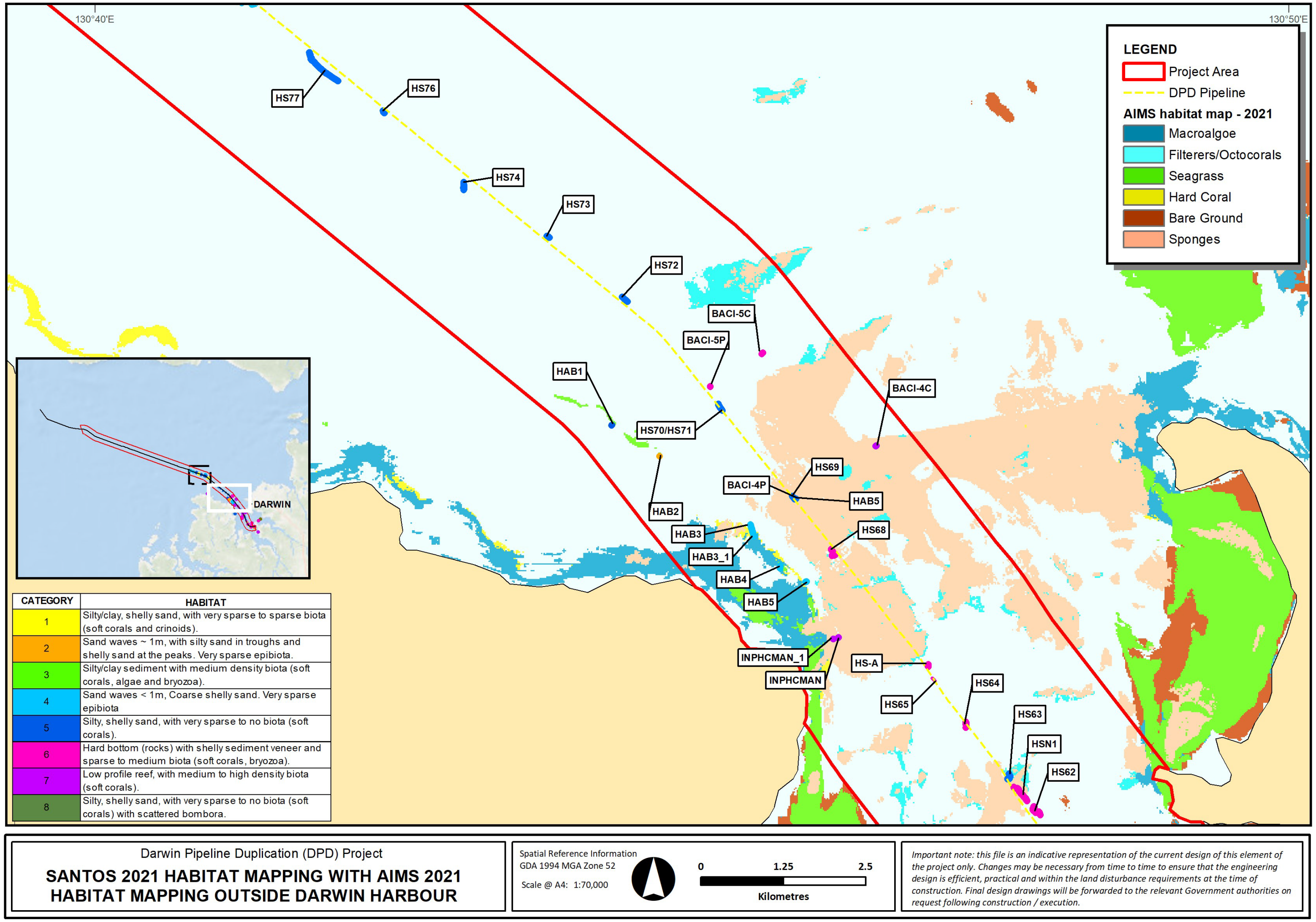


Figure 5-2: RPS survey habitat mapping against mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021)

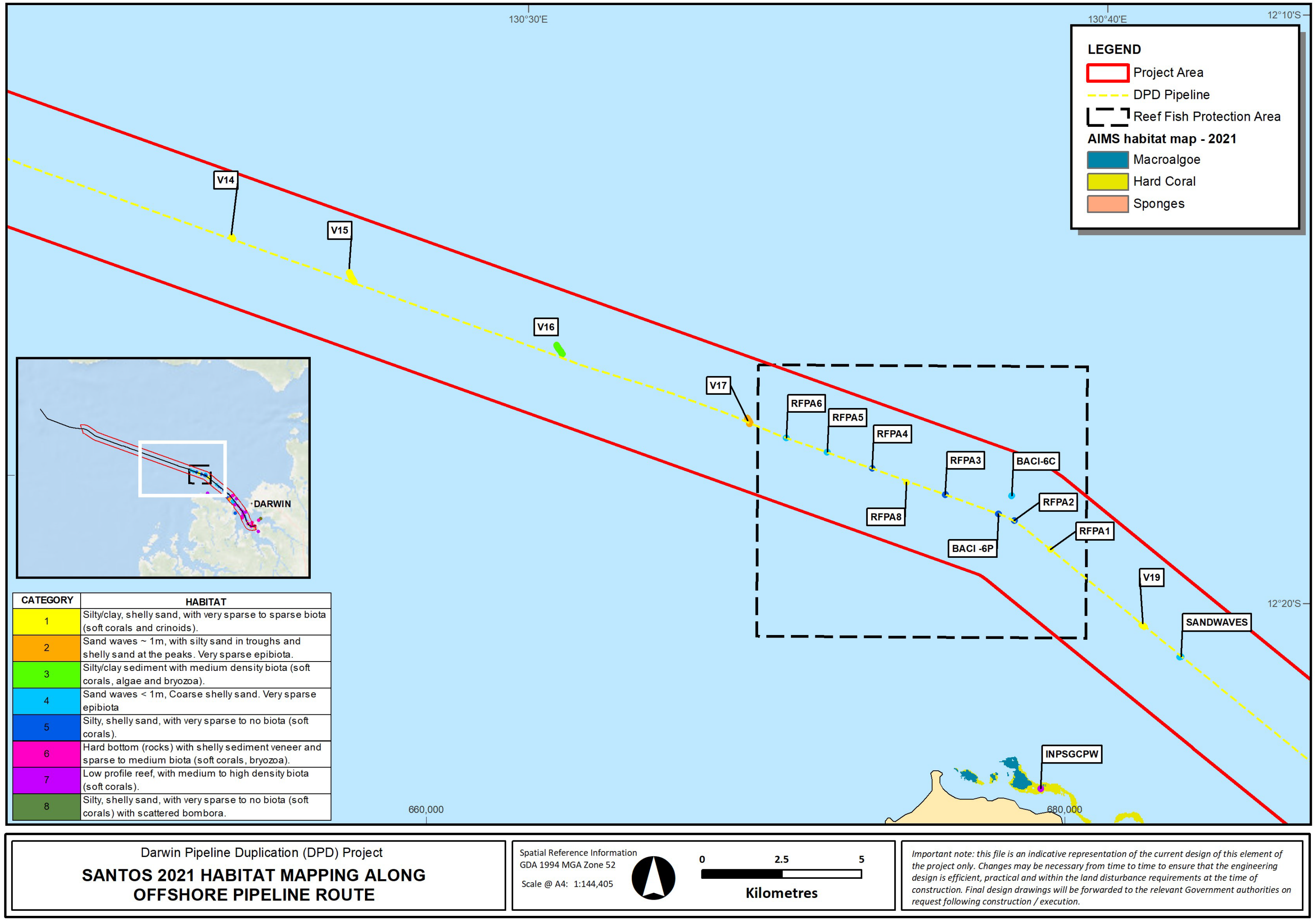


Figure 5-3: RPS surveys habitat mapping along offshore pipeline route

5.3.1.3 Protected/significant areas

Protected/significant areas identified near or overlapping the Project Area are detailed in **Table 5-2**. NT Reef Fish Protection Areas (RFPA) are described in **Section 5.3.1.3.1**.

Table 5-2: Protected areas near or overlapping the Project Area

Value/ sensitivity	Name	Overlaps Project Area	Protection classification/ zone
Nationally Important Wetlands	Port Darwin	✓	-
Northern Territory Reserves	Casuarina	✗	Coastal Reserve
	Charles Darwin	✗	National Park
NT Reef Fish Protection Areas	Charles Point Wide	✓	Reef Fish Protection Area
	Lorna Shoal	✗	Reef Fish Protection Area

5.3.1.3.1 NT reef fish protection areas

The DPD Project pipeline route intersects the Charles Point Wide RFPA and is approximately 9 km west of the Lorna Shoal RFPA (refer **Figure 5-4**). No fishing activities are permitted within RFPAs. Protection of these areas prevents over-fishing of golden snapper, black jewfish and other vulnerable reef species. The Project Area is also in close proximity to East Point Aquatic Life Reserve and Doctors Gully Aquatic Life Reserve (refer **Figure 5-4**).

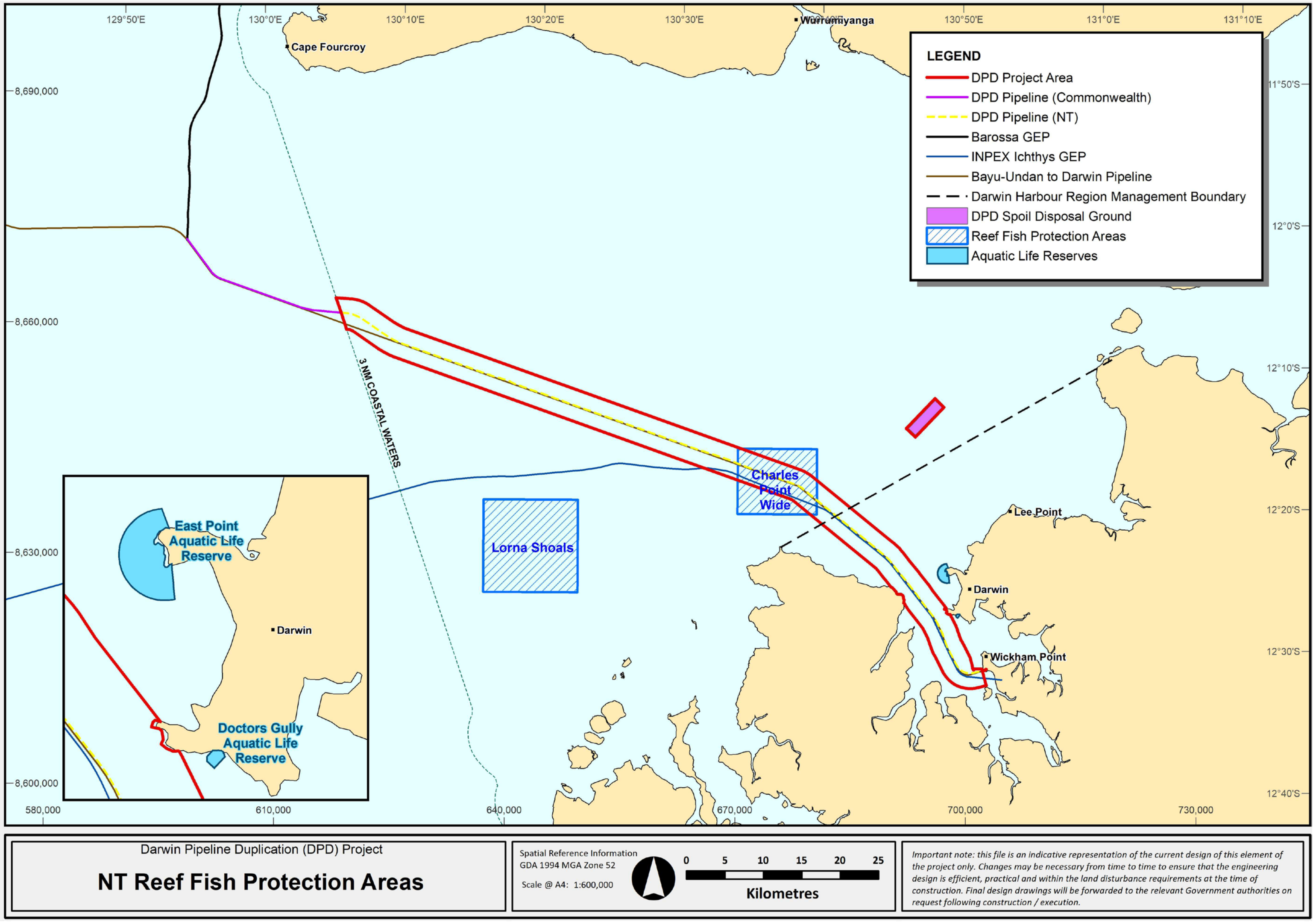


Figure 5-4: Northern Territory Aquatic Reserves and Reef Fish Protection Areas

5.4 Terrestrial ecosystems

5.4.1 Flora

A search of the DEPWS Natural Resource (NR) Maps database for threatened flora and significant flora within 5 km of the onshore Project Area identified one significant flora species, Byblis (*Byblis aquatica*) (DEPWS, 2022). This species is listed as near threatened under the *Territory Parks and Wildlife Conservation Act 1976* (TPWC Act 1976) and was recorded approximately 5 km to the south-east of the onshore Project Area. It grows in semi-aquatic conditions and is insectivorous to acquire nutrients in nutrient-poor environments (Atlas of Living Australia, 2022). This species is commonly found in areas specifically between Darwin and Berry Springs.

Previous flora surveys of the DLNG Facility disturbance envelope did not identify the presence of any threatened or conservation significant flora species (BAA-201 0003; Santos, 2021). The Byblis is unlikely to occur within the onshore Project Area as it has been previously disturbed and there are no permanent freshwater habitats present (BAA-201 0003; Santos, 2021).

5.4.2 Mangroves

Monitoring of the mangrove communities surrounding the DLNG Facility has being ongoing since 2006 (ConocoPhillips, 2018). They are comprised of predominately *Rhizophora* and *Sonneratia* species and to a lesser extent *Aegialitis*, *Avicennia*, *Osbornia* and *Aegiceras* species. The data collected indicates that the mangrove communities are in good health, with no significant deterioration or stress resulting from DLNG Facility operations.

CDM Smith's (2021) vegetation assessment of the DPD shore crossing location identified less than five individuals of one mangrove species, *Sonneratia alba*, within 20 m either side of the DPD pipeline alignment. This species of mangrove is a common taxon that is well represented and characterised in the DLNG Facility's mangrove monitoring program. CDM Smith (2021c) concluded that the vegetation in proximity to the DPD pipeline is of low ecological value and well represented in the area.

These mangroves are located outside of the pipeline alignment for the approximately 200 m section of onshore pipeline, therefore are unlikely to be impacted by the onshore works relevant to this CEMP.

5.5 Fauna

5.5.1.1 Threatened and migratory fauna

The Protected Matters Search Tool (PMST) is used to search for matters (including species) protected under the EPBC Act and generates a list of protected matters that may occur in or near a selected area. PMST searches were undertaken on 24 August 2021 within five kilometres either side of the Project Area. Copies of the PMST search reports are available in **Attachment 2**.

A summary of the Listed Threatened Species (LTS) and Listed Migratory Species (LMS) identified by the PMST for the Project Area and surrounds is shown in **Table 5-3**.

Table 5-3: Summary of EPBC Act Listed Threatened (LTS) and Listed Migratory Species (LMS) identified by the Protected Matters Search Tool

Threatened and migratory fauna type	Number of species
LTS	41 (birds – 14, mammals – 13, reptiles – 7, sharks – 8): + Critically Endangered – 4 + Endangered – 12 + Vulnerable – 24 + Conservation Dependent – 1
LMS	74 (migratory marine birds – 6, migratory marine species – 28, migratory terrestrial species – 6, migratory wetland species – 34) 21 of which are also listed as 'Threatened': + Critically Endangered – 4 + Endangered – 6 + Vulnerable – 11
Total	95

Those fauna listed as threatened or migratory species under the EPBC Act and which have been identified as being likely to occur or potentially present within the Project Area, are listed in **Table 5-4**.

Table 5-4: EPBC Act listed threatened and migratory marine fauna within the Project Area

Common name	Scientific name	EPBC Act status	Presence	Particular values or sensitivities
Marine reptiles				
Flatback turtle	*Natator depressus*	Vulnerable, Migratory	Likely	Species is known to occur in Darwin Harbour and surrounding waters. Refer **Figure 5-5**.
Olive ridley turtle	*Lepidochelys olivacea*	Endangered, Migratory	Likely	Species unlikely to occur in Darwin Harbour but is likely to occur in shallow soft-bottomed habitats of protected waters represented within the Project Area seaward of Darwin Harbour. Refer **Figure 5-6.**
Green turtle	*Chelonia mydas*	Vulnerable, Migratory	Likely	Species is known to occur in Darwin Harbour and surrounding waters.
Hawksbill turtle	*Eretmochelys imbricata*	Vulnerable, Migratory	Likely	Species is known to occur in Darwin Harbour and surrounding waters.
Leatherback turtle	*Dermochelys coriacea*	Endangered, Migratory	Potential	Species unlikely to occur within Darwin Harbour, but potentially occurs in surrounding waters.
Loggerhead turtle	*Caretta caretta*	Endangered, Migratory	Potential	Species unlikely to occur within Darwin Harbour, but potentially occurs in surrounding waters.
Salt-water crocodile	*Crocodylus porosus*	Migratory	Likely	Species is known to occur within Darwin Harbour; individuals sighted on boat ramps near Project Area. There is no important habitat for the species in the Project Area.
Marine mammals				
Australian snubfin dolphin	*Orcaella brevirostris*	Migratory	Likely	Suitable habitat for the species is present. Individuals of the species have previously been recorded in Darwin Harbour and near Catalina Island, located to the east of the Project Area. Refer **Figure 5-7**.
Dugong	*Dugong dugon*	Migratory	Likely	Individuals of the species are known to occur within Darwin Harbour.
Indo-Pacific humpback dolphin	*Sousa chinensis*	Migratory	Likely	Suitable habitat for the species is present. The species is widely known from Darwin Harbour. Refer **Figure 5-8**.
Spotted bottlenose dolphin	*Tursiops aduncus*	Migratory	Likely	Suitable habitat for the species is present. The species is widely known to occur within Darwin Harbour. Refer **Figure 5-9**.
Birds				
Asian dowitcher[1]	*Limnodromus semipalmatus*	Migratory	Potential	Some species recorded in proximity to the Project Area. Potential habitat in Darwin Harbour.
Common sandpiper [1]	*Actitis hypoleucos*	Migratory	Potential	The Project Area does not contain suitable habitat for nesting/roosting, however there is suitable habitat for foraging on either side of the Project Area which may result in this species traversing the Project Area.
Grey plover [1]	*Pluvialis squatarola*	Migratory	Potential	The Project Area does not contain suitable habitat for nesting/roosting however there is suitable habitat for foraging on either side of the Project Area which may result in this species traversing the Project Area.
Oriental plover[1]	*Charadrius veredus*	Migratory	Potential	Some species recorded in proximity to the Project Area. Potential habitat in the Darwin Harbour and offshore of Wagait Beach.
Osprey	*Pandion haliaetus*	Migratory	Potential	The Project Area and surrounds contain suitable foraging habitat for the species. It is noted that there is an osprey nest on the DLNG site (atop an artificial pole).

Notes:

1. It is important to note that although there is a number of migratory species as having the potential to or likely to occur within or nearby to the Project Area, several of these were migratory birds, most of which would likely be transiting to areas either side of the Project area where suitable habitat is known to occur (i.e. shoreline crossing is within a disturbed area). Other than the osprey, which is known to nest on tall artificial structures, migratory birds have not been considered further. In addition, given the shore crossing is located within the existing DLNG disturbance envelope and there is no suitable habitat for other migratory terrestrial species within the Project area, migratory terrestrial species have not been considered further.

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Table 5-5: Biological Important Areas (BIAs) identified within 5 km of the Project Area

Species	BIA	Project Area overlap
Marine reptiles		
Flatback turtle	Nesting/Internesting	Overlaps
Marine mammals		
Australian snubfin dolphin	Breeding	Overlaps
Indo-Pacific humpback dolphin	Breeding	Overlaps
Spotted bottlenose dolphin	Breeding	Overlaps

Relevant recovery plans, conservation advice, and wildlife conservation plans for marine fauna identified in the PMST are outlined in **Table 5-6**. Recovery plans set out the research and management actions necessary to stop the decline of and support the recovery of LTS. **Table 5-6** summarises the threats relevant to each LTS and the DPD Project with references to the CEMP sections where these are addressed.

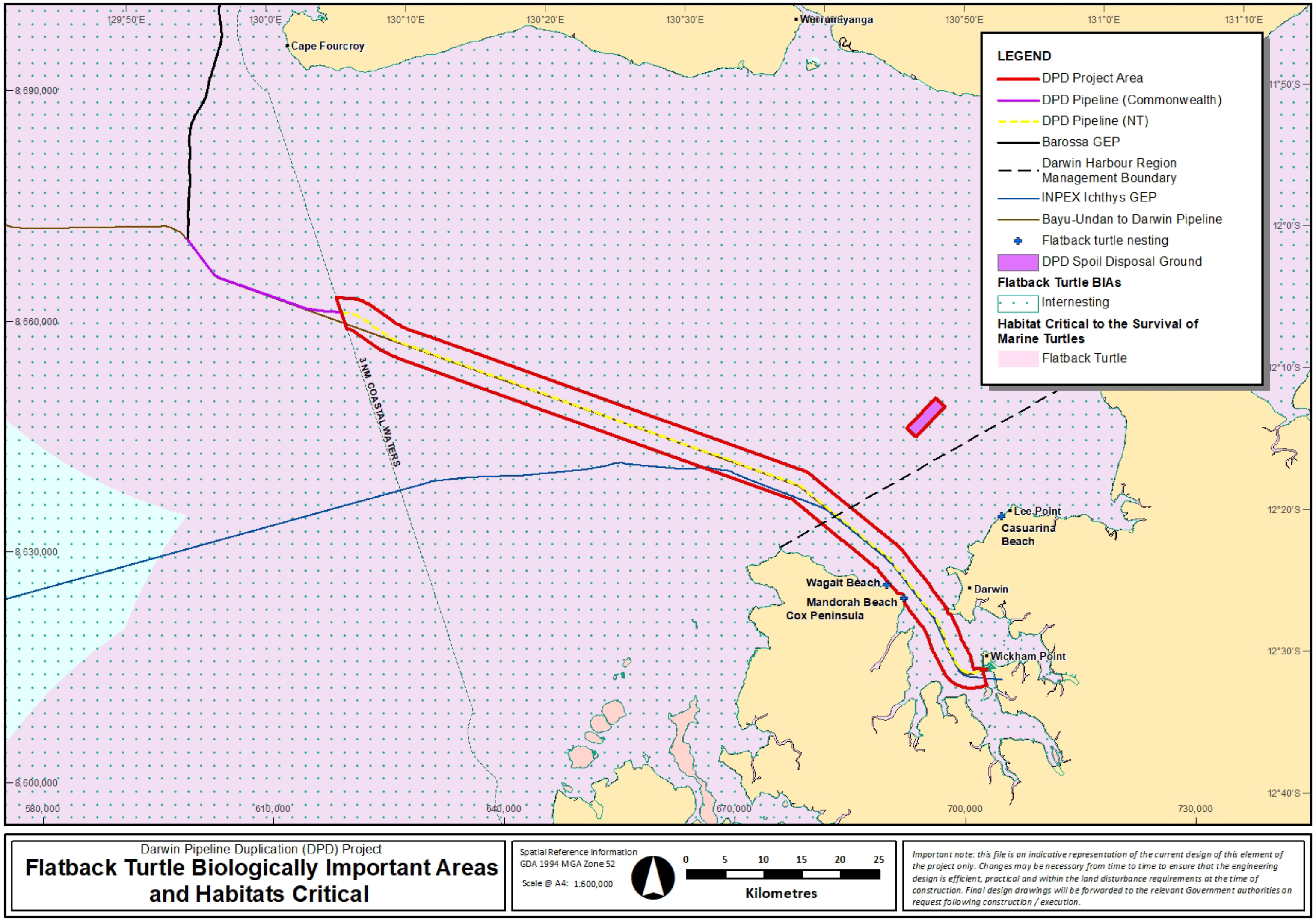

Figure 5-5: Flatback turtle BIA and Habitats Critical to survival

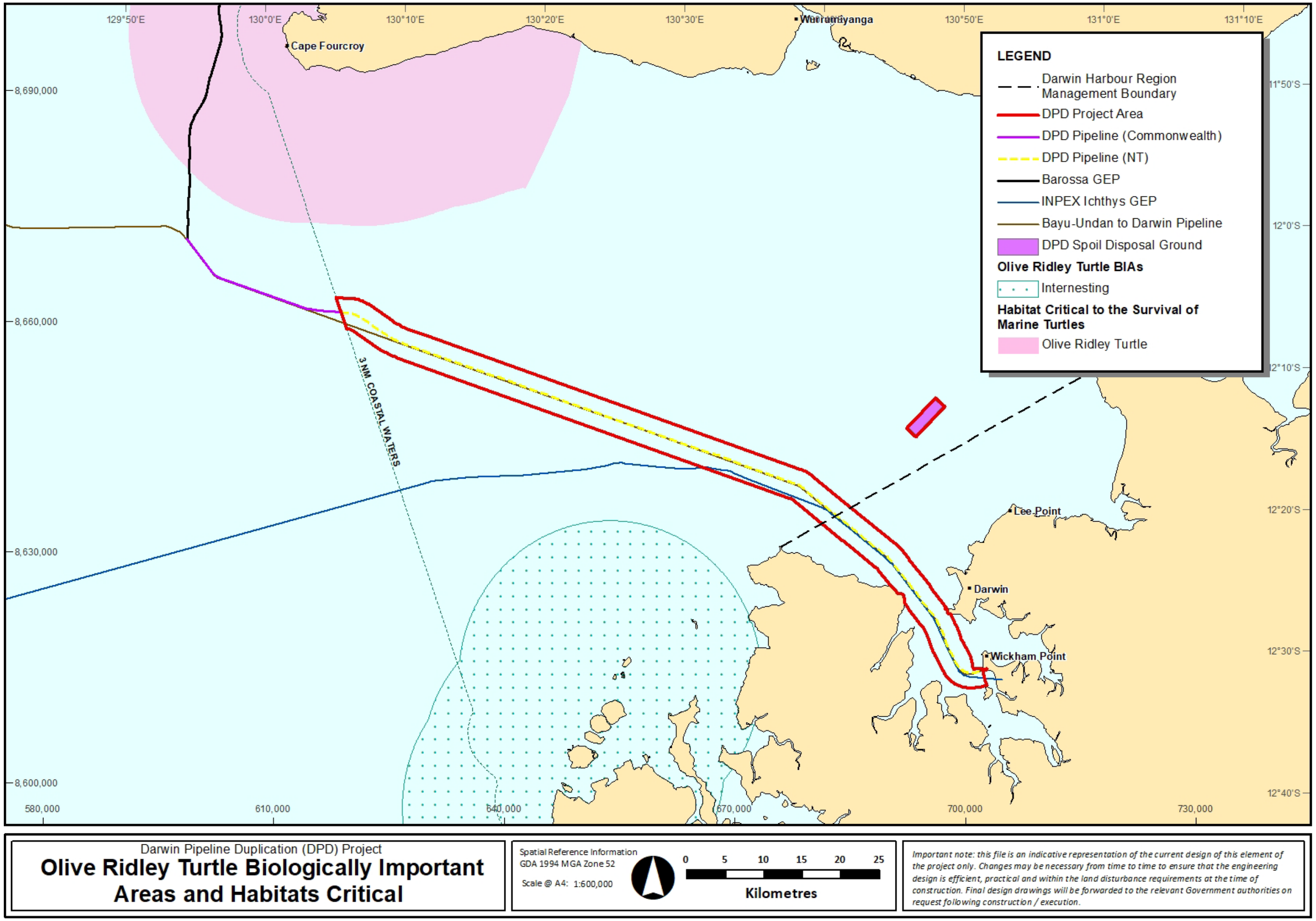

Figure 5-6: Olive ridley turtle BIA and Habitats Critical to survival

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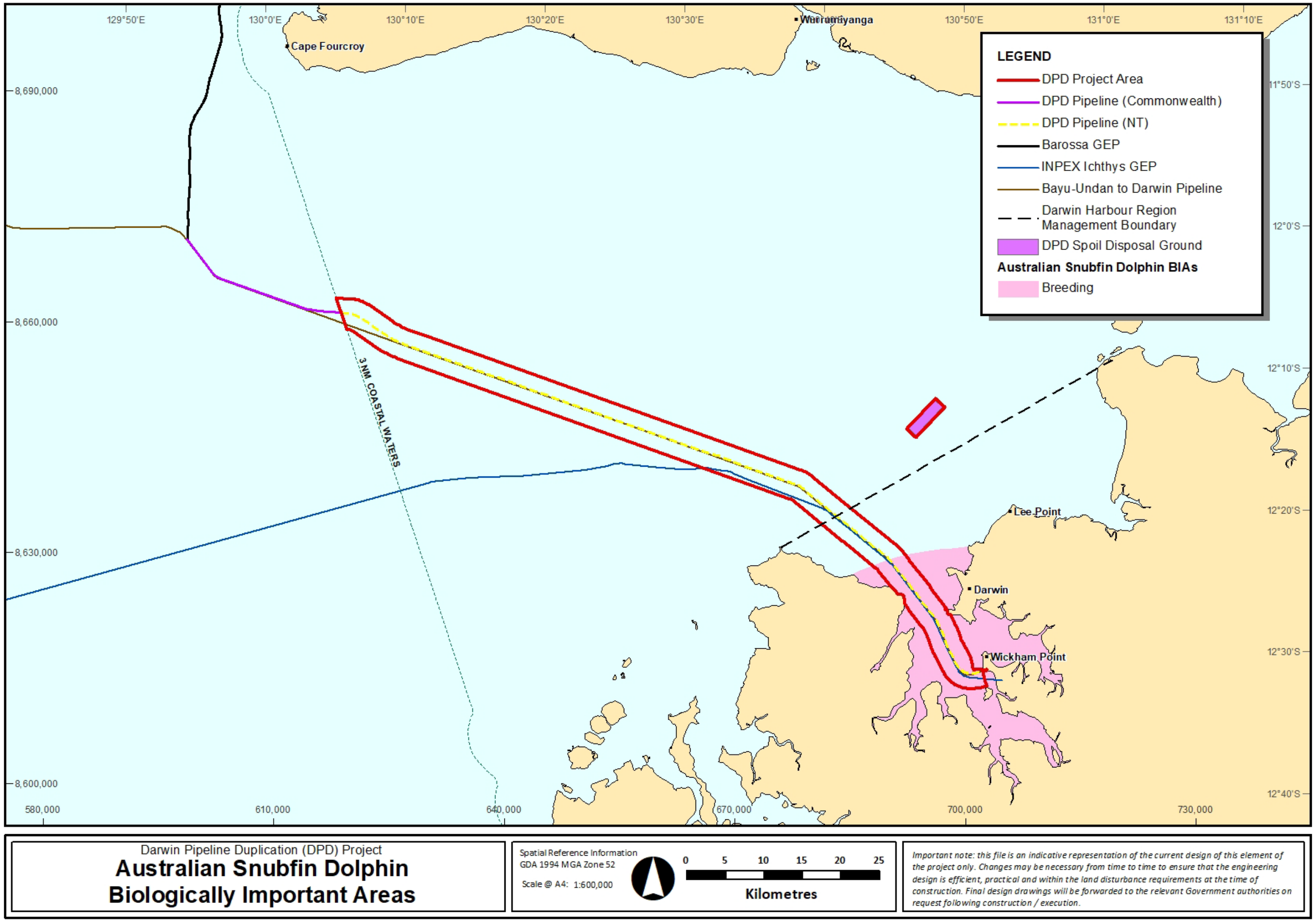

Figure 5-7: Australian snubfin dolphin BIA

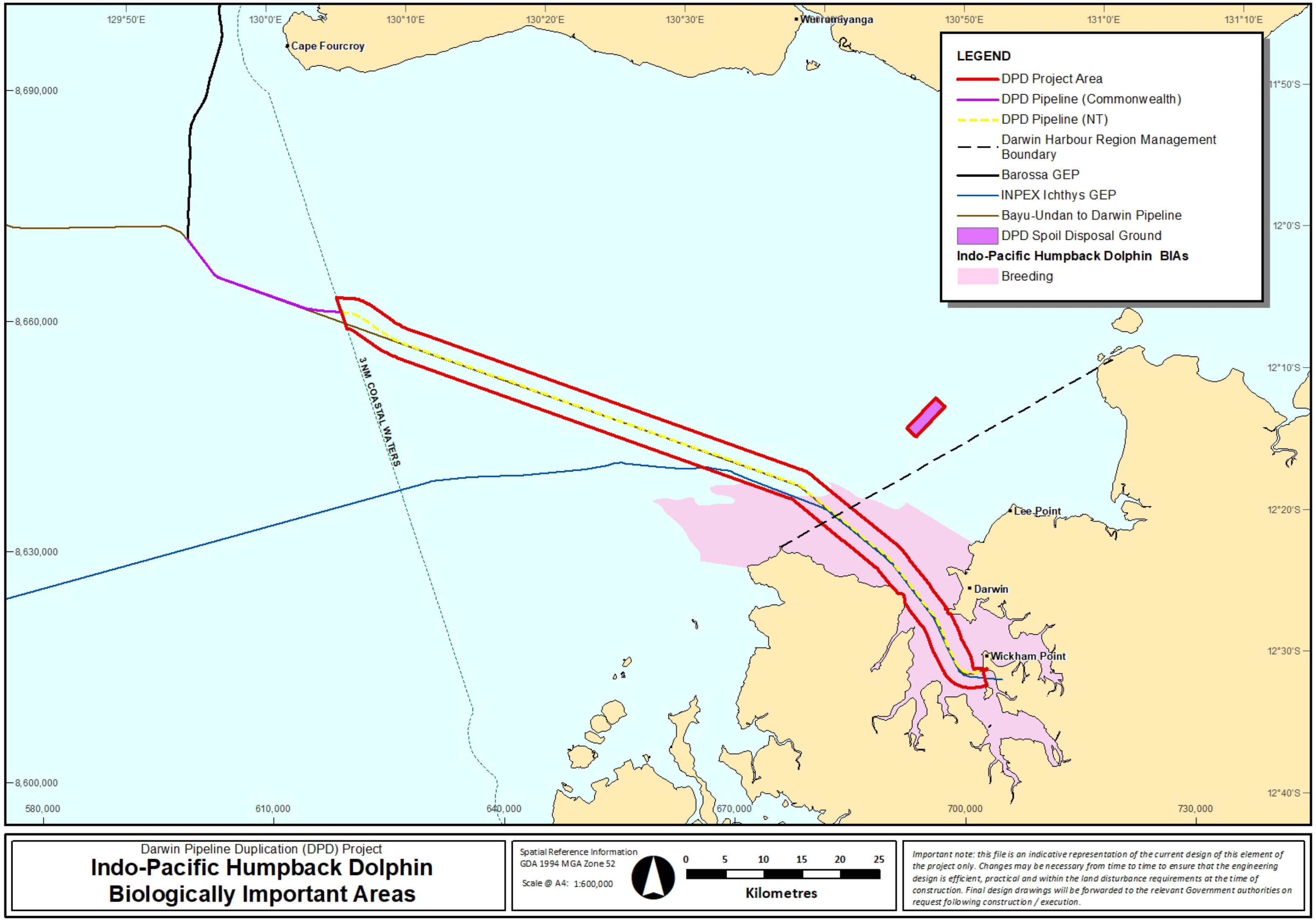

Figure 5-8: Indo-Pacific humpback dolphin BIA

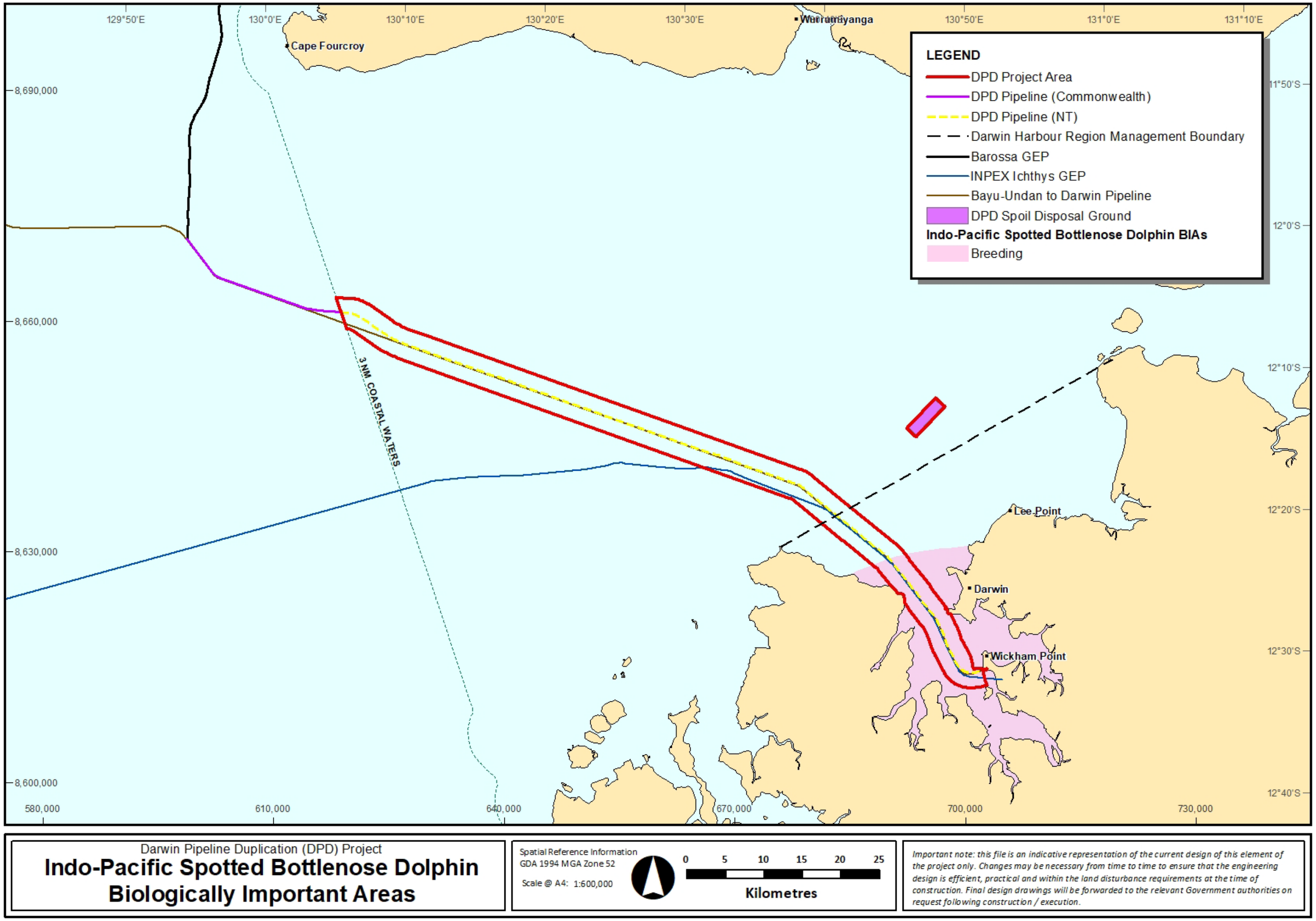

Figure 5-9: Spotted bottlenose dolphin BIA

Table 5-6: Threats from recovery plans, conservation advice and wildlife conservation plans relevant to the activity

Name	Recovery Plan/Conservation Advice/ Management Plan	Threats identified as relevant to the activity	Addressed (where relevant)
All vertebrate fauna	Threat Abatement Plan for impacts of marine debris on vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018)	Marine debris	**Section 7.6.8** **Section 7.7.1**
Marine reptiles			
All marine turtles	National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds (Commonwealth of Australia, 2020b)	Light pollution	**Section 7.6.5**
	Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017a)	Deteriorating water quality	**Section 7.6.2** **Section 7.6.5** **Section 7.6.7** **Section 7.6.9** **Section 7.7.2** **Section 7.7.3** **Section 7.7.4**
		Marine debris	**Section 7.6.8** **Section 7.7.1**
		Loss of habitat	**Section 7.6.2** **Section 7.6.9** **Section 7.7.3**
		Light pollution	**Sections 7.6.5**
		Vessel disturbance	**Section 7.6.3** **Section 7.6.6** **Section 7.7.1**
Leatherback turtle	Approved Conservation Advice for *Dermochelys coriacea* (Leatherback Turtle) (DEWHA, 2008)	Boat strike	**Section 7.6.3** **Section 7.7.3** **Section 7.7.1**
Seabird and shorebirds			
All seabirds and shorebirds	National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds (Commonwealth of Australia, 2020b) Wildlife Conservation Plan for Seabirds (Commonwealth of Australia, 2020c)	Light pollution	**Sections 7.6.5**
		Habitat loss and degradation	**Section 7.6.2** **Section 7.6.5** **Section 7.6.7** **Section 7.6.9**

Name	Recovery Plan/Conservation Advice/ Management Plan	Threats identified as relevant to the activity	Addressed (where relevant)
	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015)		**Section 7.7.2** **Section 7.7.3** **Section 7.7.4**
Common sandpiper	Wildlife Conservation Plan for Migratory Shorebirds (Commonwealth of Australia, 2015)	Pollution and contaminants	**Section 7.6.2** **Section 7.6.5** **Section 7.6.7** **Section 7.6.9** **Section 7.7.2** **Section 7.7.4**
		Habitat loss and degradation	**Section 7.6.2** **Section 7.6.5** **Section 7.6.7** **Section 7.6.9** **Section 7.7.2** **Section 7.7.3** **Section 7.7.4**

5.5.1.2 Marine reptiles

There are six species of marine turtle known to occur in NT waters, of these only green, hawksbill and flatback turtles are known to occur in Darwin Harbour regularly. Olive ridley and loggerhead turtles are known to occasionally occur in Darwin Harbour, and leatherback turtles are unlikely to occur in the Harbour as they are an oceanic species (Whiting, 2001; Whiting, 2003). The closest nesting sites to the Project Area are Casuarina Beach and Cox Peninsula beaches, although these are not considered significant nesting areas and Casuarina Beach is additionally a popular recreational area (Pendoley Environmental, 2022). Other more significant turtle nesting sites in the region include Bare Sand Island and Quail Island, located approximately 50 km from Darwin and over 25 km from the Project Area near the mouth of Bynoe Harbour.

5.5.1.3 Marine mammals

Dolphin species are the most recorded marine mammal in Darwin Harbour, with the Australian snubfin (*Orcaella heinsohni*), Indo-Pacific humpback (*Sousa chinensis*) and Indo-Pacific spotted bottlenose (*Tursiops aduncus*) having known populations in Darwin Harbour. There are approximately 150 individuals across all species thought to inhabit the Darwin region (Brooks & Pollock, 2015).

Dugongs (*Dugong dugon*) are also known to occur in the Darwin region. Ichthys NEMP dugong monitoring estimates approximately 180 to 300 individuals inhabit the Darwin Region (Cardno, 2014).

5.5.1.4 Other fauna

5.5.1.4.1 Bony fishes and sharks

Darwin Harbour supports an abundance of fish species across an array of habitats. There is a diverse range of species within the harbour, from small site-specific species such as gobies, cardinals, and pipefish to larger species of recreational and commercially importance such as mackerel, trevallies, and barramundi. Barramundi is the most targeted recreational species in the Northern Territory accounting for 26% of total recreational catch; however, barramundi only accounts for 5% of total catch in Darwin Harbour. Jewfish are the most targeted species in Darwin Harbour followed by golden snapper.

Juvenile recreationally and commercially important fish species utilise mangroves within Darwin Harbour for habitat.

Three protected sawfish species listed on the PMST search results have been recorded within the Darwin Harbour region—the dwarf sawfish (*Pristis clavata*), freshwater sawfish *(Pristis pristis* or *Prisitis microdon*) and green sawfish (*Pristis zijsron*). However, they are unlikely to be encountered in the Project Area.

Whale sharks are known to migrate to Australian waters seasonally, aggregating at Ningaloo Reef and in the Coral Sea following surges in food productivity. The migratory paths of whale sharks are not known to include Darwin Harbour and records from NT coastline are anecdotal (Woinarski *et al*., 2007).

5.5.1.4.2 Seabirds and shorebirds

Of the 37 species of migratory shorebirds that regularly visit Australia (Commonwealth of Australia, 2017b; Lilleyman *et al*., 2018), 25 of them occur along the coastlines of Darwin Harbour, which has a variety of coastal habitats that migratory shorebirds use during the non-breeding season (Lilleyman *et al*., 2018). This includes natural sites such as beaches, rocky reefs, intertidal sand and mud flats, but also an artificial site – the dredge spoil disposal ponds at Darwin Port's East Arm Wharf.

Lilleyman *et al*. (2018) undertook aerial surveys of Darwin Harbour and recorded 724 individuals of 19 species of bird during the low tidal phase of the survey and at high tide recorded 789 individual shorebirds belonging to 13 species. The study was focused on the Far Eastern curlew (*Numenius madagascarensis*), two flocks of which were identified in numbers that meet the threshold for protection of threatened shorebirds under the EPBC Act. One flock was recorded at East Arm Wharf, where large congregations assemble frequently. The other flock was at a saltpan, south-east of East Arm Wharf, adjacent to the Darwin LNG Plant (although it was noted that this roosting site may not be available at the highest tides) (Lilleyman *et al*., 2018).

5.5.1.4.3 Phytoplankton

Inner Darwin Harbour is known to have low concentrations of bio-available nutrients, low light levels and high turbidity which limits the growth of phytoplankton. The large tidal range also ensures that the Harbour is well flushed. Ichthys NEMP monitoring found low biomass of phytoplankton indicated by low chlorophyll-a fluorescence, although there was a slight increase in phytoplankton biomass during the wet season compared to the dry season. This could be due to the additional nutrient input from increase rainfall and subsequent runoff. Variations in phytoplankton biomass within Darwin Harbour follows complex patterns indicating that multiple factors may influence the productivity of phytoplankton in the Harbour.

5.6 Community and economy

5.6.1 Socio-economic environment

Socio-economic activities that may occur within the Project Area and surrounds including recreational, traditional and commercial fishing, shipping, oil and gas production, defence activities and tourism, as summarised in **Table 5-7**.

More detailed descriptions of socio-economic considerations are provided in the DPD NT EPA Referral (BAA-201 0003; Santos, 2021).

Table 5-7: Summary of socio-economic activities that occur within the Project Area

Value/ sensitivity	Description
Commercial fisheries – Commonwealth	The Northern Prawn Fishery is the only active Commonwealth managed fishery overlapping the Project Area. There are three other inactive or low operating (less than five vessels active in the fishery each year since 2005) Commonwealth managed fisheries overlapping the Project Area: Southern Bluefin Tuna Fishery, Western Tuna and Billfish Fishery and the Western Skipjack Tuna Fishery (Commonwealth of Australia, 2020d; DAFF, 2022).
Commercial fisheries – NT	There are five NT managed fisheries that intersect the Project Area: Coastal Line, Demersal, Offshore Net and Line, Spanish Mackerel, and Aquarium Fishery.
Recreational fishing	Recreational fishing does occur within the Project Area. The Darwin Harbour/Surrounds fishing zone supporting 63% of total fishing effort within the Greater Darwin Area (Matthews *et al*. 2019).
Traditional fishing	Traditional Australian Indigenous fishing in NT waters predominately occurs within inshore tidal waters. Approximately 55% of NT's coastline is owned by Traditional Aboriginal Owner groups in the Northern Land Council region (NLC, 2022).
Shipping	The closest major commercial port to the Project Area is Darwin. The Darwin Port Corporation serves multiple shipping and cargo markets, including cruise and naval vessels, livestock exports, dry bulk ore, offshore oil and gas rig services, and container and general cargo. The Australian Maritime Safety Authority (AMSA) shipping routes close to the Project Area are shown in **Figure 5-12**.
Tourism	Within Darwin Harbour common tourism/recreational activities include fishing, boating, scuba-diving, sailing, water-skiing, and beach use.
Defence	The Project Area intersects a Central Defence Practice Area of the Darwin Air Weapons Range (AWR), a maritime military zone administered by the Department of Defence. The Project Area is also nearby to the North Australian Exercise Area (NAXA) Defence Training Area approximately 3km to the South

Value/ sensitivity	Description
Petroleum industry	Several offshore petroleum projects are in operation and there is considerable exploration activity within the NMR; however, only the existing INPEX Ichthys and Santos Bayu-Undan to Darwin gas export pipelines overlap with the Project Area.
Aboriginal heritage	There are four registered/recorded sacred sites within Darwin Harbour within or adjacent to the Project Area: three rocky areas and shoals on the western side of the Harbour and an underwater sand and rock bar outside the mouth of the Harbour, north of Cox Peninsula. Santos has received an Authority Certificate from the AAPA for the DPD Project (Authority Certificate C2022/098) and will abide by conditions of the certificate.
Maritime heritage	Five historic shipwrecks listed under the *Underwater Cultural Heritage Act 2018* (Commonwealth) are overlapped by the Project Area: I-124 Japanese Submarine (1942) 800 m radial protection zone, Yu Han 22 unlisted protection zone, Song Saigon (1982) unlisted protection zone, Mauna Loa United States Army Transport ship (USAT) (1942) 100 m radial protection zone and Meigs USAT (1942) unlisted protection zone (DCCEEW, 2022b). Santos has undertaken maritime heritage surveys within the Project Area to determine the presence of additional maritime heritage objects and will apply measures to ensure these are not impacted.

5.6.1.1 Commercial fishing and aquaculture

5.6.1.1.1 Commonwealth fisheries

The Northern Prawn Fishery is the only active Commonwealth managed fishery that overlaps the Project Area (Santos, 2021). The Commonwealth managed Southern Bluefin Tuna Fishery, the Western Tuna and Billfish Fishery and the Western Skipjack Tuna Fishery overlap with the Project Area but have been excluded from assessment as these fisheries are either inactive or operate at extremely low levels (<5 vessels active each year since 2005) within or nearby the Project Area (DAFF, 2022; Santos, 2021).

5.6.1.1.2 Northern Territory fisheries

Northern Territory managed fisheries include the Aquarium Fishery, the Offshore Net and Line Fishery, the Spanish Mackerel Fishery, the Coastal Line Fishery, and the Demersal Fishery (Santos, 2021). The Aquarium Fishery includes freshwater, estuarine, and marine habitats to the outer boundary of the Australian Fishing Zone (AFZ), which is 200 nm offshore (Santos, 2021). The Offshore Net and Line Fishery and the Spanish Mackerel Fishery extend from the high water mark of NT waters to the outer boundaries of the AFZ (Santos, 2021). The Demersal Fishery extends 15 nm from the NT low water mark to the outer limit of the AFZ, excluding the area of the Timor Reef Fishery (Santos, 2021). The Coastal Line Fishery extends seaward from the high water mark to 15 nm from the low water mark, covering the entire NT coastline (Santos, 2021).

The Aquarium Fishery is a small-scale, multi-species fishery that is active within the Project Area (Santos, 2021). Licencees employ several types of nets, hand pumps, freshwater pots, and hand-held instruments to collect specimens. The fishery supplies local, interstate, and international pet retailers and wholesalers, including aquarium fishes (mostly rainbowfish, catfish, scats), invertebrates (hermit crabs, snails, whelks, and hard and soft corals) and plants.

The Offshore Net and Line Fishery permits the use of pelagic gillnets and longline gear (Santos, 2021). Pelagic gill nets are the primary gear utilised and are generally set within 15 nm of the coast (Santos, 2021). Most fishing effort is within 12 nm of the coast and immediately offshore in the Gulf of Carpentaria (Northern Territory Government, 2022b). The fishery targets Australian blacktip sharks (*Carcharhinus tilstoni*), common blacktip sharks (*C. limbatus*) and grey mackerel (*Scomberomorus semifasciatus*), other shark species (i.e. hammerhead, bull, tiger, pigeye, lemon, winghead and dusky whalers) and finfish (i.e. Spanish mackerel, longtail tina, black pomfret) are also caught by the fishery (Northern Territory Government, 2021). There is potential for fishing to overlap with the Project Area; however, stakeholder consultation conducted by Santos (2021) only identified one licence holder that may fish off the south-west end of the Tiwi Islands.

The Spanish Mackerel Fishery permits the use of troll lines, floating handlines, and rods, solely targeting Spanish mackerel (*Scomberomorus commerson*) (Santos, 2021). Most of the fishing effort occurs around reefs, headlands, and shoals off the western and eastern mainland coast and near islands including Bathurst Island, Groote Eylandt, and the Wessel Islands (Northern Territory Government, 2021). In 2012, there were 16 fishery licences with 12 actively operating (Santos, 2021). There is potential for fishing to occur close to or within the Project Area. Stakeholders have advised during stakeholder consultation by Santos (2021), that there is potential for fishing to occur within the southern extent of the original Barossa GEP (Santos, 2021).

The Coastal Line Fishery permits the use of a variety of gear types including rod and line, hand lines, cast nets (for bait only), scoop nets and gaffs (Northern Territory Government, 2016a). Drop lines and five fish traps are permitted beyond 2 nm from the coast; however, fish traps are only permitted in the Eastern zone of the fishery (Northern Territory Government, 2016b). Black jewfish and golden snapper are the main targeted species of the fishery, although emperor, cod and other snapper species are

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caught as bycatch. Fishing effort is concentrated within nearshore waters, therefore there is potential for fishing to occur within or close to the nearshore Project Area.

The Demersal Fishery permits the use of fish traps, hand lines, droplines, and semi-demersal trawl nets (Northern Territory Government, 2022). It is important to note that semi-demersal trawl nets are only permitted in two defined multi-gear areas (Northern Territory Government, 2022). Trap catch is mainly goldband snapper and red snapper with red emperor and cod caught as bycatch (Northern Territory Government, 2022). Trawl catch is mainly saddletail snapper and crimson snapper with painted sweetlip, redspot emperor and goldband snapper caught as bycatch. There are 18 licences currently issued for the fishery (Santos, 2021). Most fishing effort occurs within deep offshore waters along the Timor Reef Fishery eastern boundary in water depths 80 – 100 m, therefore there is low potential for fishing to overlap with the Project Area.

Most fisheries are not permitted to operate within Darwin Harbour, except for the Coastal Line Fishery and Aquarium Fishery (DPIR, 2015). Therefore there is little to no commercial fishing taking place within Darwin Harbour.

The Darwin Aquaculture Centre is located on Channel Island in the Middle Arm Peninsula. It is a research facility undertaking a range of research and development projects on several species including pearl oysters, sea cucumbers, giant clams, prawns, barramundi, mud crabs, reef fish, as well as undertaking several disease investigations (Northern Territory Government, 2018).

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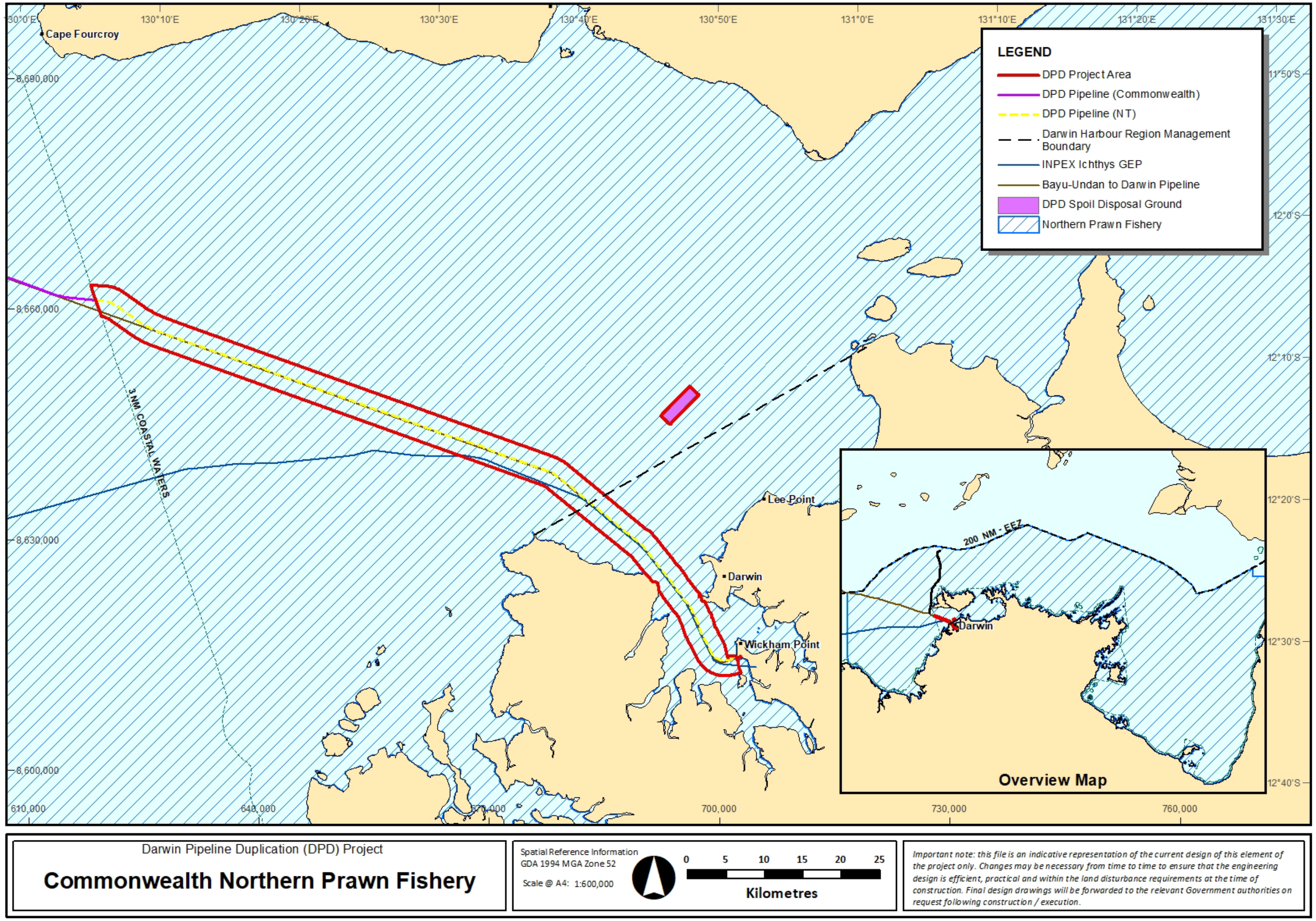

Figure 5-10: Commonwealth managed Northern Prawn Fishery

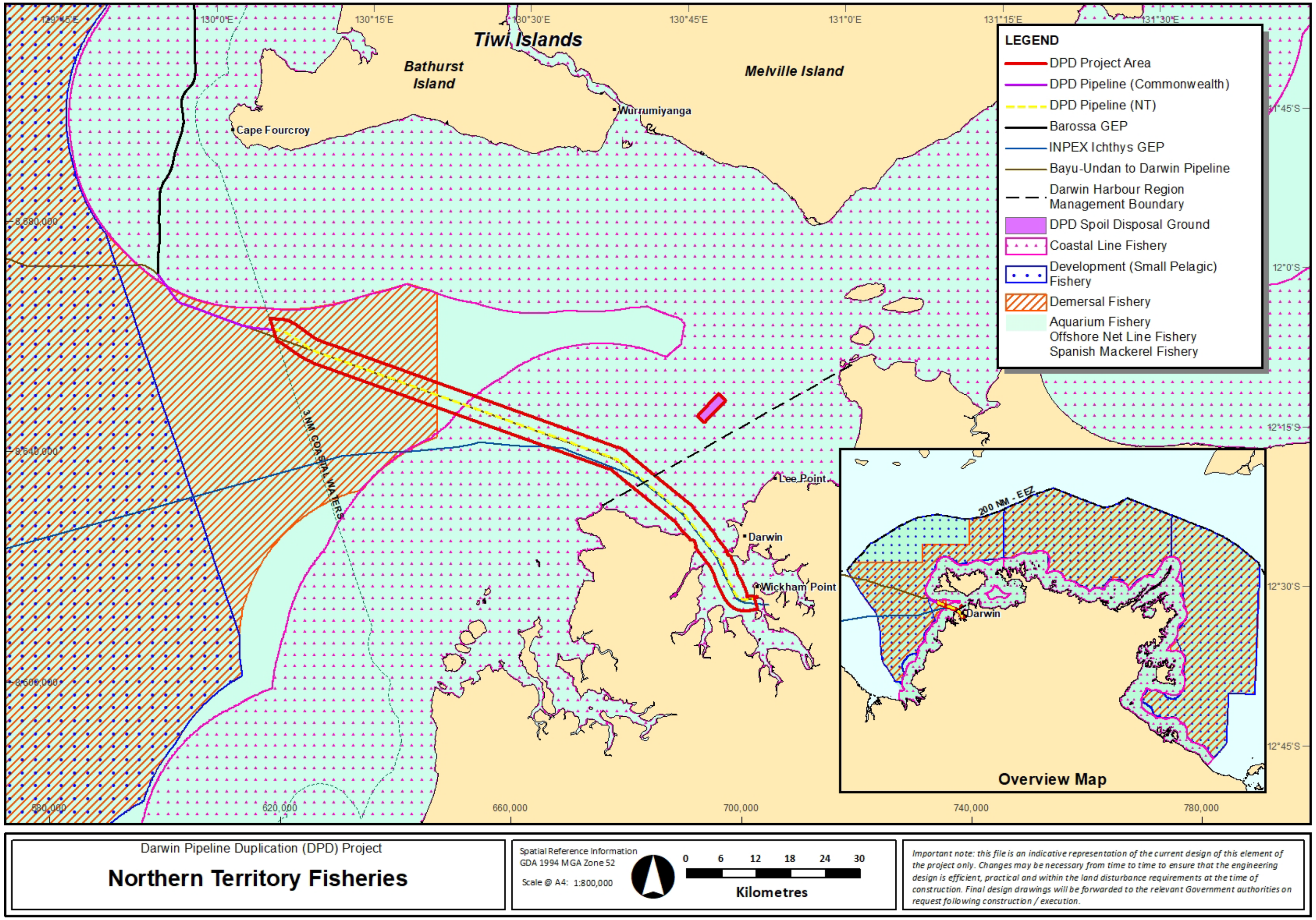

Figure 5-11: Northern Territory managed commercial fisheries

5.6.1.2 Shipping

Vessel traffic data from the AMSA Marine Traffic Database (AMSA, 2021) for the Project Area during March 2021 is shown in **Figure 5-12**, which shows the Project Area intersects areas of high shipping traffic.

Shipping traffic in the offshore NT waters of the Project Area is relatively light; however, at the approach to Darwin Harbour, and within the harbour itself, several notable shipping traffic lanes converge to create a high-density shipping traffic area that overlaps with the Project Area.

The Port of Darwin recorded 1,510 trading vessel visits in 2021-2022 (Darwin Port Authority, 2022) with traffic in the Port typically influenced by number of the well-established industrial and commercial facilities that receive a wide of maritime traffic (i.e. cargo, livestock vessels, LNG tankers and cruise ships).

Whilst 61 cruise ships visited Darwin Port in 2020-21, with the majority travelling between South East Asia and the eastern coast of Australia, this number dropped significantly with the onset of the Covid-19 pandemic with 36 cruise ships recorded in 2021-22. Regional commercial shipping activities are also associated with support and supply vessels servicing oil and gas offshore facilities. For example, in 2021-22, there were 283 rig tender vessel calls to Darwin Port facilities. The Port forms the main base for oil and gas contracted supply vessels that support northwest Australia offshore activities (Darwin Port Authority, 2021).

Although Darwin Port remains the primary active port in the region, there is small-scale port activity at the Tiwi Islands. Port Melville is located on Melville Island (122 km north of Darwin) and the wharf infrastructure at Port Melville was constructed in 2013. Shipping traffic associated with the route between Darwin Port and the Tiwi Islands, including Port Melville, is shown in **Figure 5-12**.

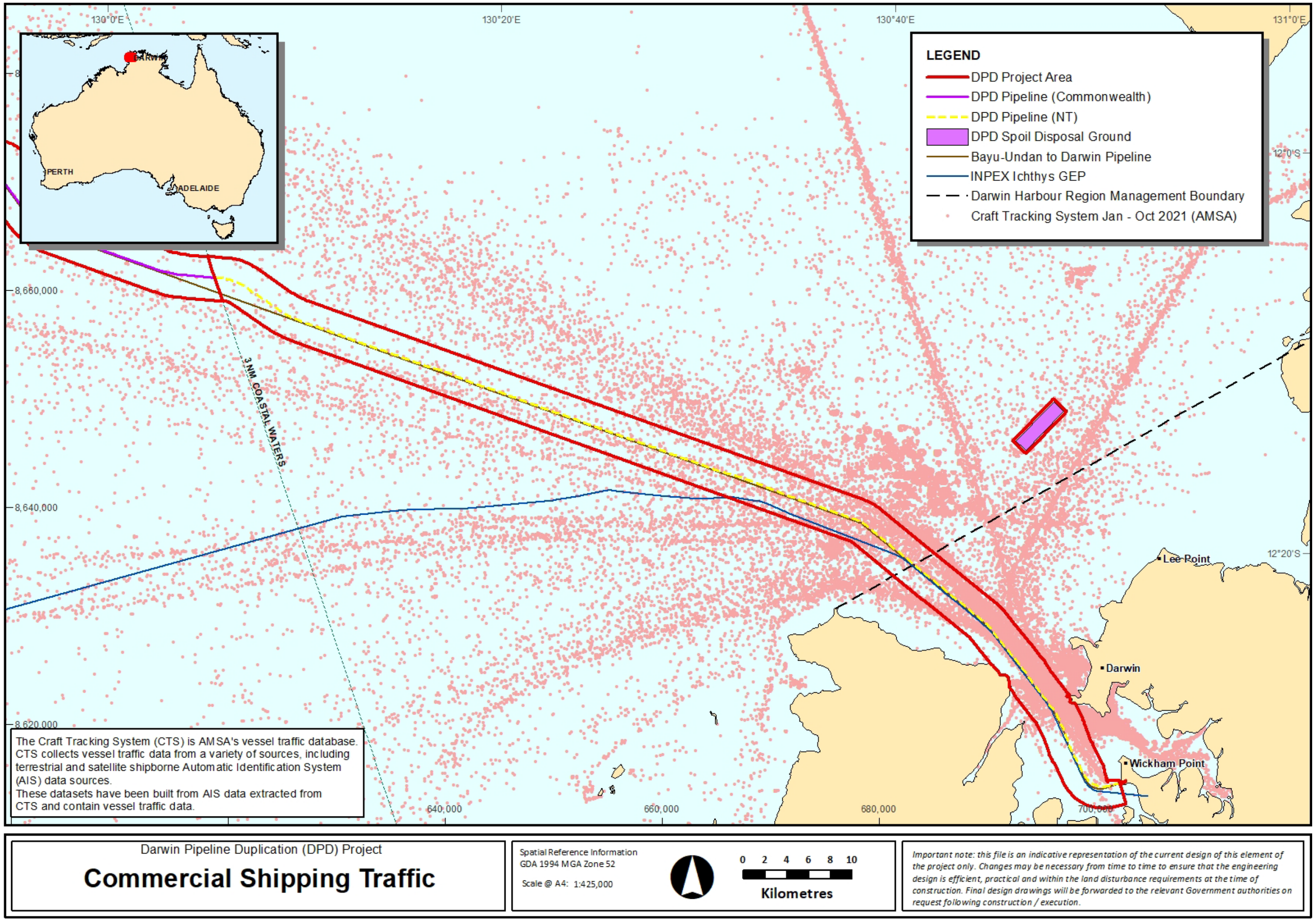

Figure 5-12: Commercial shipping traffic

5.6.1.3 Recreational activities and tourism

During 2021 there were 1,283,000 visitors to the Northern Territory, which contributed an estimated $1.84 billion to the local community (Tourism NT, 2022). This was substantially lower than 2019, with 2,001,000 visitors contributing an estimated $2.6 billion, likely due to the reduction in international visitation resulting from border closures (Tourism NT, 2022).

The Darwin Harbour supports a range of commercial and recreational uses, including fisheries, tourism and recreational shipping and boating activities. Fishing tours often frequent Fenton Patches located approximately 30 km north-west of Darwin Harbour. Recreational fishers also visit Casuarina Bay and Lee Point.

The water surrounding Middle Arm Peninsula is used for recreational fishing, sailing, and boating. However, tour boats tend to avoid this section of the Harbour due to navigational hazards associated with the shallow nearshore waters (URS, 2002).

5.6.1.4 Traditional fishing

Approximately 55% of NT's coastline is owned by Traditional Aboriginal Owner groups in the Northern Land Council region (NLC, 2022). Several areas within this coastal region have been declared Aboriginal sacred sites, which are restricted from other recreational and commercial fishing. Within Darwin Harbour, fishing and foraging for food and other resources occurs within the intertidal regions, mainly around Nightcliff, Coconut Grove, Kululuk, Sadgroves Creek, and Lee Point. As such, Indigenous fishing is likely to occur within the coastal areas of the Project Area but is likely to be restricted mainly to NT coastal waters.

5.6.1.5 Defence

A search on National Map (DCA, 2021) was undertaken and identified that the Project Area intersects the Darwin Air Weapons Range (AWR) Central Defence Practice Area and is nearby to the Australian Exercise Area (NAXA) Defence Training Area (approximately 3 km to the south), as shown in **Figure 5-13**.

5.6.1.6 Petroleum industry

Several offshore petroleum projects are in operation and there is considerable exploration activity within the NMR.

The Project Area contains two existing gas export pipelines (GEPs), the Bayu-Undan to Darwin GEP (approx. 50-100 m to the west of the proposed DPD Project pipeline route) and the INPEX Ichthys GEP which is further to the west of the Bayu-Undan to Darwin GEP (**Section 2.2**).

The two primary LNG facilities on Middle Arm Peninsula are the DLNG Facility operated by Santos, and the Ichthys LNG Project operated by INPEX. The Project pipeline will connect into the existing DLNG Facility and the Project Area overlaps the DLNG Facility.

The DLNG Facility is a gas processing facility which includes units for:

+ Gas receiving facilities (including the beach valve, pig receiver and meter station for the Bayu-Undan to Darwin pipeline)
+ Acid gas removal
+ Dehydration and mercury removal
+ Propane and ethylene refrigeration
+ Liquefaction, methane compression and nitrogen rejection.

There are several exploration and production permits and leases throughout the NT and Commonwealth waters adjacent to the Project Area, which include current exploration and production activities including platforms, FPSO (floating, production, storage and offloading) vessels, pipelines, and drilling.

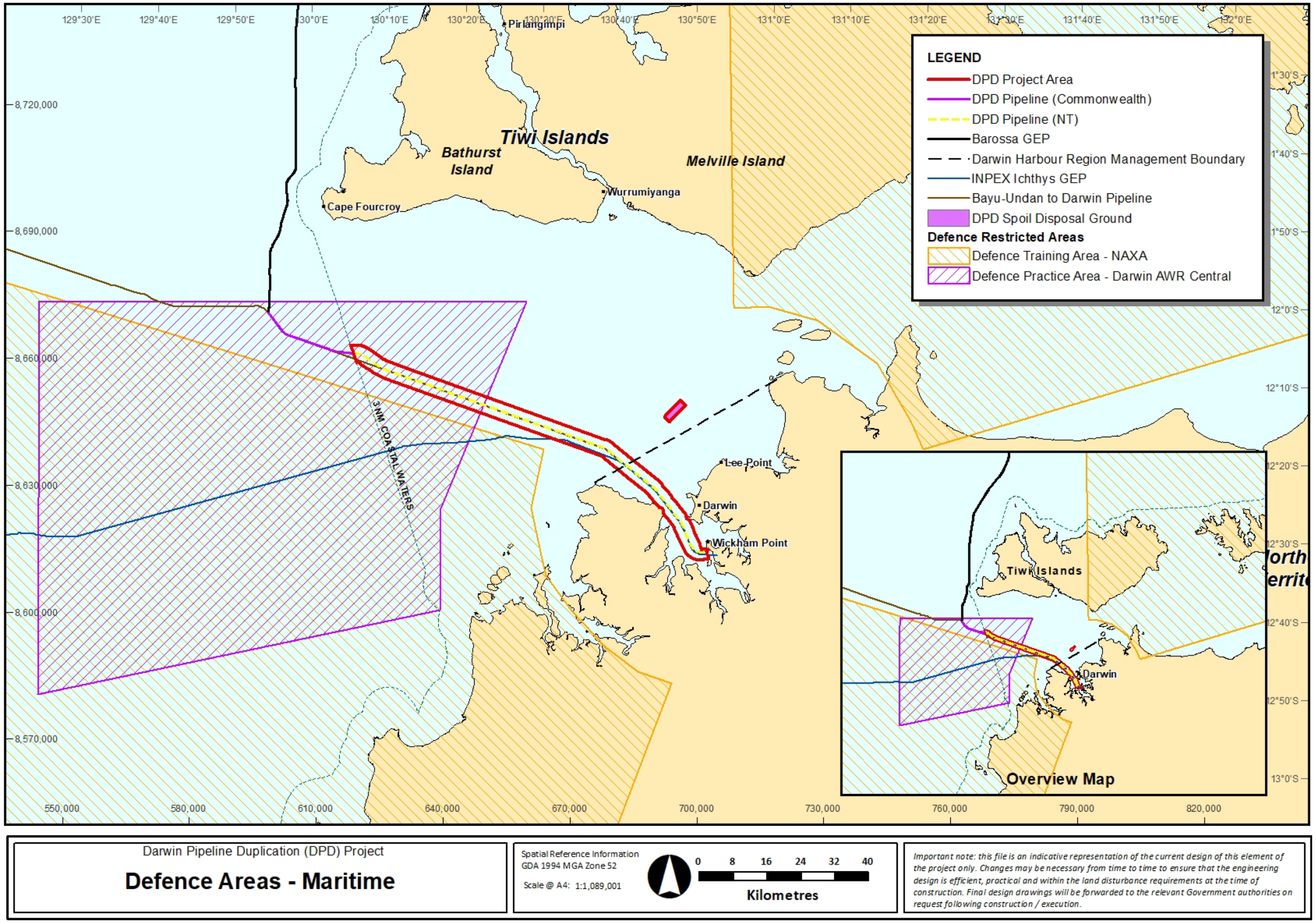

Figure 5-13: Defence areas – maritime

5.6.2 Culture and heritage

5.6.2.1 Cultural environment

Darwin Harbour is host to a wide range of historical, spiritual and heritage values that are significant to the people of the Northern Territory and Australia. These values have been broadly categorised as either Aboriginal and non-Aboriginal values and are described in more detail in the following **Sections 5.6.2.1.1** and **5.6.2.1.2**. Further detail of the cultural environment can be found in Santos' NT EPA referral (Santos, 2021).

5.6.2.1.1 Aboriginal sacred sites

Sacred sites are places within the landscape that have a special meaning or significance under Aboriginal tradition, this can include hills, rocks, waterholes, trees, plains, lakes, billabongs (AAPA, 2022). There are many sacred sites within Darwin Harbour and the surrounding waters, all sacred sites within the Northern Territory are protected under the *Northern Territory Aboriginal Sacred Sites Act 1989*. In coastal and sea areas, sacred sites may include features which lie both above and below the water (AAPA, 2022). Sacred sites are surrounded by "restricted works" areas in which no land or maritime development works of any kind is allowed, under the *Northern Territory Aboriginal Sacred Sites Act 1989*.

There are sacred sites within Darwin Harbour that are adjacent to or overlap the Project Area (INPEX, 2010). These sites as identified in INPEX (2010), include rocky areas or shoals on the western side of the Darwin Harbour, and an underwater sand and rock bar at the mouth of the harbour, north of the Cox Peninsula.

Santos has received an Authority Certificate from AAPA for the DPD Project (Authority Certificate C2022/098) and will ensure conditions of the certificate and the requirements of the *Northern Territory Aboriginal Sacred Sites Act 1989* are met including adherence to requirements to avoid work in a restricted works area (RWA) in Darwin Harbour. Refer to (**Figure 5-14**) for subject lands area covered by the Authority Certificate in Darwin Harbour.

5.6.2.1.2 Non-Aboriginal heritage sites

Darwin Harbour is host to several shipwrecks and sunken aircraft, some of which are protected under the *Heritage Act 2011* (NT) and/or the *Underwater Cultural Heritage Act 2018* (Commonwealth) (**Figure 5-16**). Most wrecks are associated with either, the bombing of Darwin in 1942 or Cyclone Tracy in 1974. The Project Area is within ~2 km east of the oldest known wreck in Darwin Harbour the *SS Ellengowan*, a nineteenth-century Norwegian-built iron steamer, which is of high significance to maritime archaeology (Northern Territory Government, 1999; **Figure 5-15**).

The *Underwater Cultural Heritage Act 2018* may declare a protected zone around wrecks which require a permit to enter, there are currently three protected zones having closed water orders in NT. These are the Japanese submarine I-124 (1942), Florence D (1942) and Sanyo Maru (1937) (**Figure 5-15**). The regional harbourmaster has also ordered the Booya and Catalina 6 wrecks to have closed water controls over them and permission from the Heritage Branch is needed to enter the zones.

The Australian National Shipwrecks Database has identified five historic wrecks that overlap the Project Area, all of which are listed under the Underwater Cultural Heritage Act (DCCEEW, 2022b). These wrecks are the Japanese submarine I-124 (1942) 800 m radial protection zone, Yu Han 22 unlisted protection zone, Song Saigon (1982) unlisted protection zone, Mauna Loa USAT (1942) 100 m radial protection zone and Meigs USAT (1942) unlisted protection zone (DCCEEW, 2022b). The pipeline route has been deliberately altered to avoid the I-124 and Mauna Loa USAT wrecks.

No European heritage is currently listed at Wickham Point, with the remnants of artefacts documented and removed prior to the construction of the DLNG facility. There are no World, National or Commonwealth Heritage places within or near the Project Area.

Santos has engaged the services of a maritime archaeologist (Cosmos Archaeology) to undertake an underwater heritage assessment of the pipeline route and surrounding buffer and will work with the Heritage Branch of the NT Department of Territory Families, Housing and Communities to ensure disruption to underwater heritage objects are avoided or minimised as far as practicable and that requirements of the *Heritage Act 2011* are met.

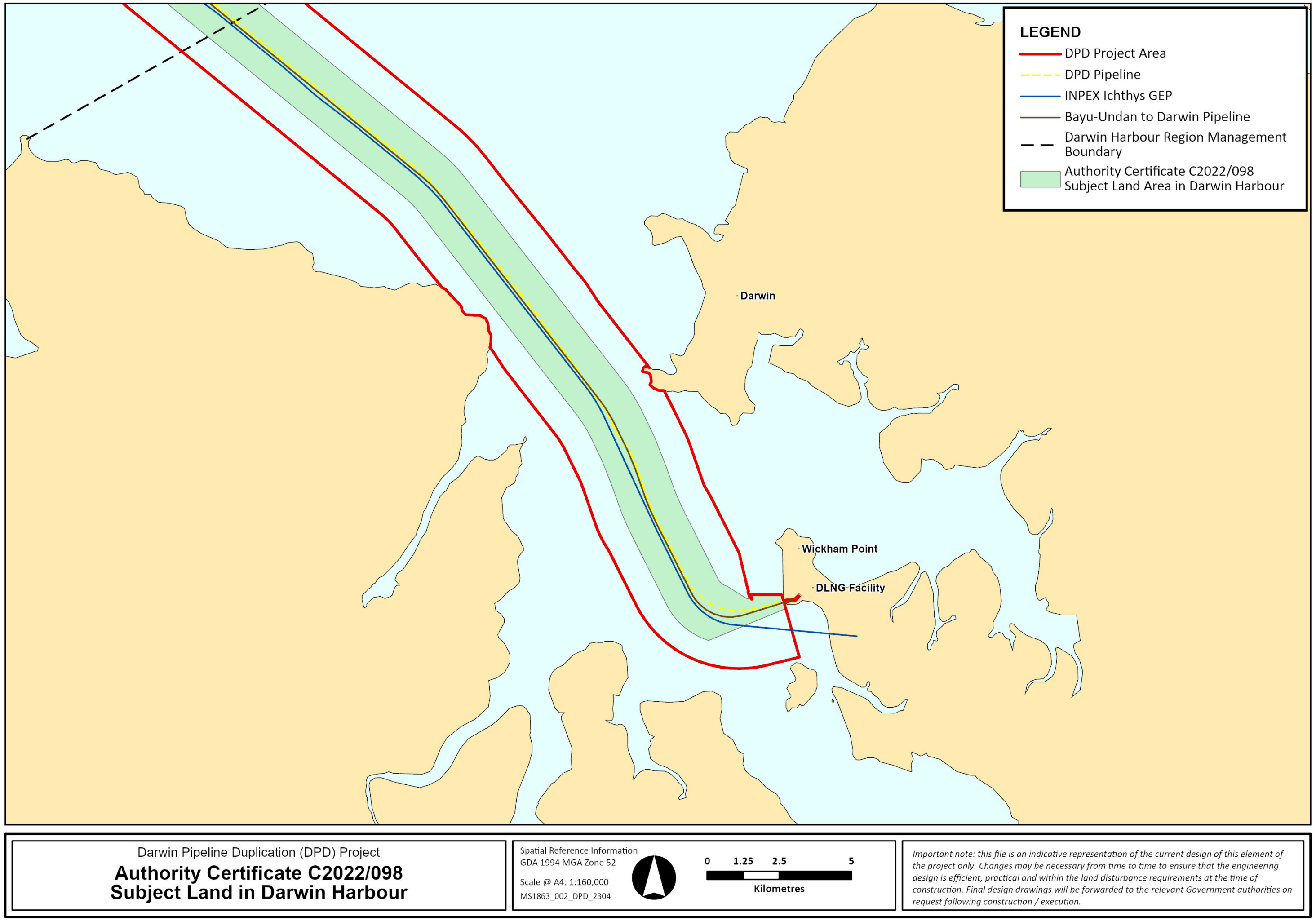

Figure 5-14: Authority Certificate C2022/098 subject land area in Darwin Harbour

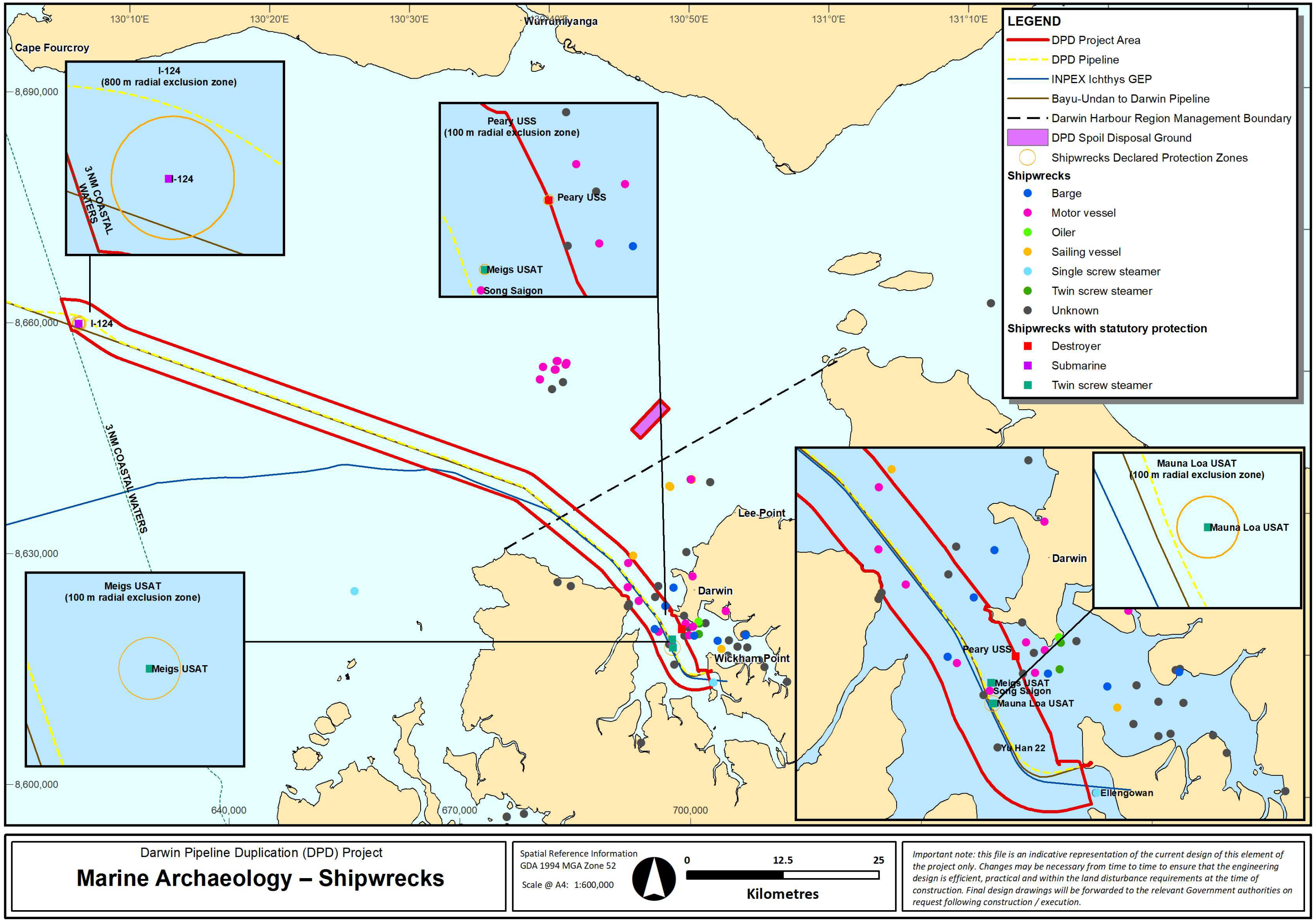

Figure 5-15: Shipwreck locations within and adjacent to Darwin Harbour

5.7 Windows of sensitivity

Timing of peak activity for threatened species and other sensitive receptors is outlined in **Table 5-8**.

Table 5-8: Windows of sensitivity in the vicinity of the Project Area

Key	
	Peak activity, presence reliable and predictable
	Lower level of abundance/activity/ presence
	Very low activity/presence
	Activity can occur throughout year

Footnotes

[1] The 'run-off' is towards the end of the wet season and is the peak Barramundi fishing season for recreational fishers (https://northernterritory.com/things-to-do/outdoor-activities/fishing/fishing-seasons/the-run-off)

[2] Chatto & Baker (2008)

Receptors (critical lifecycle stages)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Seagrass												
Coral (spawning periods)												
Larger Macroalgae												
Turf Algae										Build-up season		
Mangroves (increased productivity)												
Other benthic and terrestrial habitats												
Fish/sharks and fisheries species												
Barramundi			'The Run-Off'[1]									
Goldband snapper	Spawning								Spawning			
Black jewfish								Spawning				
Grey mackerel									Spawning			
Narrow-barred Spanish mackerel										Spawning		
Marine mammals												
Dugong (breeding)	Breeding							Breeding				
Australian snubfin Dolphin	Breeding											
Indo-Pacific Humpback Dolphin	Breeding											
Spotted Bottlenose Dolphin									Breeding			
Marine reptiles												
Hawksbill turtle (resident adult and juveniles[2])	Widespread throughout North Australian waters, highest density of adults and juveniles over hard bottom habitat (coral reef, rocky reef, pipelines, etc.)											
Flatback turtle (resident adult and juveniles[2])	Widespread throughout North Australian, increased density over soft bottom habitat 10 to 60 m deep, post-hatchling age classes and juveniles spread across shelf waters											
Flatback turtle (nesting[2])												
Green turtle (resident adult and juveniles[2])	Widespread throughout North Australian, highest density associated with seagrass beds and macro algae communities, high-density juveniles in shallow waters off beaches, among mangroves and in creeks											
Loggerhead turtle (resident adult and juveniles[2])	Widespread throughout the North Australian, increased density associated with soft bottom habitat supporting their bivalve food source, juveniles associated with nearshore reef habitat											
Socio-economic												
Northern Prawn Fishery												
Oil and gas												
Shipping												
Tourism/recreational												

6 Impact and risk assessment

This CEMP has employed a systematic impact and risk assessment process for the environmental management of the DPD Project construction activities. The impact and risk assessment process has been developed in line with Santos' Environmental Impact Identification (ENVID) process and is consistent with the requirements of the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 for NT waters and the NT EPA Draft Guideline for the Preparation of an Environmental Management Plan (NT EPA, 2015).

6.1 Conceptual site model

A conceptual site model, as required by the NT EPA, is a written or illustrated representation of the nature, fate and transport of discharges, wastes or contaminants that allows assessment of potential and/or actual exposure of the environment to contaminants (NT EPA, 2015). The Conceptual Site Model for this CEMP is embedded within the risk assessment which details receptors and pathways, refer **Table 6-7**.

6.2 Impact and risk assessment methods

The CEMP environmental impact and risk assessment was performed consistent with the Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02) and identification of management actions was consistent with Santos' Environment Hazard Controls Procedure (SMS-EXA-OS01-PD02). An environmental aspect, for the purpose of this environmental management plan, is defined as characteristics of the construction activities that could potentially affect the environment.

6.2.1 Identification of environmental hazard

Environmental hazards for this CEMP were identified using Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021), DPD Project Basis of Approval (BAS-210 0005; Santos, 2022) and discussion by the DPD Project team and environmental specialists. Key DPD Project construction activities and associated hazards and results from key technical studies were presented during ENVID workshops to inform the impact and risk assessment process.

6.2.2 Standard controls

The standard controls identified in **Table 6-7** were drawn from:

+ Santos' DPD Project NT EPA Referral (BAA-201 0002; Santos, 2021)
+ Santos' environmental plans and procedures for similar activities
+ Regulator approved management plans developed by other proponents.

Additional controls were provided by ENVID workshop attendees based on their relevant experience.

6.2.3 Impact and risk assessment

All hazards identified were assigned a consequence level following the six levels and criteria outlined in Santos' Risk Matrix Procedure (SMS-LRG-OS01-TP02). More detailed criteria were developed to assist in addressing NT EPA Key Environmental Factors. These are the NT EPA consequence descriptors shown in **Table 6-1**.

The consequence is defined as the resulting impact from an event occurring. Consequence level for this assessment was based on the credible worst-case scenario and assumed no management actions were in place. Categories of environmental consequence and detailed definitions of each severity level are outlined in **Table 6-2**.

The likelihood can be described as the probability that the described consequence will occur. When determining the likelihood of consequences, proposed prevention and mitigation controls identified to mitigate potential impacts were considered. A detailed description of likelihood levels is outlined in **Table 6-3**.

The consequence and likelihood levels are not presented in this CEMP but are contained in the ENVID documentation. **Section 6.3** and **Table 6-7** outline the residual consequences and likelihoods which is the outcome after standard and additional (as low as reasonably practicable; ALARP) management actions are applied.

A likelihood level was only assigned to unplanned events as per the Santos Risk Matrix Procedures (SMS-LRG-OS01-TP02), shown in **Table 6-4.** The consequence and likelihood for each impact was then assessed to determine the residual impact or risk that remained after proposed standard controls were considered.

Table 6-1: NT EPA Consequence Descriptors

Consequence Level		I	II	III	IV	V	VI
Acceptability		Acceptable	Acceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
Consequence Level Description		**Negligible** No impact of negligible impact	**Minor** Detectable but insignificant change to local population, industry or ecosystem factors Localised effect	**Moderate** Significant impact to local population industry or ecosystem factors	**Major** Major long-term effect on local population industry or ecosystem factors	**Severe** Complete loss of local population industry or ecosystem factors AND/OR extensive regional impacts with slow recovery	**Critical** Irreversible impacts to regional population industry or ecosystem factors
Environmental Receptors	**Marine Ecosystems** Fauna, habitat, conservation significant areas and ecological function, processes and integrity	Short term behavioural impacts only to small proportion of local population and not during critical lifecycle activity. No decrease in local population size / area of occupancy of species / loss or disruption of habitat critical / disruption to the breeding cycle/ vales of a protected area. No introduction of disease and no reduction in habitat area/function.	Detectable but insignificant decrease in local population size and threat to local population viability. Insignificant disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area. Detectable but insignificant loss of area/function of habitat with rapid recovery within 2 years.	Moderate. Significant decrease in local population size but no threat to overall population viability. Significant behavioural disruption or disruption to the breeding cycle of local population / Significant reduction in area of occupancy of species / loss of habitat critical to survival of a species. Modify, destroy, remove or decrease availability of quality habitat to the extent that a long-term decline in local population or function of habitat is likely with recovery over medium term (2-10 years) Introduction of disease likely to cause significant population decline	Long term decrease in local population size and threat to local population viability. Major disruption to the breeding cycle of local population / area of occupancy of species / loss of habitat critical to survival of a species/ values of a protected area Fragmentation of existing population / Loss or change of habitat to the extent that a long-term decline in local population and function of habitat is likely with slow recovery over decades Introduction of disease likely to cause long term population decline	Complete loss of local population, habitat critical to survival of local population or protected area/conservation significant area Widespread (regional) decline in population size or habitat critical to regional population Extensive destruction of local habitat with no recovery or long term (decades) or widespread loss of area or function of primary producers on a regional scale	Complete loss of regional population Complete loss of habitat critical to survival of regional population
	Marine Environmental Quality Water quality, sediment quality, ecosystem health and parameters that support fishing, aquaculture, recreation, aesthetics and cultural/spiritual values	Negligible. No or negligible reduction in physical environment nor decrease in ecosystem function/health. No or negligible loss of value to socio-economic activities	Detectable but localised, short term and insignificant impact to physical environment or ecosystem function/health or value to socio-economic activities. Rapid recovery evident within ~ 2 years.	Significant wide-scale medium term impact to physical environment, decrease in ecosystem function/health or value to socio-economic activities. Recovery over medium term (2-10 years).	Wide-scale, long term impact to physical environment, long term decrease in ecosystem function/health or value to socio-economic activities. Slow recovery over decades.	Extensive impact to/destruction of physical environment with no recovery or shutdown of socio-economic activities Long term (decades) and widespread loss of ecosystem function/health on a regional scale that damages value to socio-economic activities.	Complete destruction of regional physical environment / habitat with no recovery Complete loss of area or function of primary producers on a regional scale

Consequence Level		I	II	III	IV	V	VI
	Coastal Processes Geophysical processes, primary productivity/ nutrient cycling, conservation significant areas/coastal landforms and cultural, aesthetic or recreation values	Short term changes to local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale	Detectable but insignificant loss or change to local geophysical/hydrological processes, area or function of primary producers/nutrient cycling or conservation significant areas with rapid recovery within 2 years.	Moderate. Significant modification, destruction, removal or change of local geophysical/hydrological processes, wide-scale loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with recovery over medium term (2-10 years).	Long term loss or change of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with slow recovery over decades	Extensive destruction of local geophysical/hydrological processes, widespread loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale with no recovery or long term (decades)	Complete loss or change of geophysical/hydrological processes. Complete loss of area or function of primary producers/nutrient cycling or conservation significant areas on a regional scale.
	Community and Economy Includes: fisheries (commercial and recreational); tourism; oil and gas; defence; commercial shipping	No or negligible loss of value of the local industry. No or negligible reduction in key natural features or populations supporting the activity.	Detectable but insignificant short-term loss of value of the local industry. Detectable but insignificant reduction in key natural features or population supporting the local activity.	Significant loss of value of the local industry. Significant medium-term reduction of key natural features or populations supporting the local activity.	Major long-term loss of value of the local industry and threat to viability. Major reduction of key natural features or populations supporting the local activity.	Shutdown of local industry or widespread major damage to regional industry. Permanent loss of key natural features or populations supporting the local industry.	Permanent shutdown of local or regional industry Permanent loss of key natural features or populations supporting the local or regional industry
	Culture and heritage Includes: Indigenous heritage and maritime heritage (i.e. shipwrecks)	No or negligible impact on the area's cultural or heritage values. No or negligible alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Detectable but insignificant impact on one or more of the area's cultural or heritage values. Detectable but insignificant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Significant impact on one or more of the area's cultural or heritage values. Significant alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Major long-term effect on one or more of the area's cultural or heritage values. Major alteration, modification, obscuring or diminishing of the area's cultural or heritage values.	Complete loss of one or more of the area's cultural or heritage values.	Permanent loss of one or more of the area's cultural or heritage values with no recovery.

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Table 6-2: Summary environmental consequence level descriptions

Consequence Level	Consequence Level Description
I	**Negligible** – No impact or negligible impact
II	**Minor** – Detectable but insignificant change to local population, industry or ecosystem factors
III	**Moderate** – Significant impact to local population, industry or ecosystem factors
IV	**Major** – Major long-term effect on local population, industry or ecosystem factors
V	**Severe** – Complete loss of local population, industry or ecosystem factors AND/OR extensive regional impacts with slow recovery
VI	**Critical** – Irreversible impact to regional population, industry or ecosystem factors

Table 6-3: Likelihood descriptions

No.	Matrix	Description
F	Almost Certain	Occurs in almost all circumstances OR could occur within days to weeks
E	Likely	Occurs in most circumstances OR could occur within weeks to months
D	Occasional	Has occurred before in Santos OR could occur within months to years
C	Possible	Has occurred before in the industry OR could occur within the next few years
B	Unlikely	Has occurred elsewhere OR could occur within decades
A	Remote	Requires exceptional circumstances and is unlikely even in the long term

Table 6-4: Risk assessment matrix

		Consequence					
		I	II	II	IV	V	VI
Likelihood	F	Low	Medium	High	Very High	Very High	Very High
	E	Low	Medium	High	High	Very High	Very High
	D	Low	Low	Medium	High	High	Very High
	C	Very Low	Low	Low	Medium	High	Very High
	B	Very Low	Very Low	Low	Low	Medium	High
	A	Very Low	Very Low	Very Low	Low	Medium	Medium

6.3 Residual consequences and risks

6.3.1 Planned events

The residual consequence levels from the planned impacts following implementation of standard and additional (as low as reasonably practicable; ALARP) management actions detailed in **Section 7** are summarised in **Table 6-5**. Given the likelihood of a planned event occurring is 100% (in other words, it will occur), the risk ranking is not assessed. A comprehensive impact assessment for each of the planned events, and subsequent management actions proposed by Santos to reduce the impacts to ALARP and/or acceptable levels are detailed in the following sections. Within the ENVID developed by Santos some environmental aspects had multiple residual consequence ratings since multiple environmental factors were assessed. In these cases the residual consequence of greatest severity was chosen for this summary.

Table 6-5: Summary of the residual consequence levels associated with planned impacts

CEMP section	Planned event impact	Residual consequence
7.6.1	Interactions with other marine users	II - Minor
7.6.2	Seabed and benthic habitat disturbance	II - Minor
7.6.3	Onshore ground disturbance	II – Minor
7.6.4	Noise emissions	II - Minor
7.6.5	Light emissions	II - Minor
7.6.6	Routine vessel discharges	I - Negligible
	Pre-commissioning water extraction and discharges	II - Minor
7.6.8	Atmospheric emissions	I - Negligible
7.6.9	Contingency Pipeline Discharges	II - Minor

6.3.2 Unplanned events

The residual risk levels from unplanned events following implementation of standard and additional (ALARP) management actions (detailed in **Section 7**) are summarised in **Table 6-6**. Comprehensive risk assessments for each of the unplanned events, and subsequent management actions proposed to reduce the risk to ALARP and acceptable levels are detailed in the following sections. Within the ENVID some unplanned events had multiple residual risk ratings since multiple environmental factors were assessed. In these cases the residual risk of greatest severity was chosen for this summary.

Table 6-6: Summary of the residual risk level associated with unplanned risks

CEMP section	Unplanned event risk	Residual risk level
7.7.1	Dropped objects	Low
7.7.2	Introduction of invasive marine species	Low
7.7.3	Unplanned marine fauna interaction	Low
7.7.4	Release of liquid hazardous material	Low
7.7.5	Release of hydrocarbon (offshore bunkering or vessel tank rupture)	Low
7.7.6	Release of dry natural gas	Very Low

6.4 Impact/risk assessment summary

The outcomes of the impact / risk assessment are presented in **Table 6-7**, including reference to the relevant management strategy within this CEMP proposed to manage individual environmental aspects.

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Table 6-7: Summary of impact and risk assessment outcomes

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
Planned impacts							
Interaction with other marine users	Vessel activities including: + Surveys/ROV operations + Pre-lay works + Pipeline installation and pre-commissioning Marine DPD Project infrastructure including: + Pipeline and supporting/stabilising structures (including rock installation) + Pipeline crossings + Cable crossings Coastal DPD Project infrastructure and equipment required to construct it, including: + Temporary causeway/s	Impact to other marine users may occur as a result of the presence of vessels and associated exclusion zones, where applicable, in the Project Area, causing potential inconvenience. For trenching and spoil disposal activities, an expected 11 vessels will be involved, for deep water and shallow pipelay activities an expected 6 and 7 vessels, respectively, will be involved, for rock installation an expected 6 vessels will be involved and for pre-commissioning an expected 4 vessels will be involved. On an ongoing basis, subsea infrastructure may present a hazard to marine users due to the potential for snagging. The temporary physical presence of the causeway structures (approximately 200 m in length) and associated activities at the shore-crossing location may exclude other users from this intertidal/ shoreline area, although given this is within the existing disturbance footprint for the DLNG Facility, interactions are considered unlikely and impact negligible.	**Spatial** Localised around the Project vessels (and vessel exclusion zones, advised through a notice to mariners [NTM], as applicable), pipeline route and shore crossing activities including temporary causeway structures. Vessel exclusion zones are typically 500 m and will apply to Project vessels, including pipelay vessel, construction vessels and dredging vessels. **Temporal** Temporary and intermittent presence of project vessels within the Project Area within a nominal 15-month cumulative period. Ongoing presence of the pipeline within the Project Area once construction has been completed. Temporary presence of causeway structures.	+ Interactions with other marine users including potential displacement from commercial, recreation and tourism areas or alteration of routes to avoid exclusion areas. Turbidity generated from trenching activities may dissuade other users from the area while it is present. + Construction and the presence of a causeway/s at the shore-crossing area may exclude other users from the area during construction.	+ **Community and economy** (commercial fishers, traditional fishing, tourism and recreational activities, shipping traffic and other oil and gas activities)	II-Minor	**Section 7.6.1**
Seabed and benthic habitat disturbance	Pre-lay trenching with: + Cutter suction dredge (CSD) + Trailer suction hopper dredge (TSHD)	**Temporary and permanent infrastructure** Temporary and permanent infrastructure placement, resulting in direct disturbance to seabed, benthic habitat and cultural sites. Temporary	**Spatial** Localised within the Project Area to the pipeline, supporting structure footprints, trenching zones, causeway/s, spoil ground, anchoring footprints and the zones of moderate impact and zones of influence	Temporary and permanent infrastructure Disturbance of benthic habitat Disturbance of the seabed from vessel anchoring or placing of infrastructure and rock could:	**Marine environmental quality** (water quality, physical parameters that support fishing, aquaculture, recreation	II-Minor	**Section 7.6.2**

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
	+ Backhoe dredge (BHD) + Land-based excavators Spoil Disposal at: + Spoil ground + In situ Vessel activities: + Vessel anchoring during pipelay installation (pipelay, water winning, cutter dredge) + Positioning on spuds for back hoe and cutter + Installation of underwater positioning structures Installation of marine DPD Project infrastructure including: + Pipeline installation + ILT installation (including foundations) + Pre-lay span and supporting/stabilising structures including cable crossings and post-lay span rectifications + Rock placement Installation of coastal DPD Project infrastructure and equipment including: + Causeway/s (132 m x 44 m)	disturbance will occur from anchoring and the presence of temporary causeway/s. Permanent disturbance will occur from placement of permanent infrastructure (pipeline, rock protect etc.). Potential change to current flows Alteration of currents within Darwin Harbour will also occur due to temporary causeway/s blocking the flow of water. Trenching and spoil disposal Spoil from trenching areas will be transported to and disposed of in the DPD spoil disposal area in offshore NT waters, which will result in permanent disturbance from smothering due to sedimentation. Spoil from trenching activities at the shore crossing in the intertidal area will be side cast to the lower intertidal area to provide a mitigation to potential acid sulfate soil risk (i.e. to keep wet under most tidal conditions). Dependent upon access by BHD this build-up of spoil will be subsequently removed (if not already dispersed) for disposal to the DPD spoil disposal area in offshore NT waters using a BHD and SHB. **Onshore** Clearing of regrown native grasses and weeds in a previously disturbed area will be required prior to excavating a trench for onshore	derived from sediment dispersion modelling. **Temporal** Construction activities will typically occur for days to months at a site. Temporary causeway/s is in place for the duration of construction activity. Ongoing presence of the pipeline within the Project Area Permanent presence of DPD spoil ground in offshore NT waters Sporadically during high rainfall events due to increased levels of runoff.	Disturb the seabed and result in loss of habitat Impact infauna/ epifauna and primary producers Increase water turbidity and sedimentation Anchoring has the potential to result in disturbance to maritime heritage and sacred sites protected under the *Northern Territory Aboriginal Sacred Sites Act 1989* (NT) and the *Heritage Act 2011* (NT) The pipeline will create an artificial reef that could attract and support marine biota including fish which may benefit recreational fishing resources Rock placement may result in creation of artificial reef that could attract and support marine biota including fish which may benefit recreational fishing resources Creation of barrier to coastal processes Potential disturbance up to 20 m x 200 m in inter-tidal area Potential change to current flows Potential alteration of currents due to temporary project infrastructure with potential for seabed scouring/coastal erosion. Trenching and spoil disposal Increase in sedimentation and reduction in water quality from: Trenching activities	and aesthetics, sediment quality) **Marine ecosystem** (potential loss of the following habitats: macroalgae, sandy sediment with filter feeders and sponges, infauna, epifauna and biota quality, benthic habitats, and primary producer habitat, including mangroves) **Coastal processes** (bathymetry and seabed features) **Community and economy** (impacts to demersal fish habitats) **Culture and heritage** (heritage areas, shipwrecks, maritime archaeology and sacred sites)		

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
	Construction above HAT and onshore support facilities: + site clearing for onshore activities including pull winches and site buildings + placement of geotextile and hardstand + onshore laydown area + access road	pipeline section, which increases the risk of run off during rainfall event.		Additional run off created by onshore land and vegetation clearing and onshore site pad. Trenching nearshore in mangrove muds may result in ASS leaching and reduction in health of intertidal marine animals Direct and indirect impact to benthic habitats, including removal and smothering of benthic habitats Reduction in available food for marine species utilising the area Potential to impact fish health and other fauna Potential risk of coastal erosion If heavy rainfall is received, water may need to be pumped from the trench to adjacent land area. If stormwater runoff enters Darwin Harbour, coastal water quality may be impacted If trenching reaches groundwater, there is potential for acid release and metal leaching into the groundwater from oxidised ASS.			
Onshore ground disturbance	Onshore construction (above HAT) including: + trench/excavation + temporary storage of fill to be stockpiled in the disturbance footprint for use as backfill + disposal of excess fill + site clearing for onshore activities including pull	Clearing of regrown native grasses and weeds in a previously disturbed area will be required prior to excavating a trench for onshore pipeline section. Excavated soil will be temporarily stockpiled within the onshore Project Area to be used as fill or disposed of if in excess. Preparation of the DPD site pad, including vegetation clearing.	**Spatial** Localised within the Project Area **Temporal** Temporary duration when the section of trench will be open. The trench will be backfilled at the conclusion of pre-commissioning works. The clearing of any vegetation currently present onsite will be permanent.	Excavating the trench may result in: + minimal clearing of the ground/vegetation + digging soil and placing it adjacent for later re-use + additional fill of specific parameters to be brought to site if engineered backfill required. This may require disposal of excess 'original' soil – may need	+ Marine environmental quality (coastal water quality) + Marine ecosystem (marine fauna) + Terrestrial impacts (sediment quality, vegetation and terrestrial fauna) + Air quality	II – Minor	Section 7.6.3

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
	winches and site buildings + Placement of geotextile and hardstand + Access road			to be tested/treated prior to disposal + potential risk from erosion + spread of weeds + If heavy rainfall is received, water may need to be pumped from the trench to adjacent land area. If stormwater runoff enters Darwin Harbour, coastal water quality may be impacted. + If trenching reaches groundwater, there is potential for acid release and metal leaching into the groundwater from oxidised ASS.			
Noise emissions	Pre-lay works including: + Cutter suction dredge (CSD) + Trailer suction hopper dredge (TSHD) + Backhoe dredge (BHD) for excavating with potential used of hydraulic tools (Xcentric Ripper, hydraulic hammer) for fracturing rock + + Mass flow excavation (MFE) + Construction of two temporary causeways either side of the trench at the shore crossing Pipelay by nearshore pipelay barge in shallower	+ Vessel noise is considered non-impulsive (continuous) and broadband and includes vessel thrusters, engines and propellers, as well as noise emitted onboard which is converted to underwater noise through the hull. The main source of vessel noise will be from propellers or dynamic positioning (DP) thrusters (deeper water pipelay only). Project vessels (excluding trenching vessels) may emit noise up to ~180 dB re 1 µPa at 1 m. + Trenching will be completed using different trenching vessels, including a BHD, a TSHD and a CSD. Noise includes operation of vessel engines for propulsion (as applicable), onboard equipment, pumps and interaction of trenching equipment with the	**Spatial** For TSHD, CSD and BHD trenching and Xcentric Ripper tool use, permanent threshold shift (PTS) SEL24 hour ranges for dolphins, dugongs and turtles modelled at <50 m. Equivalent threshold range for hydraulic hammer modelled at 100- 160 m. For TSHD, CSD and BHD trenching and Xcentric Ripper tool use, temporary threshold shift (TTS) SEL24 hour ranges for dolphins, dugongs and turtles modelled at 40-350 m. Equivalent threshold range for hydraulic hammer modelled at 950- 2,500 m. The PTS and TTS ranges were shown to decrease with reduced hammering time (per 24 hours) for the hydraulic hammer. For behavioural response thresholds, ranges for marine mammals (dolphins and dugongs) varied from 100s of metres to 10s of kilometres for scenarios modelled at MSL.	+ Project activities including trenching, pipelay, additional vessel operations and will add to the existing underwater noise profile inside and outside Darwin Harbour during construction. + The use of sound in the underwater environment is important for marine animals, particularly cetaceans, to navigate, communicate and forage effectively, along with reptiles, sharks/rays and other fish, for a range of functions such as social interaction, foraging and orientation. Underwater noise could result in: + Acoustic masking: - Disruption to underwater acoustic cues	+ **Marine ecosystem** (marine mammals particularly cetaceans, marine reptiles, sharks, rays, pelagic and demersal fish, seabirds, shorebirds and invertebrates) + **Marine environmental quality** (impact to parameters that support fishing, aquaculture, recreation, aesthetics and cultural/ spiritual values)	II-Minor	Section 7.6.4

Santos

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
	waters including Darwin Harbour. Pipelay by dynamic positioning (DP) vessel in deeper waters outside of Darwin Harbour. Operation of onshore plant and equipment within Project Area at DLNG facility Support operations including: + General vessel operations during all DPD Project activities + Vessel and subsea positioning equipment e.g. MBES, SSS, LBL) / USBL) + Helicopter operations	seabed. The following source levels are considered representative of trenching vessel non-impulsive noise: + TSHD: 184 dB re 1µPa @1m + CSD: 182 dB re 1µPa @1m + BHD: 175 dB re 1µPa @1m + BHD rock breaking tools will be either non-impulsive from Xcentric Ripper tool or impulsive from hydraulic hammer (contingency only). Representative source levels are: + Xcentric Ripper: 184.8 dB re 1 µPa2 s m^2 + Hydraulic hammer: 192 dB 1 µPa2s m^2	Spatial scales for other activities are as follows: + Localised: A support vessel using main engines and bow thrusters to maintain position will become inaudible above background noise within thousands of metres. + Localised: A conservative estimate is that survey equipment (MBES/SSS) will be inaudible within thousands of metres, depending on the activity characteristics. + Localised: Helicopter noise will be highly localised and most of the noise will not transfer into the water. **Temporal** Vessel noise for the duration of the construction activity (12-15 months), with intermittent survey equipment and helicopter noise. Trenching vessel noise expected over indicative period of 2-3 months. Noise will be very infrequent during operations given scale of planned vessel pipeline inspection surveys indicatively every 1-3 years.	- Masking of vocalisations and signals from predators and prey + Behavioural response: - Modification of fauna behaviour (avoidance, attraction and disruption of normal behaviour) - Disturbance, leading to behavioural changes or displacement from areas - Indirectly by inducing behavioural and physiological changes in predator or prey species. + Physiological impacts: - Increased stress levels - Physical injury to fauna from exposure to excessive noise (barotrauma, hearing loss including TTS and PTS + Onshore construction activities are not expected to have an impact as they will not occur in water.			
Light emissions	Construction activities undertaken at night: + Surveys/ROV operations + Pre-lay works, pipeline installation and pre-commissioning + Lighting of Project Area at shore crossing	Potential impacts from light emissions may occur in the Project Area from: + Operational, safety and navigational lighting on the vessels including: - Pipelay vessel - CSD, TSHD and BHD - Construction vessel/survey vessel - Anchor handler (e.g. Multicat)	**Spatial** Localised: Limited light 'spill' or 'glow' on surface waters surrounding a vessel. Light spill modelling conducted for an offshore pipelay vessel and an offshore construction vessel, considered 'worst-case' in terms of vessel lighting for the DPD Project, indicates that vessel light spill intensity is around 10 times that of a full moon at 150-200m from these vessels (either individually or side by side) and drops to the intensity of a full	Change in fauna behaviour due to light emissions from vessels including: + Disrupting nesting turtles + Disorientating hatchlings + Hatchlings getting caught in vessel light pools with increased predation + Attract seabirds and shorebirds	+ **Marine ecosystem** (marine mammals, Marine reptiles, Pelagic and Demersal fish, Sharks, Rays, Seabirds and Shorebirds) + **Marine environmental quality** (impact to parameters that support fishing,	II-Minor	Section 7.6.5

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		- Platform supply vessel (psv) - SHB + Spot lighting that may also be used as needed, such as equipment deployment and retrieval + Task and security lighting at the shore crossing. Lighting will typically consist of bright white (in other words, metal halide, halogen, fluorescent) lights typical of lighting used in the offshore petroleum industry and not dissimilar to lighting used by other vessels in the Project Area, including shipping and fishing vessels.	moon at 500-1000m (Pendoley, 2022). At a distance of 2.5-4.5km, light spill was modelled to have dropped to 0.1 (10%) of a full moon. At this level, lighting is considered unlikely to have any impacts on marine turtle hatchlings (which are considered particularly sensitive to lighting impacts) (Pendoley Environmental, 2022). **Temporal** Navigational and task lighting is required 24 hours a day for the duration of the construction activities in the marine environment. When onshore it is expected that night works will be undertaken as required		aquaculture, recreation, aesthetics and cultural/ spiritual values) + **Community and economy** (fisheries and tourism)		
Routine vessel discharges	All vessel activities	Only those discharges allowable under maritime regulations will be permitted as would apply to other commercial vessel using Darwin Harbour and NT waters. Planned discharges from vessels to the marine environment include: + Deck drainage/run off including residual chemicals - Deck drainage from rainfall or wash-down operations would discharge to the marine environment. The deck drainage would contain particulate matter and residual chemicals such as cleaning chemicals, oil and grease. + Sewage and grey water - The volume of sewage and food waste is directly proportional to the number of persons on-board the vessels. Depending on waste production rates and	**Spatial** <u>Localised:</u> The small volumes of non-hazardous discharges may cause localised nutrient enrichment, organic and particulate loading, toxic impacts to marine fauna, thermal impacts and increased salinity in waters around discharge points and in the direction of the prevailing current. The environment that may be affected by operational discharges will likely be contained within the Project Area and are predicted to be localised on a scale of metres to 10s of metres in the upper 5 m of the water column. <u>Localised:</u> Backflush water will be discharged onto existing disturbed shore crossing construction site to drain into the intertidal area. Backflush water will also potentially be discharged onto the installed rock causeway to baffle the flow of the discharged backflush water.	The small volumes discharged may cause localised nutrient enrichment, organic and particulate loading, toxic impacts to marine fauna, thermal impacts and increased salinity.	+ Marine environmental quality (water quality) + **Marine Ecosystem** (ecosystem health) + **Coastal processes** (primary productivity/nutrient cycling) + **Community and economy** (fisheries commercial and recreational) and tourism)	I-Negligible	Section 7.6.6

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		the specifications of sewage systems available, the total volume of this waste stream generated typically ranges between 0.04 and 0.45 m³ per day per person. Treated sewage/greywater will be disposed in accordance with Marine Order 96. + Food wastes - Putrescible waste is estimated to consist of approximately 1 L of food waste per person per day. The vessel will dispose of food waste in accordance with AMSA and Marine Order 95, and MARPOL Annex V. + Cooling water - Seawater is used as a heat exchange medium for cooling machinery engines. Cooling water temperatures vary, depending on the vessel's engines' workload and activity. + Bilge water - While in the Project Area, the vessel may discharge oily water after treatment at a concentration of up to 15 ppm through an approved oily water filter system required by Marine Order 91. + Brine (if a reverse osmosis unit is used for water treatment) - If a reverse osmosis unit is used for water treatment, waste brine generated will be discharged to the ocean at a salinity of approximately 10% higher than seawater. The volume of the discharge depends on the requirement for fresh (or potable) water and	**Temporal** Intermittent and Short-term: During the period of the vessel activities (weeks to months), localised impacts to water quality will occur.				

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		demand based on the number of people on-board.					
Pre-commissioning water extraction and discharges	Water winning and filter flushing for pipeline pre-commissioning.	Water winning from Darwin harbour is required to provide water for filling pipeline with treated seawater for flushing, cleaning, gauging and testing (FCGT) activities. Water is required to be filtered to remove particulates prior to being treated with chemical and pumped into pipeline. The filtering equipment will be required to be backwashed back into Darwin Harbour to clean the filter. The backwashed water will have a higher particulate concentration than ambient water conditions and will cause increased turbidity at the discharge point. Total backflush volume is expected to be approximately 300 m^3 over 3 days. TSS concentration of backflush water waster will be approximately 1,500 mg/L in the wet season and 680 mg/L in the dry season. Entrainment of marine fauna during water extraction process.	**Spatial** Localised: Backflush water will be discharged onto existing disturbed shore crossing construction site to drain into the intertidal area. Backflush water will also potentially be discharged onto the installed rock causeway to baffle the flow of the discharged backflush water. **Temporal** Intermittent and Short-term: During the period of the water winning for pre-commissioning (three days).	The small volumes discharged may cause localised nutrient enrichment, organic and particulate loading, toxic impacts to marine fauna, thermal impacts and increased salinity. Injury or mortality of marine fauna entrained in water extraction.	+ Marine environmental quality (water quality) + Marine Ecosystem (ecosystem health) + Coastal processes (primary productivity/nutrient cycling) + Community and economy (fisheries (commercial and recreational) and tourism)	II - Minor	Section 7.6.7
Atmospheric emissions	Atmospheric emissions from combustion engines associated with vessels, equipment and vehicles impacting on air quality and adding to GHGs in the atmosphere .	+ Operation of vessel engines, helicopters, generators, mobile and fixed plant and equipment. These emissions will include GHG emissions, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and non-GHG emissions, such as sulphur oxides (SO_X) and nitrogen oxides (NO_X) + Operation of incinerators on vessels	**Spatial** Localised: The quantities of gaseous emissions are relatively small and will, under normal circumstances, quickly dissipate into the surrounding atmosphere. **Temporal** For the duration of the construction activities	Atmospheric emissions from activity vessels can result in deterioration of local air quality. Emissions of GHG can cause an incremental increase in global GHG concentrations. Given the nature and scale of DPD Project construction activities (low frequency and relatively short duration), both risks are considered to have a negligible impact on air quality.	+ Marine environmental quality (Local air quality) + Community and economy (tourism)	I-Negligible	Section 7.6.8

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		Although the vessels may use ozone-depleting substances (ODS), this will be in a closed rechargeable refrigeration system and there is no plan to release ODS to the atmosphere					
Contingency pipeline discharges	+ Pipeline installation and pre-commissioning: - Discharge of treated seawater in the event of pipeline remedial work during construction such as responding to a wet buckle event or stuck pig that requires flushing, filling and dewatering using treated seawater (Note – the wet buckle event is an unplanned event but in response to a wet buckle or stuck pig, there will be the planned response)	Contingency flushing and dewatering of treated seawater to the marine environment. During installation and pre-commissioning, in the event of a wet buckle or stuck pig, contingency flushing, filling and dewatering may be required in order to displace raw seawater from the pipeline that would otherwise lead to corrosion. Treated seawater discharge was modelled at three location–: + KP114 – 600 m^3 overflow + 19958.3 m^3 dewatering + KP102 – 600 m^3 overflow + 10623.3 m^3 dewatering and + KP84 – 600 m^3 overflow + 4399.9 m^3 dewatering.	**Spatial** Localised reduction in water quality in proximity to the discharge areas as treated seawater discharge modelling found (BAS-210 0035; RPS, 2022): + The discharge at KP84 resulted in a preservation chemical plume that was generally continuous up to ~1.4 km from the release location, with small, isolated patches predicted up to 9.61 km. Isolated patches beyond 2 km were predicted to occur during 2 of the 25 simulations and the plume was predicted to travel a maximum distance of 9.61 km in only one simulation. The isolated patches were due to an accumulation of the treated seawater, which had occurred during a current reversal, causing it to concentrate. The potential areas of exposure based on the PC99%, PC95% and PC90% thresholds 0.40 km^2, 0.17 km^2 and 0.08 km^2, respectively; + the discharge at KP102 resulted in isolated patches of the preservation chemical up to 6.78 km from the release location due to the plume drifting into the shallow intertidal areas, reducing the potential for mixing and dilution. The modelling also predicted a continuous area of exposure up to ~4 km west offset from the release location	Contamination/toxic effects to marine fauna. Potential impacts to fish and fisheries (commercial and recreational). Treated seawater discharge modelling does not identify any areas where dosage of biocide (time and concentration) will exceed the No Observable Effect Concentration (NOEC) and 99% species protection level (PC99%), i.e. 48 – 96 hour dosage of 0.06 – 0.1 mg/L).	+ Marine environmental quality (water quality, sediment quality and physical parameters that support fishing, aquaculture, recreation and aesthetics) + Marine ecosystem (infauna, epifauna and biota quality, marine mammals, marine reptiles, pelagic and demersal fish and sharks and rays) + Community and economy (physical parameters that support fishing and pelagic and demersal fish)	II-Minor	Section 7.6.9

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
			due to the plume migrating into the shallower waters, mixing less, resulting in the concentration accumulating. The area of exposure for the PC99% threshold was 4.14 km^2; and + the discharge at KP114, resulted in a maximum distance from the release location of 2.40 km and an area of exposure based on the PC99% threshold of 1.45 km^2. The preservation chemical concentrations did not trigger any other threshold over a 12-hour continuous duration. **Temporal** Temporary reduction in water quality in proximity to the discharge areas as treated seawater discharge modelling found (BAS-210 0035; RPS, 2022): + The release duration for pipeline overfilling or overflow has been estimated to be 38 minutes at all three locations + the release duration for dewatering activities varied due to the length of the pipeline at the given locations (KP84 >21.4 hours, KP102 >11.4 hours and KP114 >4.7 hours)				
Unplanned events							
Dropped objects	Vessel activities including: + Surveys/ROV operations + Pre-lay works + Pipeline installation and pre-commissioning, e.g. post-lay span rectification	Solid objects such as those listed below can be accidentally released to the marine environment + Non-hazardous solid wastes, such as paper, plastics and packaging, personal protective equipment, small tools and unsecured deck equipment	**Spatial** The event will only occur within the Project Area, and all non-buoyant waste material or dropped objects are expected to remain within the Project Area. Buoyant objects could potentially move beyond the Project Area. **Temporal**	If an object is dropped overboard, potential impacts would be limited to minor and localised disturbance of the seabed and benthic habitats near the dropped object. Benthic habitat loss.	+ Marine environmental quality (water quality and sediment quality) + Marine ecosystem (benthic habitats, infauna and epifauana and protected areas [Charles Point Wide RFPA])	Low	Section 7.7.1

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		+ Hazardous solid wastes, such as batteries, fluorescent tubes, medical wastes, and aerosol cans + Equipment and materials, such as hard hats, tools or infrastructure (e.g., pipe joints, mattresses, frames) Dropped could result from: + Loss of control of suspended loads (e.g. concrete mattresses for pipeline stabilisation) may also be accidentally dropped through operator error or mechanical failure + Loss of equipment and waste off vessel deck Larger objects, such as A-frames and sea containers, are secured to the vessel deck and cannot credibly be lost overboard Dropped objects resulting in damage to the Bayu-Undan to Darwin pipeline and subsequent dry natural gas release is covered specifically as a separate unplanned event below.	An unplanned release of solids may occur during construction activities. Water contamination from hazardous objects could cause prolonged or permanent reduction in water quality.	Potential damage to communication cables in Darwin Harbour Potential damage to cultural heritage objects and sites. Potential reduction in water quality from water contamination, cause by objects such as batteries.	+ Community and economy (oil and gas operations, other users, e.g. fisheries, tourism and recreational fishers and other industries e.g. telecommunications)		
Introduction of invasive marine species (IMS)	Vessel activities including: + Surveys/ROV operations + Pre-lay works Pipeline installation and pre-commissioning, e.g. post-lay span rectification	Introduction of IMS may occur due to: + Biofouling on vessels and external/internal niches (such as sea chests, seawater systems) + Biofouling on equipment that is routinely submerged in water (such as survey equipment) + Discharge of high-risk ballast water + Cross-contamination between vessels	**Spatial** Localised (seabed and water column within the Project Area) to widespread if successfully translocated to new areas via ocean currents or project equipment transit. **Temporal** Temporary to long-term (in the event of successful translocation).	Potential establishment of IMS in the marine environment as a result of the project requires IMS to: + Be present on a vector (biofouling on activity vessels and ballast water are considered credible vectors) + Be released from the vector + Establish in the receiving environment	+ Marine environmental quality (ecosystem health) + Marine ecosystem (benthic habitats, benthic communities and ecological function and processes) + Coastal processes (ecological processes)	Low	Section 7.7.2

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		Once established, IMS have the potential to out-compete indigenous species and affect overall native ecosystem function.		If established, impact could include localised (seabed and water column near the Project Area) to widespread impacts, if IMS successfully establish to new areas. IMS could displace and outcompete local species.	+ Community and economy (other users e.g. commercial and recreational users and ports and shipping)		
Unplanned marine fauna interactions	Vessel activities including: + Surveys/ROV operations + Pre-lay works + Pipeline installation and pre-commissioning, e.g. Post-lay span rectification Trenching activities – TSHD	There is the potential for vessels or equipment (for example, TSHD, CSD, and ROV) involved in construction activities to interact with marine fauna, including potential strike or collision, potentially resulting in severe injury or mortality.	**Spatial** Within the Project Area, in the immediate vicinity of the vessels or subsea equipment. **Temporal** During all construction activity.	Collisions may result in behavioural impacts, physical injury to, or the death of the fauna involved.	+ Marine ecosystem (marine fauna – marine mammals, reptiles, fish and sharks)	Low	Section 7.7.3
Release of liquid hazardous material (excluding diesel release from bunkering and vessel tank rupture which is presented below)	Vessel activities including: + Surveys/ROV operations + Pre-lay works Pipeline installation and pre-commissioning, e.g. Post-lay span rectification	Hazardous liquids used on the DPD Project include fuels and oils for equipment and machinery and other task-specific chemicals required for construction activities. Causes for accidental hazardous liquid releases include: + ROV failure (including oil seal, hydraulic system hose and quick-disconnect system failures) (approximately 0.05 m^3 (50 L)) + Stern tube oil (non-hydrocarbon-based lube oil) from the vessel thruster/propeller stern tube (approximately less than 1 m^3) + Loss of primary containment (drums, tanks, intermediate bulk containers (IBCs)) due to handling, storage and dropped objects (such as swinging load during lifting activities)	**Spatial** Volumes are likely to be small and limited to the volume of individual containers (such as IBCs, 44 gallon drums) stored on the deck of supply vessels or tank/hose sizes within equipment/machinery. A worst-case credible spill for this scenario is considered to be the loss of an intermediate bulk container (1 m^3). Spills to the marine environment of this size will disperse rapidly. Concentrations above toxic or harmful thresholds are expected to occur at short distances from the release point, and should a spill occur, potential impacts beyond the Project Area are not expected in the event of a worst-case spill. **Temporal** Potentially toxic or harmful threshold concentrations will be limited to a very short period following a release, as a spill is expected to disperse rapidly.	Decreases in water and sediment quality. The potential impacts to water and sediment quality are expected to be localised and temporary given the volumes of hazardous materials that may credibly be lost overboard. Impacts to fauna may result in injury or mortality through contact and/or ingestion; however, while this would reasonably be expected to impact upon individual animals; no population-scale impacts would credibly occur.	+ Marine environmental quality (water quality and sediment quality) + Marine ecosystem (marine fauna – marine mammals, reptiles, fish, sharks, seabirds and shorebirds)	Low	Section 7.7.4

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
		+ Vessel pipework failure or rupture, hydraulic hose failure and inadequate bunding + Spills or leaking machinery accidentally discharged overboard in deck drainage water + Overflow of the open and closed drainage systems Oily water from vessels includes bilge water and deck drainage water.					
Release of hydrocarbon (offshore bunkering or vessel tank rupture)	Vessel activities including: + Surveys/ROV operations + Pre-lay works + Pipeline installation and pre-commissioning, e.g. Post-lay span rectification Vessel bunkering	A minor spill (of up to ~10 m^3) of marine gas oil (MGO) or marine diesel oil (MDO) could occur during vessel to vessel refuelling. Spills during refuelling can occur through several pathways, including fuel hose breaks, coupling failure or tank overfilling. It is considered credible that a release of diesel to the marine environment could occur from a vessel fuel tank rupture. For the purpose of risk assessment, a worst-case discharge of up to 700 m^3 of MDO or MGO is considered credible from the offshore pipelay vesseland a spill of up to 300 m^3 is considered credible for project vessels in Darwin Harbour (e.g., the nearshore pipelay barge)	**Spatial** MDO spill trajectory modelling (BAS-210 0030; RPS, 2022) at KP 91.5 (just outside Darwin Harbour) indicated that there was some probability of a 700 m^3 marine diesel oil (MDO) spill, extending as follows (using the moderate exposure thresholds): + Shoreline loading was predicted to occur along the Cox-Finniss region, outside the Harbour to the west and within the West Arm in the dry season and along the Cox-Finniss region, outside the Harbour to the East and west and within the East Arm in the wet season. + Surface oil was predicted to occur within approximately 19.9 km (Dry season) and 19.3 (Wet season) of the release location. + Total submerged oil was predicted to occur within approximately 36.9 km (Dry season) and 51.3 km (Wet season) of the release location + Dissolved hydrocarbons were predicted to occur with approximately 10 km (Dry season) and 13.7 km (Wet season) of the release location.	A release to the marine environment, would be likely to rapidly disperse and evaporate but could lead to a reduction in: + Water quality + Sediment quality + Ecosystem health and impact to parameters supporting commercial and recreational uses Behavioural/physiological impact to marine fauna (particularly those associated with the surface such as cetaceans and marine turtles) and plankton within the upper water column and/or associated with shallow waters and shorelines. Impact to other users due to spill response activities. Impacts to benthic habitats, including intertidal habitats and primary producers. Impact to culture and heritage areas.	+ Marine environmental quality (water quality, physical parameters that support socio-economic activities) + Marine ecosystem (marine fauna, benthic habitats, intertidal habitats, protected areas [Charles Point Wide RFPA]) + Coastal processes (primary productivity e.g. mangroves) + Community and economy (community and economy e.g. commercial and recreational users) + Culture and heritage (impacts to sacred sites or important cultural heritage significance)	Low	Section 7.7.5

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
			MDO spill trajectory modelling for vessel fuel tank rupture (BAS-210 0030; RPS, 2022) at KP 114 (in the middle of Darwin Harbour) indicated that there was some probability of a 300 m^3 marine diesel oil (MDO) spill respectively, extending as follows (using the moderate exposure thresholds): + Shoreline loading was predicted to occur within the East Arm, Middle Arm, West Arm of the Harbour and at Wickham Point in both wet and dry seasons. During the wet season shoreline loading is also expected outside the harbour to the east and west. + Surface oil was predicted to occur within approximately 19.6 km (Dry season) and 18.9 km (Wet season) of the release location. + Total submerged oil was predicted to occur within approximately 30.3 km (Dry season) and 32.4 km (Wet season) of the release location + Dissolved hydrocarbons were predicted to occur with approximately 0.6 km (Dry season) and 7.3 km (Wet season) of the release location. The extent of shoreline loading, and distance travelled of MDO from smaller spills of 87.5 m^3 and 10 m^3 modelled at KP 114 will be lower than that described for the 300 m^3 scenario **Temporal** + MDO spill trajectory modelling at KP 91.5 for 700 m^3 indicated that within a 50-day simulation: 85% of spilled oil will have evaporated into the atmosphere.				

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
			+ 5% of spilled oil will remain on the shoreline. + 8% of spilled oil will have decayed by the end of the simulation. + No spilled oil will remain on the water's surface MDO spill trajectory modelling at KP 114 for 87.5 m^3 indicated that within a 20-day simulation: + 85% of spilled oil will have evaporated into the atmosphere. + 12% of spilled oil will remain on the shoreline. + 2% of spilled oil will have decayed by the end of the simulation. + No spilled oil will remain on the water's surface MDO spill trajectory modelling at KP 114 for 10 m^3 indicated that within a 10-day simulation: + 80% of spilled oil will have evaporated into the atmosphere. + 20% of spilled oil will remain on the shoreline. MDO spill trajectory modelling at KP 114 for 300 m^3 indicated that within a 30-day simulation: + 71% of spilled oil will have evaporated into the atmosphere. + 25% of spilled oil will remain on the shoreline. + 3% of spilled oil will have decayed by the end of the simulation. No spilled oil will remain on the water's surface				

Aspect	Activity	Description of hazard	Spatial and temporal scale	Potential impacts / risks	Sensitive receptors	Residual consequence level/ risk rating (planned impact / (unplanned risk)	Management strategy
Release of dry natural gas	During DPD Project construction – dropped object damages the existing Bayu-Undan to Darwin GEP.	A Bayu-Undan pipeline leak would result in a release of dry gas to the environment. Damage to the Bayu-Undan pipeline during construction activities could occur due to anchor impact/drag or objects being dropped from vessels	**Spatial** The scale of a pipeline leak is dependent on the nature of the damage. Small 'pinhole' leaks will result in a stream of bubbles which may dissolve before reaching the surface. A major rupture (e.g. catastrophic failure) would result in the discharge of a large volume of dry gas forming a large plume in the water column and dispersing into the atmosphere. A catastrophic failure is considered to be the worst-case credible release from the pipeline. **Temporal** The worst case discharge could occur during construction.	The gas cloud may result in impacts to air-breathing fauna, such as marine mammals, marine reptiles and birds. Animals breathing in the immediate vicinity of the release may be asphyxiated, potentially resulting in mortality. Given the dispersion of gas into the atmosphere, this potential effect would be highly localised to the release location. The gas cloud poses a risk to the health and safety of other users, such as fishers (traditional and commercial), tourism and recreational users. A gas cloud could potentially form an explosive mix which, if ignited, result in injury/death and damage to property. However, all other marine users will be excluded from the exclusion zone and therefore will not be within 500 m of an event, if it occurs.	+ Marine environmental quality (water quality, ecosystem health and physical parameters tat support socio-economic activities) + Marine ecosystem (marine fauna and protected areas [Charles Point Wide RFPA]) + Community and economy (other users e.g. commercial and recreational activities) + Culture and heritage	Very Low	Section 7.7.6

6.5 Assessment of potential for cumulative impacts

The following sections provide a summary of the assessment of potential cumulative impacts associated with DPD Project construction activities within the DPD Project Supplementary Environmental Report (SER) (BAS-210 0020).

6.5.1 Cumulative assessment methodology

Existing activities and proposed projects in the Darwin region were screened to determine their potential to cumulatively interact with the DPD Project impacts. This included government and private infrastructure projects, Darwin Harbour dredging projects and resource processing operations. The degree of cumulative impact between the DPD Project and identified nearby projects and activities was determined based on the potential for spatial and temporal interaction. The list of projects and activities considered to have a high or medium potential to interact cumulatively with DPD Project impacts, based on spatial and temporal overlap, is provided within the SER (BAS-210 0020). The potential cumulative impacts are discussed in further detail within the SER (BAS-210 0020) and have been summarised below. Cumulative impacts to all NT EPA Environmental Factors from the DPD Project and other projects/activities are not considered to be significant.

6.5.2 Cumulative impacts to marine environmental quality

This CEMP's activities have the potential to elevate turbidity levels within Darwin Harbor due to sediment suspension from trenching activities. Sediment dispersion modelling completed for the DPD Project (BAS-210 0036; RPS, 2022) predicted that there will be no exceedance of suspended sediment concentration (SSC) thresholds where influence or impact to sensitive benthic habitats (hard corals and seagrass) could occur, with modelling showing that sedimentation threshold exceedance would be restricted to within or immediately adjacent to the trenching footprint (RPS, 2022). These zones do not overlap with equivalent zones for other dredging activities in Darwin Harbour that may occur at the same time or close to the time of DPD Project trenching (including Mandorah Marine Facilities, HMAS Coonawarra dredging, INPEX maintenance dredging and Darwin Shiplift and Marine Industries dredging). Therefore, there is low potential for turbidity to result in cumulative impacts to water and sediment quality with other projects activities.

6.5.3 Cumulative impacts to marine ecosystems

This CEMP's activities will have direct impacts to the benthic habitats which will all be restricted to within or immediately adjacent to Project infrastructure footprints, including the designated spoil disposal ground. Benthic habitats in the infrastructure footprints do not consist of rare or sensitive receptors (i.e., hard corals or seagrass) and are predominately hard substrate or sediment substrates supporting filter feeding biota; these habitats are well represented throughout the Project Area. Direct impacts to benthic habitat are not predicted to have significant impacts to ecosystem functions. Although other projects will have direct impacts to benthic habitats, the cumulative impacts are unlikely to be significant when considered against the total available benthic habitat within Darwin Harbour.

There is also potential from indirect impacts to marine ecosystem, for example impacts to benthic habitats from increased SSC and sedimentation. As described above, SSC and sedimentation from DPD Project trenching is unlikely to interact significantly with water quality impacts from other dredging projects in Darwin Harbour, therefore the DPD Project is unlikely to result in significant cumulative indirect impacts to marine ecosystems.

Construction activity will temporarily increase vessel traffic in Darwin Harbour and if construction activity timing overlaps with other projects activities then vessel traffic will be further increased. Increased vessel activity has the potential to result in higher levels of sound and light emissions. It is however unlikely that cumulative activity from noise and light emissions will have a significant impact, as Santos considers proposed controls and management actions to be effective.

6.5.4 Cumulative impacts to atmospheric processes

This CEMP's activities will generate atmospheric emissions during construction which will contribute to the overall concentration of greenhouse gases (GHG) in the Earth's atmosphere. Emissions resulting from construction activities (i.e., vessel combustion engines) will occur on a short-term basis and be limited to the construction phase of the project. As an overall contribution to GHG gas levels, this will be a negligible increase. The DPD Project is included in Santos' Climate transition action plan and will adhere to the Santos GHG Management plan and energy management program.

6.5.5 Cumulative impacts to coastal processes

This CEMP's activities are not expected to significantly alter hydrological or geophysical process. The trenching activity and the installation of temporary (e.g., causeways at the shore crossing) or longer-term infrastructure (e.g., pipeline and rock protection) may have a slight and local effect on water movement, however not to the extent where this would be expected to change coastal geomorphology or coastal ecosystem processes. Furthermore there are no known projects which would interact with any localised changes in hydrology from the DPD Project to create cumulatively impacts.

6.5.6 Cumulative impacts to community and economy

This construction activities will increase vessel activity within Darwin Harbour, which has the potential to cause cumulative impacts to other commercial and recreational harbour users, in particular if the timing of construction activities overlap with other projects activities. It is important to note that the potential for cumulative impacts from vessel activities would occur primarily during the construction phase, which will be temporary (12 – 15 months). Furthermore, the increase in vessel activity related to the DPD Project is not expected to add significantly to the overall movements within Darwin Harbour based on annual harbour statistics and historical year to year variation. Therefore, DPD Project vessel activities are unlikely to contribute a significant extent to cumulative vessel impacts on harbour marine users.

6.5.7 Cumulative impacts to culture and heritage

Following controls in place, the DPD Project will not impact on indigenous sacred sites and will avoid maritime heritage objects as far as practical, with any maritime heritage disturbance localised to the pipeline route and done in accordance with regulatory requirements. There are no other activities or projects which are considered to have the potential for cumulative impacts with the DPD Project to identified cultural heritage sites.

7 Environmental management strategies

This section outlines the environmental management strategies (EMS) that will be implemented for management of areas and activities associated with the DPD Project construction works, therefore minimising and/or mitigating impacts and risks to the environment.

The EMS to be implemented as part of this CEMP comprise the following:

- Planned impact management strategies (**Section 7.6**)
- Unplanned risks management strategies (**Section 7.7**).

These EMS outline environmental performance objectives (EPOs) and measurable targets and management actions in place to ensure that the EPOs and targets are met. Performance indicators and monitoring activities (where applicable) are used to quantify success in meeting targets and identify the need for corrective actions. This ensures the continuous improvement of the effectiveness of the DPD Project's EMS. The EMS define the reporting requirements, terms, and responsibilities.

All EMS are structured to align with the template presented in **Table 7-1**.

Table 7-1: Environmental management strategy template

Item	Content
Environmental Performance Objectives (EPO)	Environmental management goal(s) tailored to each aspect per NT EPA requirements.
Target	Aspect specific measurable performance necessary to successfully achieve objective. Part 1 of NT EPA required performance criteria.
Performance Indicator	Quantitative or qualitative measures representing the performance related to Target(s). Part 2 of NT EPA required performance criteria.
Management actions	Tasks to be undertaken to meet objective/s. For example, install turtle deflection chains on TSHD drag head, comply with Darwin Port vessel speed restrictions etc.

7.1 NT EPA hierarchy

In the development of the EMS outlined within this CEMP Santos applied the Environmental Decision-Making Hierarchy outlined within the EP Act. This hierarchy being:

- To ensure that actions are designed to avoid adverse impacts on the environment
- To identify management options to mitigate adverse impacts on the environment to the greatest extent practicable
- And if appropriate, provide for environmental offsets in accordance with the EP Act for residual adverse impacts on the environment that cannot be avoided or mitigated[2].

[2] No offsets were deemed appropriate for this project.

7.2 Environmental performance objectives

Environmental performance objectives (EPOs) have been defined and are listed in following sections for each planned and unplanned event. The EPOs set the desired outcomes/goals for the activity, consistent with the NT EPA environmental factor objectives, and guide the setting or performance criteria.

7.3 Performance criteria

To assess whether EPOs are being achieved, specific performance criteria have been defined, taking the form of targets and performance indicators. Detailed specific measurable targets must be defined and then met to achieve overarching EPOs. Performance indicators are the factor that is measured to assess whether the performance targets have been achieved.

7.4 Management actions

To mitigate impacts of the DPD project construction activities and to achieve EPOs and performance criteria, management actions have been defined. This will include standard management actions that will be implemented as part of normal operations, and adaptive management actions that will be implemented if triggered.

7.5 Adaptive management mechanism

While the consequences of all planned impacts were assessed as either minor or negligible and the level of unplanned risks were assessed as low or very low, a monitoring and adaptive management mechanism will be applied to the following events to ensure EPOs are met:

+ Seabed and benthic habitat disturbance via generation of turbid plumes and sedimentation during trenching. These adaptive management actions are detailed in **Table 7-6** and the TSDMMP [BAS-210 0023]
+ Disturbance of marine fauna via noise generated during construction activities. These adaptive management actions are detailed in **Table 7-10** and the MMNMP [BAS-210 0045].

Adaptive management can also be triggered through Santos' incident response and assurance processes (**Section 8.3**), with corrective actions implemented and management adapted as required to address any identified incidents and non-conformances.

7.6 Planned event - impact management strategies

Santos' environmental impact assessment identified impacts related to nine planned events associated with DPD Project construction activities in the Project Area (Refer to **Section 6**).

7.6.1 Interaction with other marine users

7.6.1.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-2**.

Table 7-2: Interaction with other marine users (including construction activities and Project infrastructure) EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Avoid incidents resulting from interaction with other marine users	Zero incidents resulting from interactions.	Number of recorded incidents
Minimise impacts to other marine users	Zero impacts to other marine users activities	Number of complaints from other marine users
Stakeholders are well-informed of the DPD Project and its associated restrictions	DPD Project stakeholder are provided with activity update/s and notification of commencement of trenching and spoil disposal activities.	Records demonstrate that stakeholder communications (meetings, publications etc.) performed as indicated in Stakeholder Engagement process

These EPOs in conjunction with the economic benefits of the Project to the Darwin economy align with the following NT EPA Factor objective (NT EPA 2022):

+ Community and economy – Enhance communities and the economy for the welfare, amenity and benefit of current and future generations of Territorians.

The management actions for this planned event are shown in **Table 7-3**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-3: Management actions for interaction with other marine users

MA Reference	Management Action
Standard management actions	
Avoidance	
DPD-MA01	Intertidal and shoreline construction is in pre-disturbed area (DLNG footprint) with no public access
DPD-MA02	Installation of the pipeline within pre-agreed route, with minimal incursions into the shipping channel (as defined in consultation with the regional harbour master)
Mitigation	
DPD-MA03	Anti-snag protection for mechanical support structures
DPD-MA04	Activity vessels equipped and crewed in accordance with Australian maritime requirements
DPD-MA05	Development and implementation of communication plan (including applicable notifications) for relevant stakeholders (including recreational and commercial fishing bodies and tourism operations) to minimise adverse impacts on other marine users
DPD-MA06	Implementation of cautionary zones around DPD Project vessel to mitigate against adverse interactions
DPD-MA07	One vessel will act as a surveillance vessel within the operational area during gas export pipeline installation and trenching activity
DPD-MA08	The proposed pipeline route will be marked on marine charts, in the same way that the existing pipelines are gazetted and marked on marine charts
DPD-MA09	Construction activities undertaken in accordance with Santos HSE management and marine vessel vetting processes
DPD-MA10	Causeway/s will be temporary structure/s and will be removed following trenching and pipeline installation
Additional (ALARP) management actions	
Avoidance	
DPD-MA11	Pipeline will not be installed in the vicinity of the jewfish aggregation area within the Charles Point Wide RFPA

Table 7-4: Additional management actions not adopted for interaction with other marine users.

Additional management actions not adopted		Reasoning for rejection
1	Signage to alert small boat users of activities and key locations (e.g., boat ramps)	Evidence from previous construction activities in Darwin Harbour indicates that this is not an effective method of public notification. Therefore Santos has committed to ongoing consultation with relevant stakeholders to develop more effective public notification.
2	Divide the pipeline installation scope into multiple campaigns to minimise work performed during the Northern Prawn Fishery season periods of sensitivity (2 April to 15 June and 1 August to 21 November)	The Project Area does not overlap areas historically fished by prawn trawlers.

7.6.1.2 Demonstration of ALARP and residual impact

No alternative options to the use of vessels are possible to undertake the marine activity.

The presence of the vessels, the pipeline and associated infrastructure (together with cautionary zones) and causeway/s is not expected to significantly impact tourism, commercial and traditional fishing operations or shipping traffic, given the localised areas of vessel activities, the relatively short durations of activities at any given point along the pipeline route, the various routes that can be taken to avoid the area and the limited number of users active in the vicinity.

The proposed management controls for marine user interaction are considered appropriate to manage the risk to ALARP. Standard management actions to reduce interaction with other marine users due to vessel presence during construction activities have been adopted.

An additional management actions that was deemed practicable and reduce the consequence of the presence of the pipeline on other marine users has been adopted (**Table 7-3**). Additional management actions that have not been adopted and the reasoning for rejection are found in

Table 7-4. The overall worst-case consequence is assessed as Minor. If the management controls are adhered to, then the risk of interfering with other marine users will be reduced to ALARP and the impact level is considered Minor and acceptable.

Stakeholders have been informed throughout the preparation of the CEMP of the proposed vessel activities and the presence of the pipeline as detailed in **Section 9**.

7.6.2 Seabed and benthic habitat disturbance

7.6.2.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-5**.

Table 7-5: Seabed and benthic habitat disturbance EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	**Performance Indicator/s**
Minimise direct impacts to sensitive marine habitat, cultural values and socio-economic sensitivities	Pipeline alignment and trench areas designed to minimise trenching requirements and direct footprint of seabed disturbance	+ Quantitative risk assessment (BAS-201 0925) + Nearshore pipeline route selection report- Darwin Harbour (BAS-200 0642)
	No trenching outside the pre-defined boundaries[1] of the trench areas	+ Nearshore pipeline trench and trench backfill alignment details 34in northern route (BAS-200 0523 001) + Trenching out-survey reports
	No anchoring on sensitive seabed areas	+ Incident reports of anchoring inside anchoring exclusion zone

EPO	Performance criteria	
	Target/s	Performance Indicator/s
	No installation activities (pipelay, and causeway construction, trench backfill etc.) outside of the proposed footprint	Records of construction areas, including: + Construction activity logs, vessel logs + Post-construction survey
	No damage to known heritage sites of significance or existing submerged infrastructure	Incident reports of damage to heritage sites/ artefacts of significance, or existing infrastructure
	Potential culturally significant objects discovered during construction reported and managed as per Unexpected Finds Protocol (BAS-210-0051)	Unexpected finds notification records
Avoid sediment dispersion and sedimentation related impacts on seagrass and hard coral habitats from trenching and spoil disposal activities	No DPD Project related reduction in water quality or sedimentation resulting in impact to seagrass and hard coral marine habitats	+ Water quality and benthic habitat monitoring data (refer to TSDMMP; BAS-210 0023) + Attributability assessments + Reports on adaptive management actions and effectiveness
Minimise impacts from spoil disposal	No spoil disposal outside of DPD spoil disposal ground	+ During and post spoil disposal Hydrographic surveys + Spoil disposal logs

Notes:

1. Boundaries of direct seabed and benthic habitat disturbance are defined by the trench design and any approved changes to that design.

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Coastal processes – Protect the geophysical and hydrological processes that shape coastal morphology so that the environmental values of the coast are maintained.
+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.
+ Culture and heritage – Protect culture and heritage.

The management actions for this planned impact are shown in **Table 7-6**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-6: Management actions for seabed and benthic habitat disturbance

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA12	Trenching, stabilisation and freespan correction/ prevention will only be undertaken at identified areas (using standard positional accuracy measures used in the industry)
Mitigation	
DPD-MA13	Overflow from the TSHD will be undertaken through the adaptive management processes There will be 'environmental valve' or 'green valve' where available (attached to O/F to reduce air entrained, to reduce billowing and facilitates sediment sinking) as standard which will be used as a first step
DPD-MA14	Standard operating procedure for spoil disposal will be used.
DPD-MA15	Spoil will not be disposed of in a single location, to avoid developing a single large mound.
DPD-MA16	Spoil will only be placed *in situ* within a short section of trenching within intertidal zones to keep wet under most tidal conditions and will be removed subsequently where accessible by BHD and SHB for offshore disposal
DPD-MA17	When available, the base case is for the DP pipelay vessel to be used to install as much of the pipeline as depth allows DP vessel can be used in deeper water from KP23 (Territorial water boundary) to ~KP91.5 where the shallow water pipelay (<20 m) and associated anchoring will begin
DPD-MA18	Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, trenching and other support activities in the vicinity of sensitive habitats and nearshore heritage or sacred sites
DPD-MA19	Trained and competent anchor handling operators will be used
DPD-MA20	Anchors exclusion areas will be implemented to avoid sensitive habitats and heritage sites
DPD-MA21	Objects identified as cultural heritage objects that cannot be avoided will be managed as per NT Heritage Branch requirements

MA reference	Management actions
DPD-MA22	Differential global positioning system (DGPS) will be operational on the pipelay vessels to maintain accurate vessel position during installation
DPD-MA23	+ DGPS used to confirm ILT foundation structure position during installation + Underwater positioning system (USBL/ transponders) and ROV to confirm installation location and positioning (within required location accuracy to reduce disturbance to the seabed)
DPD-MA24	Installation plan will be developed and include: + requirement for trained and experienced vessel crews + pipe to be installed in trench as per approved design
DPD-MA25	Span-specific rectification plans developed that include: + pre-span method selection + real-time monitoring of span rectification + post-rectification inspections
DPD-MA26	Permanent rock installation will be limited to only those pipeline sections requiring stabilization and/or anchor protection, as informed by a quantitative risk assessment
DPD-MA27	Causeway/s will be temporary structure/s and will be removed following trenching and pipeline installation
Monitoring	
DPD-MA28	Adaptive management process will be implemented as defined within the TSDMMP (BAS-210 0023) which will include environmental monitoring of water quality with management measures applied if water quality exceeds trigger levels
DPD-MA29	Continuous monitoring of anchor wire tensions to prevent anchor drag on seabed and wire length measurement of the winch will be monitored to prevent anchor drag
Additional (ALARP) management actions	
Avoidance	

MA reference	Management actions
DPD-MA30	Pre-lay surveys will confirm the nature of the seabed within the ILT foundation location to ensure the structure is installed on bare area of the seabed. Post-lay surveys will allow verification of the impact assessment
DPD-MA31	Where practicable rock installation will not exceed seabed level within practical installation tolerances.

Table 7-7: Additional management actions not adopted for seabed and benthic habitat disturbance

Additional management actions not adopted		Reasoning for rejection
1	No trenching using CSD	Not technically feasible to stabilize and protect pipeline without trenching. The CSD is a significant mitigation in the event hard soils are encountered. Not utilizing the CSD may pose substantial schedule and cost impacts if harder soil types are encountered that are beyond the operating limits of the TSHD and BHD.
2	No trenching using TSHD	Not technically feasible to stabilise and protect pipeline without trenching using TSHD
3	No trenching using BHD	Not technically feasible to stabilise and protect pipeline without using BHD
4	Restrict timing of activities to operate outside of known sensitive periods. Flatback turtle peak nesting period is May to October and Dolphin peak calving is October to April.	Beaches closest to the Project Area are not considered significant turtle nesting beaches. Beyond ALARP to prevent trenching in peak dolphin calving period, based on excessive cost and schedule implications relevant to the potential minor impacts identified. Monitoring programs have been unable to determine spatial and temporal patterns in occurrence and abundance of dolphins in Darwin Harbour or any links to anthropogenic activities and behavioural disruption. Trenching areas are adjacent high use areas for vessels and the effects of turbidity are expected to be minor in the context of natural variability.
5	No offshore spoil disposal	Spoil will be generated from trenching activities. The only alternative is for onshore disposal of spoil, however the additional time in the field that would be required, would be prohibitive, prolong impact to other users of Darwin Harbour and additional environmental impacts would occur with onshore disposal. Given the minor impacts predicted from the offshore disposal of spoil, this control is rejected.
6	Spoil to be disposed of in a manner to create a uniform thickness of spoil	Spoil will not be disposed in one area only however will not be uniformly spread. The additional effort to ensure uniform thickness of spoil is not reasonably practicable in comparison to any potential benefits and would create additional turbidity. Sediment modelling has not identified re-suspension and ongoing transportation of sediments to be significant.

Additional management actions not adopted		Reasoning for rejection
7	No vessel anchoring	Given the shallow water depths, it is not feasible to use a DP vessel to install the pipeline and consequently, the use of an anchored pipelay vessel is required. Using a DP vessel will add a lot of noise in the shallow waters which is likely to be a bigger problem and disturbances from anchoring.
8	Pre-lay and post-lay benthic habitat surveys along the full gas export pipeline route	Habitats along the pipeline route are well known having been extensively studied through geophysical surveys and drop camera/ROV survey. The route has been shown to be devoid of unique habitat or high value primary producer habitat and additional surveys would provide no significant further information for informing management measures.
9	Pre-lay and post-lay surveys at anchoring locations	A conservative approach has been adopted for managing anchoring activities. Exclusion zones will apply to seabed areas identified as sacred sites, potential maritime heritage sites (identified by maritime heritage assessment) and mapped sensitive benthic habitat (hard coral and seagrass). Given the numerous anchoring locations which would be required to be surveyed and the conservative approach taken to delineate avoidance areas, pre- and post- anchoring surveys are considered to have a disproportionate level of cost and effort.
10	Pre-lay and post-lay surveys at ILT foundation location	Habitats along the pipeline route are well known as having been extensively studied through geophysical surveys and drop camera/ROV survey. The route has been shown to be devoid of unique habitat or high value primary producer habitat such as seagrass and hard corals. Pre- or pos-lay benthic habitat surveys would provide no significant further information of environmental benefit and have been ruled out.
11	Not using rocks to protect and stabilize the pipeline	Rocks are required to provide anchor protection adequate for mitigating risks associated with current and future vessel use within the Project Area. Rock protection has been reduced as far as practical while still maintaining adequate protection.
12	Do not use temporary causeway/s	Causeway/s required to allow excavator to access into deeper waters.

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7.6.2.2 Adaptive management mechanism

An adaptive management process is defined within the TSDMMP (BAS-210 0023) which includes a water quality monitoring program with management measures applied if water quality exceeds turbidity trigger levels.

7.6.2.3 Demonstration of ALARP and residual risk

Trenching has been minimised as far as practicable to reduce impacts and where possible dynamic positioning (DP) vessel will be used to reduce anchoring disturbance.

Standard management actions have been adopted to reduce the impact of construction activities and the presence of the pipeline to the seabed and benthic habitats. Additional feasible management actions that reduce the impacts from seabed and benthic habitat disturbance have been adopted, including an adaptive management strategy designed to reduce turbidity effects from trenching through the application of management actions if monitored turbidity exceeds set threshold levels (detailed in the TSDMMP BAS-210 0023) (**Table 7-6**). Additional management actions that have not been adopted are outlined in **Table 7-6**, with the reasoning for their rejection.

Management actions are considered to manage risks to ALARP. Activities which may cause seabed and benthic habitat disturbance are localised in nature and there is a lack of unique habitats, hard coral or significant seagrass areas within the pipeline route and trenching areas. Additionally, original habitat that will be disturbed or removed is expected to recolonise rapidly on the pipeline and rock installation.

Residual impacts are expected to be temporary, as habitats under the pipeline and trenching zone footprints will be removed permanently but will recover rapidly as new habitat establishes. The area potentially impacted is small compared to the total area that the same habitats occupy outside of the disturbance footprint. The habitats in the direct disturbance footprint are not considered rare nor identified as critical foraging habitats for marine species. Additionally, no impacts are predicted to benthic habitats outside of the direct disturbance footprint. Therefore, no long-term impacts to marine species are expected.

Seabed disturbance created from trenching activities and construction activities associated with the causeway/s are not expected to significantly impact coastal processes, given the large volumes of water movement and temporary and localised nature of activities.

To avoid/manage impacts to maritime heritage, Santos has followed guidance provided by Department of Territory Families, Housing, and Communities – Heritage Branch. Additionally, Santos has received an Authority Certificate from AAPA for the DPD Project (Authority Certificate C2022/098) and will ensure conditions of the certificate and the requirements of the *Northern Territory Aboriginal Sacred Sites Act 1989* are met.

The residual impacts are therefore considered acceptable.

7.6.3 Onshore ground disturbance

7.6.3.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-8**.

Table 7-8: Ground disturbance and clearing EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid impacts to native vegetation and fauna from ground disturbance and clearing	Ground disturbance within previously cleared areas	+ Recorded areas disturbed via excavation logs
	Zero incidents of disturbance to vegetation outside previously cleared areas	+ Number of recorded incidents of damage to environment outside of previously cleared areas
	Zero incidents of injury to terrestrial native fauna as a result of the DPD construction activities	+ Number of recorded incidents relating to terrestrial fauna injury or mortality as a result of ground disturbance.
Prevent project attributable mobilisation of heavy metals and acidification products to the surrounding environment	No incidents of project attributable mobilisation of heavy metals and acidification products to the surrounding environment	+ Records of ASS presence in sediment/soil via excavation logs/ daily observations/ photographs + Incident investigation records

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Terrestrial environmental quality – Protect the quality and integrity of land and soils so that environmental values are supported and maintained.
+ Terrestrial ecosystems – `Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.
+ Marine environmental quality (coastal water quality)
+ Marine ecosystem (marine fauna)

The management actions considered for this planned event are shown in **Table 7-9**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-9: **Management actions for onshore ground disturbance during offshore DPD construction activities**

MA Reference	Management Action
Standard management actions	
Avoidance	
DPD-MA32	Restrict disturbance to within the onshore Project Area and existing DLNG site area
DPD-MA33	Establish appropriate access restrictions into the onshore Project Area
Mitigation	
DPD-MA34	Direct stormwater runoff from the open trench to filter through the rock causeway, when present
DPD-MA35	Install geotextiles under primary construction area (i.e., site pad)
DPD-MA36	Return area to natural grade to match existing topography
DPD-MA37	All personnel to complete the DLNG HSE site induction
DPD-MA38	Maintain batters or install fauna ladders on trench entry and exit to allow fauna to exit the trench
DPD-MA39	Implement ASS and groundwater management and monitoring requirements within the ASSDMP (BAS-210-0049). The ASSDMP includes requirements for: + Soil stockpiling, laboratory testing and treatment, dependent upon location of work and encountering ASS + Groundwater laboratory testing and treatment, if groundwater is reached + Maintenance of testing and inspection records
DPD-MA40	Plan onshore works to minimise the amount of time soil is exposed to the air
DPD-MA41	Trench inspections to be performed daily to check for trapped wildlife

MA Reference	Management Action
DPD-MA42	Insert caps on ends of pipe if the pipe is to be unattended for periods >12 hours; to prevent fauna ingress.
DPD-MA43	Ensure any native vertebrates injured by DPD construction activities are referred to an appropriate wildlife carer group or veterinarian
Additional (ALARP) management actions	
Avoidance	
DPD-MA44	Limit vehicles to access roads, prepared site pad or defined boundaries within the onshore Project Area/DLNG disturbance
Mitigation	
DPD-MA45	Use water truck for dust suppression
DPD-MA46	Establish and implement vehicle speed controls
DPD-MA47	Wet parking area will be monitored daily, with photographs taken.

7.6.3.2 Demonstration of ALARP and residual impact

Construction works for the activities in this CEMP will be confined to the Project area and existing disturbed areas within the DLNG site area. Given the type of construction occurring there are no credible alternatives to reduce ground disturbance. **Table 7-9** details the management actions to reduce impact to onshore sediment quality, water quality, air quality, vegetation, and terrestrial fauna.

There will be regular inspections of trenches and preventative measures in place to control fauna egress. Engineering design will also prevent fauna entrapment.

During the construction of the Bayu-Undan pipeline natural material within the onshore Project Area was replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m below ground level. Hence it is considered that material at the site is likely to be non-ASS. None-the-less, should ASS material be encountered during earthworks within the onshore Project Area, it will be managed in line with the ASSDMP (BAS-210-0049).

Terrestrial fauna and vegetation may interact with stockpiled soils, however given that these will be managed within short temporal scales in accordance with the ASSDMP there would be an insignificant impact.

Given the temporary and localised nature of the impacts, and the existing disturbance at the site, the implementation of standard and additional (ALARP) management actions in place, including the implementation of the ASSDMP (BAS-210 0049) are appropriate for the nature and scale of this activity. Therefore, the assessed residual consequence for the impact of physical presence is minor and acid sulfate soils is negligible and both cannot be reduced further. Additional known residual impacts have been reduced to ALARP and are considered acceptable noise emissions.

7.6.4 Noise Emissions

7.6.4.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-10**.

Table 7-10: Noise emissions EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Avoid hearing injury impacts to protected marine species from underwater noise generated by DPD Project trenching and spoil disposal activities	Zero incidents of injury or mortality to EPBC Act listed marine fauna from noise generated during DPD construction activities	+ Incident reports of injured or dead EPBC Act listed fauna + MFO records of EPBC Act listed fauna within vessel observation/exclusion zones
	Zero incidents of trenching or rock breaking while EPBC Act listed marine fauna observed in exclusion zone	+ MFO records of EPBC Act listed fauna within vessel exclusion zone

This EPO aligns with the following NT EPA Factor objectives (NT EPA 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this planned impact are shown in **Table 7-11**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-11: Management actions for noise emissions during routine construction including the use of an Xcentric Ripper tool

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA48	Observation and exclusion zones for marine fauna developed based on noise modelling results and standard protocols
Mitigation	
DPD-MA49	Vessel inductions for all crew to address marine fauna risks and the required management controls
DPD-MA50	Vessel and helicopter to complete Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA51	Personnel trained in MFO to be present on pipelay, dredge and rock installation vessels/barges during daylight hours, including one crew member with MFO training on the bridge at all times
DPD-MA52	All marine fauna interactions and observations to be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW as required
DPD-MA53	Maintenance of vessel, vehicle and equipment combustions engines and vessel incinerators as per planned maintenance system
Additional (ALARP) management actions	
Avoidance	
DPD-MA54	Observation and shut-down zones for marine fauna have been developed based on noise modelling results for trenching and standard protocols and include: + Observation (150 m) and exclusion (50 m) zones for marine mammals and turtles. + Observation zone monitored for 10 minutes prior to commencing trenching during daylight only. A Marine Megafauna Observation and Adaptive Management Protocol for routine trenching operations, including the use of Xcentric Ripper tool, is to be followed as per MMNMP (BAS-210 0045)
Mitigation	

MA reference	Management actions
DPD-MA55	+ Soft start (ramp-up) of hydraulic tools (rock breaking) by BHD, where practicable + Soft start (ramp-up) of trenching equipment, where practicable, will apply to the CSD and TSHD

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Table 7-12: Additional environmental management actions for contingency rock breaking using hydraulic hammer

MA reference	Management actions
Contingency management actions	
1	Increased Observation and Exclusion Zones for hydraulic hammering based on noise modelling results will be applied as follows: + If up to 8 hours of rock breaking is required, an increased Observation Zone of 2.5km (marine mammals) and 1km (turtle) will apply and an increased Exclusion Zone of 150m for marine mammals and turtles will apply + If up to 6 hours of rock breaking is required, an increased Observation Zone of 2 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100m for marine mammals and turtles will apply + If up to 4 hours of rock breaking is required, an increased Observation Zone of 1.5 km (marine mammals) and 750 m (turtle) will apply and an increased Exclusion Zone of 100 m for marine mammals and turtles will apply + If up to 2 hours of rock breaking is required, an increased Observation Zone of 1 km (marine mammals) and 500 m (turtle) will apply and an increased Exclusion Zone of 50 m for marine mammals and turtles will apply
2	Contingency hydraulic hammering protocols for managing noise impacts will be followed as per MMNMP (BAS-210 0045)
3	Hydraulic hammering for no greater than 8 hrs over a 24 hr period.
4	No hydraulic hammering at night
5	A separate vessel with MFO onboard will be required to patrol the Observation Zone prior to and during hydraulic hammering

Table 7-13: Additional (ALARP) management actions not adopted for noise emissions

Additional management actions not adopted		Reasoning for rejection
1	Schedule trenching activities outside of peak flatback turtle nesting period (May to October) or outside of peak Darwin Harbour dolphin calving period (October to April).	+ It would not be possible to avoid both peak periods. + The potential benefit of avoiding locations of higher marine megafauna sensitivity at certain times of the year, such as nesting periods for turtles and dolphin calving periods, is considered disproportionately low compared to the implications to Project scheduling and costs - While there are known flatback turtle nesting sites (Cox Peninsula and Casuarina Beach), and a known period of increased nesting activity (May to October), the densities of nesting turtles in these areas are very low and not significant on a regional scale (Chatto and Baker, 2008). Furthermore, these sites are on a scale of 1000s of meters away from the pipeline route and trenching areas (as they are from existing vessel traffic using navigation channels) and the relative risk of behavioural effects to turtles at this scale from vessel noise is considered low (Popper et al., 2014). For dolphins, there is evidence that there is a peak in calving within Darwin Harbour between October and April (Palmer, 2010). Important areas have not been defined however and given the high mobility of dolphin species within Darwin Harbour and the use of adjoining coastal areas (Griffiths et al., 2019) it is unlikely that behavioural disturbance around DPD Project activities, relative to the total area of Darwin Harbour and surrounding coastal waters, would have a significant impact on calving behaviour.
2	The observation period for marine megafauna prior to commencing dredging and pile driving is 20 minutes and the MFO is solely dedicated to the task of sighting and recording marine megafauna interactions prior to, and during, dredging and pile driving operations.	+ A 20-minute observation period was considered excessive for the size of the Observation Zone (150 m) and a 10-minute observation period was considered sufficient to monitor this zone for marine fauna. An additional 10 minutes would prolong dredging operations without any appreciable benefit. + A MFO for the pre-start up observation period was considered warranted however a MFO solely to the task of sighting and recording marine megafauna for the entirety of dredging operations was not considered warranted given that the dredging vessel to have multiple crew with marine fauna observation training onboard during daylight hours and the

Additional management actions not adopted		Reasoning for rejection
		vessel bridge to be constantly manned with at least one crew with MFO training on the bridge at all times.
3	No use of DP vessels.	Not using DP vessels will cause additional seabed and benthic habitat impacts through the need to use anchoring to hold position during pipelay. The use of DP also decreases pipelay duration and reduces impact to other users through shorter timeframe.
4	Cease noise generating activities (e.g. DP) when near marine fauna.	Ceasing DP activities when near sensitive fauna may reduce the potential for impacts, however, the potential for impacts beyond behavioural disturbance are very low. Engine/DP thruster noise cannot reliably be ceased due to the safety critical role of vessel propulsion. It is also not practical to cease pipelay or other critical construction activities in a short timeframe as safely abandoning such operations can often take a number of hours (namely laying down the pipeline or disconnecting from a structure), during which time the impacted fauna will have left the area. Therefore, this control is not deemed feasible.
5	Soft start/power-up procedures for use of sonar equipment and use of fauna observation and shutdown zones.	The systems being used are at a low power or are an intermittent type such that the reduced cumulative exposure would reduce TTS or PTS impacts for marine fauna and behavioural impacts were not considered credible
6	No use of helicopters.	Use of helicopters required (e.g. vessel/crew transfers) and restriction will result in an overall longer duration construction activity and therefore noise impacts
7	Avoidance of night work for routine trenching and Xcentric Hammer use.	Avoidance will result in an overall longer duration construction activity and therefore noise impacts and also increase the safety risk profile. The cost of implementing this far exceeds the benefit gained.

7.6.4.2 Adaptive management mechanism

Adaptive management mechanisms related to noise emissions are outlined in the MNMMP (BAS-210 0045).

7.6.4.3 Demonstration of ALARP and residual impact

Use of vessels and subsea equipment will be required to complete construction activities, therefore underwater noise emissions are unavoidable if the planned activity is to proceed.

Trenching and rock breaking activities will follow industry standard measures to prevent physiological impact to marine megafauna from noise, including implementation of Observation and Exclusion Zones and associated adaptive management measures, use of marine fauna observers to monitor zones and use of soft-starts where practicable. These zones have been informed by underwater noise modelling and appropriate thresholds to ensure the scale of these zones are sufficient to meet environmental objectives. In addition to the implementation of monitored zones, marine megafauna are expected to display avoidance behaviour of sound source at close ranges, thereby reducing the potential for physiological impact. For contingency hydraulic hammering, while not expected to be required, the zones have been increased significantly and additional measures put in place to ensure physiological impacts to do not occur to marine megafauna.

While there is the potential for behavioural response on larger scales of 100s of metres to 1000s of metres from continuous noise from trenching activities, depending upon fauna type, the activities are not expected to produce emissions significantly louder than other marine vessels that frequent or transit through the vicinity of the Project Area (e.g. cargo ships, LNG tankers, cruise ships and offshore oil and gas vessels). Given construction activity is temporary and trenching is expected to last for ~2-3 months, the addition of Project noise sources to the existing ambient noise environment is not expected to result in any significant additional behavioural effects within Darwin Harbour. The activity is unlikely to affect the health of and/or displace marine megafauna, as biologically important behaviours can continue given the widespread availability of suitable habitat within Darwin Harbour relative to the size of behavioural effect ranges.

Santos has considered the actions prescribed in various recovery plans and conservation advice, such as the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017), when developing the controls relevant to potential construction activities to minimise noise impacts on marine fauna. Management controls are in place to reduce operating noise, including vessel operational protocols, and to adhere to the fauna interaction management stated in EPBC Regulations (Part 8). As such, noise emitted during the activities is not expected to significantly impact on marine fauna within the Project Area.

The potential benefit of avoiding locations of higher marine megafauna sensitivity at certain times of the year, such as nesting periods for turtles and dolphin calving periods, is considered disproportionately low compared to the implications to Project scheduling and costs. There are also mutually exclusive sensitivity periods for dolphins and turtles. While there are known flatback turtle nesting sites (Cox Peninsula and Casuarina Beach), and a known period of increased nesting activity (May to October), the densities of nesting turtles in these areas are very low and not significant on a regional scale (Chatto and Baker, 2008). Furthermore, these sites are on a scale of 1000s of meters away from the pipeline route and trenching areas (as they are from existing vessel traffic using navigation channels) and the relative risk of behavioural effects to turtles at this scale from vessel noise is considered low (Popper et al., 2014).

For dolphins, there is evidence that there is a peak in calving within Darwin Harbour between October and April (Palmer, 2010). Important areas have not been defined however and given the high mobility of dolphin species within Darwin Harbour and the use of adjoining coastal areas (Griffiths et al., 2019) it is unlikely that behavioural disturbance around DPD Project activities, relative to the total area of Darwin Harbour and surrounding coastal waters, would have a significant impact on calving behaviour.

Other additional management actions were considered but rejected due to lack of feasibility, the associated cost or because the effort was disproportionate to any benefit (**Table 7-11**). Therefore, the risks to marine fauna from noise associated with the DPD Project activities are considered to be ALARP.

The potential consequence of noise emissions on receptors is assessed as II - Minor following the implementation of standard and additional (ALARP) management actions and will not have a significant impact on any habitat identified as critical to the survival of marine megafauna. With the management actions in place, no significant impacts are expected. Therefore, the impacts of noise emissions to the receiving environment are ALARP and considered environmentally acceptable.

7.6.5 Light emissions

7.6.5.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-14**.

Table 7-14: Light emissions EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise light disturbance to fauna and fauna habitat (including to turtle nesting beaches and turtle hatchlings)	Nighttime task light generation is minimised as described in management actions.	+ Records of vessel light spill on Darwin Harbour turtle nesting beaches + Records of HSE inspections. + Records of inductions i.e., inductions cover use of excessive task lighting at night

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this planned impact are show in **Table 7-11**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

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Table 7-15: Management actions for light emissions

MA Reference	Management actions
Standard management actions	
Avoidance	
DPD-MA56	Pipelay vessels will have enclosed pipe welding decks
Mitigation	
DPD-MA57	Shielding, where practicable, and/or orienting operational lights (excluding navigational lighting) on vessels to limit light spill to the environment
DPD-MA58	Housekeeping measures will be adopted, including requiring all crew to keep shutters on windows closed at night, to limit light emissions from vessels
Additional (ALARP) management actions	
Mitigation	
DPD-MA59	Vessel searchlights will only be operated in an emergency situation.
Monitoring	
DPD-MA60	Santos will document vessel light spill on Darwin Harbour turtle nesting beaches as part of the DPD Project's environmental monitoring program

Table 7-16: Additional management actions not adopted for light emissions

Additional management actions not adopted		Reasoning for rejection
1	Crew transfers or loading of supplies (not including linepipe deliveries) which require direction of floodlights outside vessel will not occur during hours of darkness within 10 km of turtle nesting beaches during peak hatchling season. Linepipe loading may require additional lighting as deemed necessary during operation to maintain a safely lit work area.	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area. Therefore, the cost of this management action is disproportionately higher than the change to environmental impact.
2	Do not undertake gas export pipeline installation during peak turtle nesting and hatchling emergence season.	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area. Therefore, the cost of this management action is disproportionately higher than the change to environmental impact.

Additional management actions not adopted		Reasoning for rejection
3	Sequence activities to limit the time pipelay, and associated activities, are performed within peak internesting periods and near important habitat for listed marine turtles.	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area. It is additionally not practicable to time the start date of the activity due to scheduling constraints. Therefore, the cost of this management action is disproportionately higher than the change to environmental impact.
4	Vessels shall be fitted with turtle friendly (low vapour sodium or LED) directional lighting (requirement applies to external lighting only).	Nearby beaches are not significant turtle nesting beaches. Significant turtle nesting beaches are >10 km from the Project Area. Not practicable to change out vessel lights for short duration activities and also lighting must meet navigational requirements. White lights required for operational requirements will be directed onto work areas and/or shielded to limit external light spill. It is therefore not feasible.
5	Marine fauna observers specifically looking out for turtle hatchlings entrapped within light spill with adaptive management measures should a significant number be spotted.	Possibility of entrapment will be low, due to use of shaded and directed inward lighting and with only very low density turtle nesting locations nearby. Nearby beaches are not significant turtle nesting beaches. While dedicated observers for turtle hatchlings are not proposed, project vessels will record all fauna interactions and incidents observed. Corrective actions will apply as part of the incident reporting and investigation process.
6	Do not perform pipe transfer operations at night when operating within 10 km of marine turtle nesting habitat during peak hatchling emergence season.	Nearby beaches are not significant turtle nesting beaches. If pipe transfer is restricted to day light hours, the pipelay vessel will run out of pipe and it will have to slow lay, stop laying or lay down the pipe . Slowing down pipelay will result in an increase in the amount of time that the pipelay is operating within 10 km of marine turtle nesting habitat. Light spill during pipe transfer will be minimal as flood lights will be directed onto the deck of the PSV and not the surface of the water. It is also temporary. Therefore, the cost of this management action is disproportionately higher than the change to environmental impact.
7	Restrict lighting to navigation lights only	Operational lighting, including lighting of work areas and decks, is required for safe working conditions. Therefore, the cost and increased risk of this management action is disproportionately higher than the change to environmental impact.

7.6.5.2 Demonstration of ALARP and residual impacts

Artificial lighting is required 24 hours a day during the activity to maintain operational and navigational safety. A minimum level of artificial lighting is required on a 24-hour basis to alert other marine users of the activity. There are also minimum light requirements that will be necessary to provide safe working conditions. To reduce lighting at night further would restrict the activity hours resulting in the activity taking approximately twice as long to complete. This would increase the period of time the Project Area would need to be avoided by other marine users and the amount of waste, discharges and emissions produced. The larger scale consequences associated with reducing light levels during construction activities are disproportionate to the environmental benefits.

Lighting of the vessels is industry standard and required to meet relevant maritime and safety regulations. The potential consequences of the anthropogenic light sources in the Project Area are considered to be restricted to short-term behavioural impacts on individual fauna that may be present in the Project Area during the activity.

The activity will not compromise the objectives as set out in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017), the Wildlife Conservation Plan for Seabirds (Commonwealth of Australia, 2020c) or the National Light Pollution Guidelines for Wildlife (Commonwealth of Australia, 2020b), as biologically important behaviours of nesting turtle adults and emerging/dispersing hatchlings at important sites can continue given that there are no regionally significant turtle nesting beaches close to the Project Area. Additional management actions that were considered feasible and cost effective were adopted (**Table 7-15**). Therefore, the use of 24-hour per day artificial lighting at an intensity to allow work to proceed safely is considered ALARP.

BIAs for flatback turtles overlap the Project Area. Significant impacts are not expected on nesting turtles or emerging/dispersing hatchlings, and light emissions from the activity will not cause turtles to be displaced from these habitats. The nearest known nesting sites are at Cox Peninsula and at Casuarina Beach, although these are not considered significant nesting areas and Casuarina Beach is additionally a popular recreational area with significant potential for land disturbance from people and animals, including lighting (e.g., bonfires).

The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017) specifies the following priority action for the turtles in relation to light pollution:

+ Artificial light within or adjacent to habitat critical to the survival of marine turtles will be managed such that marine turtles are not displaced from these habitats.

The Project Area overlaps an internesting buffer habitat critical to the survival of flatback turtles, which extends 60 km from key nesting locations. However, internesting female turtles are not impacted by light emissions from either natural or anthropogenic sources, as they do not use light as a cue for this behaviour. Therefore, light emissions will not have a significant residual impact on marine turtles or any habitat identified as critical to the survival of marine turtles and residual impact is considered environmentally acceptable.

7.6.6 Routine vessel discharges

7.6.6.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-17**.

Table 7-17: Routine vessel discharges EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise environmental impacts from waste and liquid discharges generated during DPD construction activities	Zero recorded environmental incidents of vessel discharges not meeting regulatory requirements	+ Incident records of non-compliant discharges

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this planned impact are shown in **Table 7-18**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-18: Management actions for routine vessel discharges

MA reference	Management Action
Standard management actions	
Mitigation	
DPD-MA61	Vessels will comply with relevant Marine Orders with respect to planned discharges, including: + Marine Order 91 – Marine Pollution Prevention: Oil, which implements Annex I of the MARPOL + Marine Order 96 – Marine Pollution Prevention: Sewage, which implements Annex IV of the MARPOL
DPD-MA62	Santos Marine Assurance Process
Additional management actions	
N/A	

Table 7-19: Additional management actions not adopted for routine vessel discharges

Additional management actions not adopted		Reasoning for rejection
1	Storage and transport of sewage, putrescible and waste for disposal onshore regardless of legislative requirement.	Waste is managed in accordance with required legislative controls and discharge of sewage, greywater, and putrescible results in a negligible impact. The additional costs for transport and disposal, increased health, and safety risks (e.g., hygiene) and increased environmental impact (e.g., atmospheric emissions from vessels transporting waste) outweigh any environmental benefit gained.

7.6.6.2 Demonstration of ALARP and residual impact

Vessel waste is managed in accordance with marine legislation and results in negligible impacts in the discharge of sewage, greywater, and putrescibles. The additional costs, health and safety risks (i.e., hygiene) and environmental impact (i.e., emissions) outweigh any environmental benefit gained by taking vessel waste for onshore disposal. The Project Area is within NT waters i.e., within 3 nm of 'nearest land' (territorial baseline) therefore discharges of sewage and food wastes cannot occur in the Project Area (i.e., within 3 nm of land) as per MARPOL Annex IV and V. To reduce the impacts and risks associated with discharging liquid wastes, these wastes will be treated in line with industry best practice. Discharge of sewage and other liquid wastes from vessels in Australian waters is permissible under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, which reflects requirements of MARPOL 73/78 Annexes IV, V and I and AMSA Marine Orders 95 and 96. The MARPOL standard is considered to be the most appropriate standard, given the nature and scale of the activities. These standards are internationally accepted and used industry wide.

Stakeholders have been informed throughout the preparation of the CEMP of the proposed vessel activities as detailed in **Section 9**.

The proposed standard management actions and additional management actions that are considered feasible and cost effective for routine vessel discharges are considered appropriate to manage the risk to ALARP. Additional management actions that were not adopted are detailed in **Table 7-19**, with reasoning for their rejection.

Routine vessel discharges are not expected to have significant residual impact to the receiving environment with the management controls proposed, including compliance with all MARPOL requirements. Therefore, compliance with the relevant and appropriate MARPOL requirements and standards is expected to reduce the residual impacts to a level which is considered environmentally acceptable.

7.6.7 Pre-commissioning water extraction and discharges

7.6.7.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-20**.

Table 7-20: Pre-commissioning discharges EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise environmental impacts from pre-commissioning water extraction and discharges generated during DPD construction activities	Zero environmental harm resulting from mismanagement of pre-commissioning water extraction and discharges	+ Number of recorded incidents and severity of incidents

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this planned impact are shown in **Table 7-21**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-21: Management actions for pre-commissioning water extraction and discharges

MA reference	Management Action
Standard management actions	
Mitigation	
DPD-MA63	Protection/screening of abstraction hose end to prevent fauna entrainment
DPD-MA64	Backflush water will be discharge onto existing disturbed shore crossing construction site so that it drains into the intertidal area and solids disperse with tidal movement, minimising turbidity effects
Additional management actions	
DPD-MA65	Where possible, and dependant on the progress of shore crossing rock installation at time of FCGT activities, backflush water will be discharged onto installed rock, to baffle the flow of discharged backflush water

Table 7-22: Additional management action not adopted for pre-commissioning water extraction and discharges

Additional management actions not adopted		Reasoning for rejection
1	Use of potable water instead of sea water for pre-commissioning activities	Potable water isn't typically used for pre-commissioning due to the difficulties in obtaining the large volumes required –potable water is normally transported by road tankers with only 20 – 30m^3 capacity, compared with ~ 50,000 m^3 required to fill the DPD Pipeline. Potable water would also require treatment with some chemicals such as oxygen scavengers and biocides to mitigate oxygen or bacterial corrosion. A reverse osmosis (RO) plant could be set up on site to manufacture "potable water" from sea water, but normally the chloride levels will be higher from an RO plant than potable water which could lead to corrosion. This would also need a sea water winning spread. This would introduce additional impacts such as discharge of a high salinity waste stream and would have large pumping/energy requirements.

7.6.7.2 Demonstration of ALARP and residual impact

There are no additional practicable alternatives to using seawater for pre-commissioning. Potable water is not used for testing due to the difficulties in obtaining the large volumes required. As discussed in **Table 7-22**, the use of potable water or an RO plant are not practicable.

The proposed standard management actions and additional management actions that are considered feasible and cost effective for pre-commissioning water extractions and discharges are considered appropriate to manage the risk to ALARP. Additional management actions that were not adopted are detailed in **Table 7-21**, with reasoning for their rejection.

Stakeholders have been informed throughout the preparation of the CEMP of the proposed vessel activities and the presence of the pipeline as detailed in **Section 9**.

Pre-commissioning discharges are not expected to have significant residual impact to the receiving environment with the management controls proposed, including compliance with all requirements. Therefore, compliance with the relevant and appropriate requirements and standards is expected to reduce the residual impacts to a level which is considered environmentally acceptable. Although, there is potential for marine fauna entrainment from water winning activities the abstraction hose will be fitted with protection/screening preventing this, which is deemed environmentally acceptable.

Deteriorating water quality is identified as a potential threat to turtles in the marine turtle recovery plan and some bird and shark species. However, the routine vessel and pre-commissioning discharges are not expected to have significant residual impact to the receiving environment with management controls proposed. Therefore, the impact level of routine vessel and pre-commissioning discharges due to vessel-based activities is considered acceptable.

7.6.8 Atmospheric emissions

7.6.8.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-23.**

Table 7-23: Atmospheric emissions EPOs and associated performance criteria

EPO	Performance criteria	
	Target/s	Performance Indicator/s
Minimise environmental impacts from atmospheric emissions generated during DPD construction activities	Compliance with preventative maintenance procedures for equipment utilised for construction activities that generate atm emissions combustion engines, incinerators and ozone depleting substances (ODS) containing equipment	+ Planned maintenance records

These EPOs align with the following NT EPA Factor objective (NT EPA 2022):

+ Air quality – Protect air quality and minimise emissions and their impact so that environmental values are maintained.

The management actions for this planned impact are shown in **Table 7-24.** Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-24: Management actions for atmospheric emissions

MA reference	Management actions
Standard management actions	
Mitigation	
DPD-MA53	Maintenance of vessel, vehicle and equipment combustions engines and vessel incinerators as per planned maintenance system
DPD-MA66	Atmospheric emissions from combustion, incinerators and ODS managed in accordance with standard maritime practice (MARPOL) MARPOL standards include no incineration in harbour
DPD-MA67	Monitoring and reporting of fuel consumption and calculated GHG emissions
DPD-MA68	Use of low sulphur diesel
Additional (ALARP) management actions	
N/A	

7.6.8.2 Demonstration of ALARP and residual risk

Power generation through combustion of fossil fuels is essential to undertaking the construction activities. There are no practicable alternatives to the use of equipment, vessels and vehicles powered by combustion engines for the activity. Given the routine maintenance of these systems by suitably qualified personnel, all practicable management measures are considered to have been implemented.

Atmospheric emissions from vessels are managed in accordance with marine legislation and results in negligible impacts. Part of the Project Area is within Darwin Harbour, where incineration is prohibited. The additional costs, health and safety risks and environmental impact (i.e., emissions) from returning waste to shore for vessel operating outside of the harbour (i.e., hygiene additional increased fuel combustion for additional vessel trips) outweigh any environmental benefit gained by preventing incineration.

There is no option other than to use refrigeration systems (e.g., air conditioning and food refrigeration) to provide acceptable workplace conditions and meet food hygiene standards. Additionally, there is no practical alternative to using ozone depleting substances (ODS) as refrigeration chemicals. Accidental release and fugitive emissions of ODS has the potential to contribute to ozone layer depletion. Maintenance of refrigeration systems containing ODS is on a routine, but infrequent basis, and with controls implemented, the likelihood of an accidental ODS release of material volume is considered rare.

Records of fuel consumption during construction works will be maintained to identify the quantity of GHG emissions generated from fuel combustion. This information would inform annual reporting under the *National Greenhouse and Energy Reporting Act 2007*. Atmospheric emissions from vessels are permissible under the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, which is enacted in Australian waters by Marine Order 97 (Marine pollution prevention – air pollution) (which also reflects MARPOL Annex VI requirements). This is an internationally accepted standard that is used industry wide, and compliance with MARPOL standards is required under Australian law. Regulations include the requirement to control the level of NO_X and SO_X from vessel engines. Compliance with these requirements, together with implementation of the controls listed above, reduces to ALARP the environmental impacts associated with air emissions.

The assessed residual consequence for this impact is negligible and cannot be reduced further. It is considered therefore that the impact of the activities conducted is ALARP and considered environmentally acceptable.

7.6.9 Contingency pipeline discharges

7.6.9.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-25**.

Table 7-25: Contingency construction and pre-commissioning pipeline discharges EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Minimise environmental impacts from contingency treated seawater discharge	No significant impact to marine water quality from due to contingency pipeline dewatering	+ Water quality monitoring report
	Treated seawater chemical usage and discharge preformed as detailed in management actions (**Table 7-26)**	Contingency treated seawater discharge procedure and post-discharge report

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this planned impact are shown in **Table 7-26.** Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-26: Management actions for contingency construction and pre-commissioning pipeline discharge

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA69	Pipeline installation procedures Maintenance requirements for pipelaying equipment to minimise risk of operational failure Redundancy in nearshore pipelay vessel anchors Pipelay vessel will have redundancy in station keeping capabilities in operating in DP2 (as a minimum)
Mitigation	
DPD-MA70	Chemical selection procedure for all chemicals planned to be release to the marine environment
DPD-MA71	Calibrated chemical dosing system in place to ensure accuracy of chemical dosing
DPD-MA72	If contingency use and discharge of treated seawater is required, the lowest required concentration of treated chemical will be evaluated and used (up to a maximum of 550 ppm) in order to meet pipeline preservation requirements.
DPD-MA73	Release of treated seawater from pipeline will be through a valve orientated vertically to promote dispersion and direct discharge away from seabed
Monitoring	
DPD-MA74	In the unlikely event that the pipeline requires contingency filling and subsequent dewatering of treated seawater in response to a wet buckle event and prolonged repair, water quality monitoring at the discharge location will be conducted to confirm the concentration and dispersion of treatment chemicals.

Table 7-27: Additional management actions not adopted for contingency pipeline discharges

Additional management actions not adopted		Reasoning for rejection
1	Do not discharge treated seawater	Chemically treated seawater will be used as a last resort, should it be necessary to ensure the long-term integrity of the Nearshore GEP Pipeline. If recovery from a wet buckle does not occur within a short period (days to 1-2 weeks), then the risk of corrosion beyond that already that already allowed for in the pipeline design will need to be mitigated, with the displacement of any raw seawater with treated seawater. Company requires the ability to use treated seawater to protect the integrity of the pipeline to cover all possible scenarios.

7.6.9.2 Demonstration of ALARP and residual impact

Contingency treated seawater discharge is a planned response to prolonged wet buckling or a stuck pig which is an unplanned event. The use of chemically treated seawater will only occur if it is necessary to ensure the long-term integrity of the DPD Pipeline (NT). If recovery from a wet buckle does not occur within a short period (days to 1 – 2 weeks), then the risk of corrosion beyond that already allowed for in the pipeline design will need to be mitigated, with the displacement of any raw seawater with treated seawater. Santos requires the ability to use treated seawater to protect the integrity of the pipeline to cover all possible scenarios.

Standard management actions have been adopted to reduce the impact of treated seawater discharge. All feasible and cost-effective additional management actions have been adopted to manage the risks to ALARP. Additional management actions that have not been adopted are described in **Table 7-26**, with the reasoning for rejection.

The potential consequences of contingency pipeline discharges has been determined by discharge modelling and impacts are predicted to be minor and not significant. The assessed residual consequence for this impact cannot be reduced further and is considered ALARP and acceptable.

7.7 Unplanned event - risk management strategies

The Santos environmental assessment identified six unplanned events associated with for the activities to be undertaken in the Project Area. Risk management strategies have been adopted in this CEMP based on the ENVID undertaken for construction activities in June 2022 (Refer to **Section 6**).

7.7.1 Dropped objects

7.7.1.1 Environmental performance objectives, performance criteria and management actions

The EPO relevant to this impact, including performance criteria, are described in **Table 7-28**.

Table 7-28: Dropped objects (including accidental release of non-hazardous waste) EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No environmental impact resulting from accidental release of non-hazardous solid waste and dropped objects	Zero incidents of loss of equipment/cargo overboard from vessels resulting in a consequence II – Minor or above	+ Incident records

These EPOs align with the following NT EPA Factor objectives (NT EPA 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this unplanned risk are shown in **Table 7-29**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-29: Management actions for dropped objects

MA reference	Management Actions
Standard management actions	
Avoidance	
DPD-MA61	Vessels will comply with relevant Marine Orders, including: + Marine Order 95 – Marine Pollution Prevention: Garbage
DPD-MA75	Implementation of Santos approved standards and procedures for outboard lifts
DPD-MA76	All lifting and winching equipment will undergo inspection, testing and certification as per applicable Laws, Codes and Standards
Mitigation	
DPD-MA77	Dropped object recovered where safe and practicable to do so
DPD-MA78	Identification of no lift zones where relevant in proximity to subsea assets and infrastructure as documented in relevant lifting and operational procedure/s
DPD-MA79	No outboard lifting operations will be completed in Company defined "no lifting zones" which will be identified in navigational systems
DPD-MA80	Emergency response implemented to minimise potential for impacts in the event a dropped object causes a loss of containment from the existing Bayu-Undan GEP
Additional management actions	
Avoidance	
DPD-MA81	Pipeline installed along pre-approved route, which is designed where practicable to avoid the potential for impact to habitat / cultural seabed features or assets from a dropped object.
Additional management actions not adopted	

MA reference	Management Actions
N/A	

7.7.1.2 Demonstration of ALARP and residual risk

Table 7-17 details the management actions adopted to reduce impacts of dropped objects to ALARP. These control measures are well understood and defined through legislative requirements and are standard industry practice. With the above controls in place, Santos considers the residual risk arising from a dropped object is ALARP.

The activity, and management actions will be conducted in a manner that is acceptable under the Threat Abatement Plan for Impacts of Marine Debris on Vertebrate wildlife of Australia's coasts and oceans (Commonwealth of Australia, 2018), relevant recovery plans, conservation advice, and wildlife conservation plans.

With the controls in place to prevent accidental release of dropped objects the residual impact to the marine environment is considered low and reduced to a level that is considered acceptable.

7.7.2 Introduction of invasive marine species

7.7.2.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-30**.

Table 7-30: Introduction of invasive marine species EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid introducing invasive marine species (IMS) into NT waters	+ DPD Project vessels assessed as low risk for IMS prior to entry into Project Area/Darwin Harbour + Ballast water management will be done according to the Australian Ballast Water Management Requirements	+ Records of vessel IMS risk assessment + Ballast water records system maintained by vessels

These EPOs align with the following NT EPA Factor objective (NT EPA 2022):

+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this unplanned risk are shown in **Table 7-31**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-31: Management actions for introduction of invasive marine species

MA reference	Management Action
Standard management actions	
Avoidance	
DPD-MA82	Vessels equipped with effective anti-fouling coatings as required for class
DPD-MA83	Ballast water management will comply with MARPOL requirements (as applicable to class), Australian Ballast Water Management Requirements and *Biosecurity Act 2015*
DPD-MA84	Apply risk-based IMS management for vessels and immersible equipment – vessel and immersible equipment mobilised from outside of the Project Area/Darwin Harbour must be assessed as having a low risk of IMS prior to entering the Project Area/Darwin Harbour
DPD-MA85	Vessels having suitable anti-fouling coating (marine growth prevention system) in accordance with the *Protection of the Sea Act 2006*

Table 7-32: Additional management actions not adopted for the introduction of invasive marine species

Additional management actions not adopted		Reasoning for rejection
1	Use of Australian vessels only	Not feasible to only use Australian vessels given constraints on availability and suitability. This also doesn't guarantee that a vessel is IMS free depending on where in Australia the vessel is mobilised.
2	All vessels to be dry docked, cleaned, and inspected for IMS	Santos requires a risk assessment to be undertaken for project vessels which considers factors that lessen the risk of IMS incursion and requires vessel to achieve a low risk score. These factors include a vessel's history of dry-docking, cleaning and IMS inspection but these activities are not necessarily mandatory depending upon vessel history and other risk factors. The costs of applying mandatory dry-docking and cleaning is considered disproportionate given the existing risk-based approach being applied.
3	Heat or chemical treatment of ballast water to eliminate IMS	Cost and effort is considered to outweigh benefits given existing regulatory requirements for ballast exchange will be adhered to

7.7.2.2 Demonstration of ALARP and residual risk

Vessels and submersible equipment are required for the DPD Project.

Ballast water exchange will be managed consistent with the Australian Ballast Water Management Requirements (Commonwealth of Australia, 2020a), and a vessel biosecurity risk assessment in accordance with the Santos IMSMP (EA-00-RI-10172) will be undertaken to demonstrate vessels have low risk of IMS introduction. The vessels and equipment that are internationally mobilised will meet Australian biosecurity requirements, and proposed management is consistent with National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Commonwealth of Australia, 2009c).

Santos has adopted a risk-based approach to managing biofouling. Such an approach is consistent with other petroleum operators and is beyond that enforced on the majority of commercial and recreational vessels that regularly transit the same bioregion. International vessels are given the highest priority to prevent the introduction of IMS into Australian waters. However, domestic vessels (interstate and locally sourced) mobilising from outside of the Project Area/Darwin Harbour are also risk-assessed to reduce the likelihood of spreading marine pest species already established in Australian waters. The biofouling risk assessment approach adopted by Santos will ensure the associated regulations prohibiting the introduction of non-endemic marine species will be met.

A combination of international and domestic vessels will be sourced for construction activities. Standard management actions to reduce the risk of an introduction of IMS to ALARP have been adopted. Other identified management actions were deemed not feasible and the reasoning for their rejection is provided in **Table 7-31**. Therefore, with the above management actions and adherence to legislation and regulations , the risk of introducing IMS has been reduced to ALARP. Therefore, the residual risk associated with IMS is considered by Santos to be environmentally acceptable.

Stakeholders have been informed throughout the preparation of the CEMP of the proposed vessel activities and the presence of the pipeline as detailed in **Section 9** and have not raised any concerns regarding this aspect.

7.7.3 Unplanned marine fauna interaction

7.7.3.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-33**.

Table 7-33: Unplanned marine fauna interactions EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid interactions resulting in injury to or mortality of protected marine megafauna	Zero incidents of interactions resulting in the injury or mortality of marine megafauna	Number of recorded incidents relating to marine fauna injury or mortality MFO reports of sightings of live, injured or dead marine megafauna

These EPOs align with the following NT EPA Factor objective (NT EPA, 2022):

- Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this unplanned risk are shown in **Table 7-34**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-34: Management actions for marine fauna interaction

MA reference	Management Actions
Standard management actions	
Avoidance	
DPD-MA50	Vessel and helicopter contractor procedures will comply with Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA51	Personnel trained in marine fauna observation (MFO) will be present on pipelay, dredge and rock installation vessels during daylight hours, including one crew member with MFO training on the bridge at all times
DPD-MA63	Protection/screening of abstraction hose end to prevent fauna entrainment during water winning activities
DPD-MA82	Inductions to include observing marine fauna (e.g., crocodiles and shorebirds)
DPD-MA83	The TSHD shall be fitted with pre-sweeping mechanisms / chain curtains to mitigate turtle entrapment (fauna strike – unplanned)
Mitigation	
DPD-MA52	All marine fauna interactions and observations will be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW
Additional management actions	
N/A	

Table 7-35: Additional management actions not adopted for unplanned marine fauna interactions

Additional management actions not adopted		Reasoning for rejection
1	Restrict the timing of activities to operate outside of known sensitive periods only. Flatback turtle peak nesting period is May to October and Dolphin peak calving is October to April	Project schedule is unable to avoid sensitive periods. Additionally, there is a low risk of impacts to individual fauna, and there is not expected to be an impact at population level or significant impacts on migratory or breeding behaviours. Beaches closest to the project area are also not considered significant turtle nesting beaches so this control is not considered relevant.
2	Activities will only occur during daylight hours	Construction works need to occur 24/7 to maintain project schedule. Increased project schedule may result in increase in vessel movements and potential for more cumulative impacts.

7.7.3.2 Demonstration of ALARP and residual impact

No alternative options to the use of vessels are possible in order to undertake the activity. Any impact caused by the physical presence of vessels is likely to be localised and temporary behavioural impacts only (e.g., avoidance behaviour) and are not expected to significantly impact any key life-cycle processes of marine fauna. Marine species are expected to resume normal behavioural patterns in the waters surrounding the Project Area in a short time frame following completion of the construction activities.

TSHD and water winning activities pose a risk of fauna entrainment. Dredging has been listed as a key threatening process for turtles (Commonwealth of Australia, 2017a) with dredging equipment potentially being the direct source of turtle mortality however the TSHD shall be fitted with pre-sweeping mechanisms / chain curtains to mitigate unplanned impact with turtles. Additionally, the abstraction hose for water winning activities will have protection/screening for marine fauna. This is considered to manage this to ALARP.

The inherent likelihood of encountering fauna in the Project Area is limited by the expected behaviour of individuals to move away from vessel noise. With low vessel speeds and compliance with fauna interaction procedures, including Regulation 8 of the EPBC Regulations 2000, which aim to prevent adverse interactions of vessels with marine megafauna, a fauna collision is considered very unlikely. With the controls adopted, the assessed residual risk for this impact is ALARP.

Marine fauna interaction risks are well understood and subject to regulation. The vessels and personnel that are mobilised will meet Australian requirements, and proposed management is consistent with relevant recovery plans, conservation advice, wildlife conservation plans, including the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017a). Vessel personnel will complete Inductions outlining fauna interaction requirements and, there will be watchkeeping maintained from the vessel bridge further reducing the impact.

Stakeholders have been informed throughout the preparation of the CEMP of the proposed vessel activities and the presence of the pipeline as detailed in **Section 9**.

It is considered that the proposed controls will reduce the residual level of impact to minor. Therefore, the residual risk associated with marine fauna interactions is considered by Santos to be environmentally acceptable.

7.7.4 Release of liquid hazardous materials

This section does not include management strategies for the release of fuels due to a vessel bunkering incident or a vessel tank rupture; these risks are discussed in **Section 7.7.5**.

7.7.4.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-36**.

Table 7-36: Release of liquid hazardous materials EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid significant environmental impact resulting from release of hazardous materials	Zero incidents of release of hazardous materials to the marine environment during DPD construction activities	+ Number of recorded incidents
	Response to incident implemented as per the relevant emergency response plans	+ Incident report including details of response

These EPOs align with the following NT EPA Factor objectives (NT EPA, 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this unplanned risk are shown in **Table 7-37**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

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Table 7-37: Management actions for release of hazardous material

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA84	Inspection and maintenance for all equipment containing chemicals/ hydrocarbons and chemical/ hydrocarbon storage areas
DPD-MA85	Santos chemical selection procedure applied for chemicals
DPD-MA86	ROV operations undertaken in accordance with good industry practice (in relation to hydraulic fluid control)
DPD-MA87	Procedures for helicopter refuelling
Mitigation	
DPD-MA88	Chemical storage areas designed to contain leaks and spills and inspected routinely
DPD-MA89	Spills will be managed in accordance with standard maritime practices as per vessel shipboard oil pollution emergency plan (SOPEP)
DPD-MA90	Spill clean-up kits available in high-risk areas
DPD-MA91	Bunding/secondary containment
Additional management actions	
N/A	

7.7.4.2 Demonstration of ALARP and residual impact

Storage and use of chemicals and hydraulic and lubricating oils or fluids for equipment and machinery, including for ROV operations, are required to undertake the DPD Project. While the use of hazardous chemicals cannot be avoided, the Santos chemical selection process will ensure that project chemicals are risk assessed and selected with consideration of alternatives, so hazardous chemicals are not discharged.

Only volumes of hazardous materials as required for maintaining vessel capabilities or for project-specific purposes will be stored or handled on-board the vessels. The vessels will implement safeguards, as per relevant AMSA Marine Orders/MARPOL and Santos requirements. Such safeguards include (but are not limited to) designated storage and handling areas, correct stowage, accurate labelling and marking, Safety Data Sheet (SDS) information, spill clean-up equipment and containment.

Other management actions will be implemented include vessel maintenance systems, chemical management procedures, and shipboard marine pollution emergency plan (SMPEP)/ spill response procedures included in shipboard oil pollution emergency plan (SOPEP) which will reduce the likelihood of an accidental release, and reduce the residual impact if a release does occur.

Containment of small spills and use of spill containment kits on-board vessels will reduce the risk of spills reaching the marine environment. The inspection and maintenance of bunding and drainage systems and of spill response kits provides assurance that these are available to contain spills. Hazardous liquids will be managed in accordance with relevant legislation and industry standards and Santos' procedures. Stakeholders have been informed throughout the preparation of the CEMP of the proposed vessel activities and the presence of the pipeline as detailed in **Section 9**.

The management actions proposed are in line with applicable actions described in relevant recovery plans and conservation advice to reduce the risk of habitat degradation and deteriorating water quality (for example, from pollution) to a level considered to be ALARP by Santos. The assessed residual risk for this impact is low. It is considered therefore that the impact of the activities conducted is ALARP.

With the management actions in place to prevent and mitigate accidental spills and the minor impacts predicted from a minor spill of hazardous chemicals/ hydrocarbons, the environmental risk is considered low. Potential risks are unlikely to be greater than those caused by other commercial marine vessels or offshore petroleum activities in deep water using the Project Area. Therefore Santos deems the risk acceptable.

7.7.5 Release of hydrocarbon (offshore vessel bunkering or vessel tank rupture)

7.7.5.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-38**.

Table 7-38: Hydrocarbon release (offshore vessel bunkering or vessel tank rupture) EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
No release of hydrocarbons to the marine environment as a result of the DPD Construction Activities	Zero incidents of unplanned discharge of hydrocarbons into the marine environment as a result of DPD construction activities	+ Number of recorded incidents

These EPOs align with the following NT EPA Factor objectives (NT EPA, 2022):

+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions for this unplanned risk are shown in **Table 7-39**. Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-39: Management actions for hydrocarbon release (offshore bunkering incident or vessel fuel tank rupture)

MA reference	Management Actions
Standard management actions	
Avoidance	
DPD-MA07	One vessel will act as a surveillance vessel within the operational area during gas export pipeline installation
DPD-MA92	Vessel-specific bunkering procedures and equipment consistent with Santos marine vessel vetting requirements including: + Use of bulk hoses that have quick connect ‘dry break’ couplings + Correct valve line-up + Defined roles and responsibilities, and the specific requirement for bunkering to be completed by trained personnel only + Visual inspection of hoses prior to bunkering to confirm they are in good condition + Testing of the emergency shutdown mechanism on the transfer pumps + Assessment of weather/sea state + Maintenance of radio contact with Vessel during bunkering operations + Bunkering checklist + Visual monitoring during bunkering + Ensuring deck drainage bungs are in place prior to bunkering + Marine Order 91 – Marine Pollution Prevention: Oil + Bunkering to commence in daylight hours
DPD-MA93	Vessel equipped and crewed in accordance with Australian maritime requirements
DPD-MA94	Safety exclusion zone around DPD Project construction vessels, e.g. pipelay vessels, and an NTM will be issued for offshore works advising all major shipping traffic formally. In addition, pipelay vessels will have attendant vessels that may act as guard vessels for work within the harbour
DPD-MA95	No intermediate fuel oil (IFO) or heavy fuel oil (HFO) will be used in activity vessels working in the Project Area

MA reference	Management Actions
Mitigation	
DPD-MA90	Spill clean-up kits available in high-risk areas
DPD-MA96	Implement tiered spill response as per DPD Project specific OPEP in the event of an MDO spill
Additional management actions	
Monitoring	
DPD-MA97	Santos to make oil spill tracking buoys available on primary project vessel/s with Santos CSR/s and/or at local supply base for immediate deployment to assist with tracking of an oil spill

Table 7-40: Additional management actions not adopted for release of hydrocarbon (offshore bunkering incident or vessel fuel tank rupture)

Additional management actions adopted		Reasoning for rejection
1	No bunkering of fuel during the pipeline installation activity	Vessels will routinely bunker when in port, as this is the safest and most cost effective means to refuel vessels. However due to the gas export pipeline installation method, the pipelay vessel cannot bunker alongside port facilities and requires bunkering within the operational area to undertake the activity. Following implementation of the selected existing controls, the risk reduction associated with eliminating bunkering at sea is considered to be negligible. The potential impacts to schedule and associated cost of implementing the control is considered to be grossly disproportionate to the reduction in risk. The control has not been adopted.
2	Bunkering only during daylight hours	Bunkering only during daylight hours increases the likelihood of detecting a leak, as surface hydrocarbon sheens are typically more visible under sunlight. Bunkering operations are typically completed during daylight hours; however, circumstances may occur where bunkering is required during darkness (e.g., large volume transfers at slow rates or when bunkering is safer to perform at night due to prevailing metocean conditions). Bunkering will only commence in daylight hours however. Following implementation of the selected existing controls, the risk reduction associated with prohibiting bunkering during darkness is considered to be negligible. The cost of implementing the control is considered to be grossly disproportionate to the reduction in risk. The control has not been adopted.
3	Schedule activities to avoid coinciding with sensitive periods for marine fauna present in the operational area	Project schedule is unable to avoid sensitive periods. Beaches closest to the Project Area are also not considered significant turtle nesting beaches. The cost of limiting the timing of activities would be excessive compared to the little to no reduction in risk of oil spill to significant turtle nesting beaches. Therefore, the impact to the Project schedule is greater than the environmental risk reduction.
4	Require all support vessels involved in the activity to be double hulled.	Cost and availability of double hulled vessels make this control not feasible.

7.7.5.2 Demonstration of ALARP and residual impact

The use of vessels is integral to activity and therefore risk of an unplanned hydrocarbon fuel releases cannot be eliminated completely.

Offshore vessel refuelling is standard industry practice and oil pollution legislation (*Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and MARPOL Annex I) has been developed to safeguard against the risk of a hydrocarbon spill occurring during refuelling. Other hydrocarbon types such as heavy fuel oil and intermediate fuel oil have specifically been prohibited as DPD Project vessel fuels, only MDO/marine gas oil (MGO) and aviation fuel will be used in the Project Area to ensure potential environmental impacts are reduced to ALARP.

The combination of the standard prevention management actions (**Section 7.7.5**) (which reduce the likelihood of the event happening), the spill response strategies (which will reduce the consequence) together reduce the overall hydrocarbon spill risk. Management controls that will be implemented, including pre-bunkering checklists spill clean-up equipment and SMPEP/SOPEP not only to minimise the risk of an accidental release, but also to reduce the impact if a release does occur. In addition to the vessel's SMPEP/SOPEP, Santos will provide support as required to a shipboard spill through the implementation of its DPD Project OPEP (BAS-210 0026). Resources available to be deployed by Santos to support a vessel base spill include spill tracking buoys which will be located onboard primary project vessels.

Barriers in place to contain spills (e.g. ensuring deck drainage bungs are in place prior to start of bunkering and spill containment kits) would prevent spills from reaching the marine environment. A vessel will act as a surveillance/guard vessel during gas export pipeline installation which will prevent collisions with Project vessels and other marine users. Santos will implement a safety exclusion zone around DPD Project construction vessels e.g. pipelay vessels and issue an NTM for offshore works further preventing vessel collisions.

Additional controls have been identified and given the controls in place detailed in **Table 7-40**, the assessed residual risk for this impact is Low and cannot be reduced further. It is considered therefore that the impact of the activities conducted is reduced to ALARP.

The potential impacts from an MDO/MGO release from a vessel collision are acceptable based on the residual risk ranking.

Relevant requirements have been met, including Santos' internal processes, COLREGS, SOLAS, STWC Convention and related Marine Orders. Pollution, such as could occur from a hydrocarbon spill, is identified as a threat in conservation advice for several marine species that may occur in the Project Area and as a threat in the North Marine Parks Network Management Plan (2018). Santos considers the selected controls are effective in managing the risk to these species and the to a level that is acceptable.

7.7.6 Release of dry natural gas

7.7.6.1 Environmental performance objectives, performance criteria and management actions

The EPOs relevant to this impact, including performance criteria, are described in **Table 7-41**.

Table 7-41: Release of dry natural gas EPOs and associated performance criteria

EPO	Performance Criteria	
	Target/s	Performance Indicator/s
Avoid environmental impacts from the accidental release of dry natural gas from Bayu-Undan to Darwin pipeline	No releases of gas from the Bayu-Undan pipeline to the environment as a result of impact/drag or dropped object from the DPD construction activity	+ Number of recorded incidents
	Response to incident implemented as per the relevant emergency response plans	+ Incident report including details of response

These EPOs align with the following NT EPA Factor objectives (NT EPA, 2022):

+ Air quality – Protect air quality and minimise emissions and their impact so that environmental values are maintained.
+ Marine environmental quality – Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.
+ Marine ecosystems – Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

The management actions considered for this unplanned risk are shown in **Table 7-42.** Environmental Performance Standards for these management actions will be defined and documented prior to finalisation of the CEMP.

Table 7-42: Management actions for release of dry natural gas

MA reference	Management actions
Standard management actions	
Avoidance	
DPD-MA75	Implementation of Santos approved standards and procedures for outboard lifts (including lifts over live infrastructure)
DPD-MA79	No outboard lifting operations will be completed in Company defined “no lifting zones”
DPD-MA80	Emergency response implemented to minimise potential for impacts in the event a dropped object causes a loss of containment from the existing Bayu-Undan GEP
DPD-MA98	Trenching will only occur within pre-programmed areas (using standard positional accuracy measures used in the industry)
DPD-MA99	Exclusion zones programmed on all primary vessels associated with the works to clearly indicate no entry zones and nearby pipelines – this will clearly identify areas for spud placement, anchor positioning and trenching activities
DPD-MA100	Navigation charts
Additional management actions	
Avoidance	
DPD-MA78	Identification of no lift zones where relevant in proximity to subsea assets and infrastructure as documented in relevant lifting and operational procedure/s

7.7.6.2 Demonstration of ALARP and residual impact

The proposed DPD pipeline will typically be within 100 m of the existing Bayu-Undan Pipeline; therefore vessels will be operating in the vicinity of the Bayu-Undan pipeline. Damage to the Bayu-Undan pipeline may be caused by structure impact/drag or a dropped object with potential to result in a release of dry gas to the environment. By having the DPD Project pipeline in close proximity (<100 m) to the Bayu-Undan pipeline, incursion into the shipping channel is reduced and seabed disturbance is concentrated adjacent to a previously disturbed corridor.

Stakeholders have been informed throughout the preparation of the CEMP of the presence of the pipeline as detailed in **Section 9**.

Implementation of the management actions relating to Santos standard lifting procedures and lifting procedures over live infrastructure and emergency response procedures reduces the risks to the environment and other users to ALARP. All additional management actions that were deemed feasible have been adopted to reduce the impact to ALARP (**Table 7-42**). There were no additional management actions that were identified and not adopted.

With the management actions in place to prevent an accidental release of dry natural gas, the likelihood level of ‘unlikely’ for a release and the minor impacts predicted from an unplanned release, the residual impact to sensitive receptors is reduced to very low and is environmentally acceptable.

8 Implementation strategy

This section presents the processes and procedures that will be implemented to ensure the environmental requirements within this CEMP will be met, including:

- Specific systems, practices and procedures that ensure both environmental impacts and risks are reduced to ALARP and Environmental Performance Objectives (EPOs), Performance Criteria and Performance Standards of this CEMP are being met;
- A clear chain of command, outlining roles and responsibilities of personnel involved in the implementation, management and review of this CEMP;
- Measures to ensure that employees and/or contractors working in relation to this activity are aware of their responsibilities regarding the environment and have the appropriate skill and training;
- Auditing, review and revision processes;
- Incident recording and reporting in line with Santos and regulatory requirements;
- Maintenance of quantitative records of discharges and emissions; and
- Details of emergency response and oil spill arrangements.

This implementation strategy is consistent with the Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

Stakeholder engagement is assessed separately for the requirements of the activity. Ongoing stakeholder management strategies are discussed in **Section 9**.

8.1 Leadership, accountability and responsibility

To enable the DPD Project to succeed in meeting environmental objectives as outlined within this CEMP, the following measures apply:

- Appropriately skilled and qualified DPD Project team is established with HSE accountabilities, responsibilities, and resources clearly defined;
- Setting of EPOs and Performance Criteria (incl. Targets and Performance Indicators) and establishment of the practices and tools used to measure performance and drive continual improvement (**Section 7**); and
- Implementing HSE Leadership Teams with key contractors to discuss HSE performance and improvement

The Barossa Project Director is responsible for delivery of the Barossa Development, including the DPD Project, and has responsibilities for:

- Accountability for project HSE performance
- Demonstrating strong and visible HSE leadership
- Endorsing HSE performance indicators and targets
- Communicating HSE performance and events to the Chief Operating Officer, Upstream Oil & Gas
- and Group Executive Committee.
- Providing HSE resources.
- Engaging with senior regulatory managers.

The Barossa Project Director is supported by the Barossa Project Management Team. The effective implementation of this CEMP requires collaboration and cooperation among Santos Barossa Team personnel and contractors. The accountabilities of key Santos and contractor personnel in relation to the implementation, management and review of the CEMP is outlined in **Table 8-1**. Santos' OPEP will outline the roles and responsibilities in an emergency.

Table 8-1: Chain of command, key leadership roles and responsibilities

Title (role)	Environmental responsibilities
Office-based personnel	
Santos Barossa Subsea and Pipelines Manager	+ Confirm that the campaign is undertaken in accordance with this CEMP. + Provide sufficient resources to implement the management controls in this CEMP. + Confirm Contractor personnel attend an environmental induction (**Section 8.2.1**) upon commencing work on the campaign. + Action the management actions, as detailed in the EPSs in this CEMP (**Section 7**), as required, prior to the commencement of the activity. + Confirm the Contractor meets the requirements of the Santos management system and relevant standards/procedures.
Santos Barossa HSE Manager	+ Provide assurance that adequate resources are provided to support all environmental activities associated with this CEMP. + Develop a program to implement and monitor CEMP commitments. + Liaise with NT EPA, DITT, DCCEEW and other regulators. + Ensure incident notification process is in place and investigations completed to identify root causes. + Review and submit environmental performance reports and external environmental incident notification reports.
Santos Barossa GEP Package Lead	+ Confirm the campaign is undertaken in accordance with this CEMP. + Communicate any changes to the activity that may affect the risk and impacts assessment, EPOs, EPSs and MAs detailed in this CEMP to the Santos HSE team. + Coordinate resources required to enable the commitments in this CEMP to be maintained. + Confirm the reporting of environmental incidents meets both external and Santos' incident reporting requirements. + Liaise with Santos Environmental Advisor on environmental incidents and what constitutes a reportable incident. + Track and close out of any corrective actions raised from environmental audits as required by this CEMP.
Santos Marine Manager	+ Confirm vessel vetting as per the Santos Offshore Marine Assurance Procedure (SO 91 ZH 10001).

Title (role)	Environmental responsibilities
	+ Ensure relevant inspections are undertaken to confirm vessels comply with relevant Marine Orders and Santos marine standards/procedures and on boarding requirements to meet safety, navigation and emergency response requirements.
Santos Barossa Crisis and Emergency Management Specialist	+ Develop Santos Crisis Management and Emergency Response Plans and procedures. + Ensure emergency response drills are undertaken as per Santos Crisis Management and Emergency Response plans and procedures.
Santos Emergency Response Coordinator	+ Undertake Santos Incident Management Team (IMT) drills and exercises in accordance with the Crisis and Incident Management Exercise Schedule. + Undertake assurance activities on oil spill response arrangements. + Review Santos Emergency Response Plans and procedures.
Santos Barossa Environmental Advisor/s	+ Develop offshore environmental approval documents, including DPD Project EMPs and OPEP, for submission and acceptance by DITT. + Provide environmental inductions to contractor personnel. + Ensure environmental inspections and audits are undertaken against CEMP commitments as per the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635). + Review and approve chemical products that will be discharged to the marine environment and require assessment. + Review biofouling risk assessments undertaken by Contractors. + Prepare environmental performance reports. + Advise on environmental incident reporting requirements, including what constitutes a reportable incident
Santos Barossa External Relations Advisor	+ Prepare and implement the relevant and interested persons consultation program for the DPD activity. + Manage and report on any relevant and interested persons consultation received in relation to the activity. + Undertake ongoing engagement with relevant and interested persons, for the duration of the activity, as required.
Contractor Project Manager	+ Undertake the pipelay installation in accordance with this CEMP. + Provide the resources required to enable the commitments in this CEMP to be maintained. + Confirm vessel management system and procedures are implemented and comply with the requirements detailed in this CEMP. + Confirm personnel receive an environmental induction that meets the requirements outlined in this CEMP + Ensure invasive marine species and pests are risk assessment on all vessels mobilised to the operational area.

Title (role)	Environmental responsibilities
	+ Ensure that all crew attend HSE inductions and that attendance records saved. + Ensure incidents are reported and investigated, as required.
Site and offshore based personnel	
Santos Senior Client Site Representative	+ Confirm contractors undertake the activity in a manner consistent with the EPOs and environmental management procedures detailed in this CEMP. + Confirm the management measures detailed in this CEMP are implemented. + Communicate any changes to the activity to the Santos Environmental Advisor. + Confirm all subsea chemical components and other fluids that may be discharged to the marine environment are approved for use. + Confirm that the Vessel Master and all crew adhere to the requirements of this CEMP. + Advise the Santos GEP Package Lead of any changes in activities that may lead to nonconformance with the EPOs in this CEMP. + Report environmental incidents to Santos GEP Package Lead.
Vessel Master (contractor personnel)	+ Confirm vessel management system and procedures are implemented and comply with the requirements detailed in this CEMP. + Confirm personnel receive an environmental induction that meets the requirements outlined in this CEMP on commencing work on the vessel. + Confirm crew personnel are competent to undertake the assigned work tasks. + Confirm SOPEP drills are undertaken in accordance with the vessel's schedule. + Comply with vessel entry and movement requirements within exclusion zones. + Maintain ballast water management plan, valid ballast water management certificate, ballast water management records, and Antifouling System Certificate specific to the vessel. + Maintain records of fuel use and vessel discharges/ transfers (including waste, sewage and oily water) as per MARPOL and Santos requirements + Confirm vessel crew are provided with sufficient training to implement the SOPEP/SMPEP (as appropriate to vessel class). + Ensure supervision of all bunkering/transfer operations to the vessel. + Report any environmental incidents or non-conformance with the EPOs, EPSs or MA in this CEMP in accordance with Santos and statutory requirements.
Offshore Construction Superintendent	+ Responsible for ensuring that pipeline construction activities are performed in accordance with this CEMP.

Title (role)	Environmental responsibilities
(Contractor Personnel)	
Offshore HSE Advisors (Santos and/or Contractor)	+ Support the Santos Senior Client Site Representative to ensure that the controls detailed in this CEMP relevant to offshore activities are implemented and assist in collection and recording of evidence of implementation (other controls are implemented and evidence collected onshore). + Support the Santos Senior Client Site Representative to ensure environmental incidents or breaches of objectives and/ or standards outlined in this CEMP, are reported, and corrective actions for incidents and breaches are developed, tracked and closed out in a timely manner. + Ensure periodic environmental inspections/reviews are completed and corrective actions from inspections are developed, tracked and closed out in a timely manner. + Review Contractors procedures, input into Toolbox talks and JSAs. + Provide day to day environmental support for activities in consultation with the Santos Environmental Advisor.
All Project personnel	+ Act in an environmentally responsible manner. + Undertake work in accordance with accepted HSE systems and procedures. + Comply with this CEMP and all regulatory requirements as applicable to assigned role. + Report any unsafe conditions, near misses or environmental incidents immediately to supervisors. + Attend environmental inductions and HSE meetings, and complete training as required. + Report marine megafauna sightings as applicable to role in accordance with Project requirements

8.2 Workforce training and competency

This section describes the mechanisms that will be in place, so all Project personnel (including employee and contractor roles) are aware of his or her responsibilities in relation to the CEMP and has appropriate training and competencies.

8.2.1 Inductions

Santos and its contractors will develop a mandatory project induction, which will detail CEMP requirements. Project induction attendance will be logged and held with the Project Administration Assistant. Santos personnel will be required to complete required contractor site and facility inductions, including DLNG facility inductions, including permitting requirements, as applicable for working in and around the DLNG facility.

All Project site roles will complete an induction that will include a component addressing their CEMP responsibilities. Induction attendance records for all personnel will be maintained. Inductions will include information about:

+ Environment, Health and Safety Policy
+ Regulatory regime
+ Operating environment (for example, nearby marine protected areas)
+ Activities with highest risk
+ CEMP EPOs, Performance Indicators and management commitments
+ Incident reporting and notifications
+ Regulatory compliance reporting
+ Importance of marine communications regarding any potential interactions with other marine users
+ Process for assessing changes to CEMP activities
+ Oil pollution emergency response.

8.2.2 Training and competency

The implementation of training requirements will ensure project personnel have the skills, knowledge and competencies to conduct work in a safe manner without harm to their health or the environment.

All members of the workforce will complete relevant training and/or hold relevant qualifications and certificates for their roles.

Santos and its contractors are individually responsible for ensuring that their personnel are qualified and trained. The systems, procedures and responsible persons will vary and will be managed using online databases, staff on-boarding process and training departments, etc. Personnel qualification and training records will be sampled before and/or during an activity. Such checks may be performed during the procurement process, inductions, crew change, and operational inspections and audits.

Crew trained in marine fauna observation will ensure marine megafauna can be reliably identified to species during observation periods.

8.2.3 Workforce involvement and communication

Daily operational meetings will be held at which HSE will be a standing agenda item. It is a requirement that supervisors attend daily operational meetings and that all personnel attend daily toolbox or pre-shift meetings. Toolbox or pre-shift meetings will be held to plan jobs and discuss work tasks, including HSE risks and their controls.

HSE performance will be monitored and reported during the activity, and performance metrics (including environmental performance indicators and the number of environmental incidents) will be regularly communicated to the workforce. Workforce involvement and environmental awareness will also be promoted by encouraging offshore personnel to report marine fauna sightings and marine pollution (for example, oil on water, dropped objects). Findings, learnings and corrective actions identified from assurance activities and incident investigations will be communicated to project personnel to drive continuous improvement (e.g., through HSE Alerts, pre-shift / toolbox meetings).

8.3 Audits and inspections

Environmental Audits and Inspections undertaken to provide assurance of requirements within this CEMP are being met may include:

+ Vessel pre-mobilisation inspections
+ Routine vessel environmental inspections (weekly / monthly during Project execution)

+ Contractor Environmental Audits
+ Regulator Inspections and Audits (as required by Regulator)

For this CEMP the environmental audit and inspection processes are described in the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635).

An Environmental Assurance Activities Schedule (EAS) will be developed and maintained by the Barossa HSE Team which will align with the Barossa Project Integrated Audit Schedule. The EAS will provide an overview and schedule of assurance (verification) activities required to meet compliance for each activity (e.g., inspections, audits, assessments, and reviews). Additionally, it will allow Santos and the Barossa HSE Team to plan and resource appropriately to ensure all environmental assurance requirements can be met.

Audit criteria, as included within a terms of reference (ToR), will typically include a selection of management actions and environmental performance standards and outcomes; however, may also include parts of the activity description, stakeholder consultation and implementation strategies.

Audit findings may include opportunities for improvement and non-conformances (requirements not met). Audit non-conformances are managed as described in **Section 8.3.6**.

8.3.1 Environmental Incident Reporting

8.3.1.1 Internal incident reporting

All personnel will be informed through inductions and daily operational meetings of their duty to report HSE incidents and hazards. Reported HSE incidents and hazards will be shared during daily operational meetings and will be documented in the incident management systems as appropriate. HSE incidents will be investigated and reported in accordance with the Santos Incident Reporting and Investigation Procedure (SMS-HSS-OS07-PD01) and contractor procedures.

The incident reporting requirements will be provided to all crew on-board the facilities and support vessels with special attention to the reporting time frames to provide for accurate and timely reporting.

8.3.1.2 External incident reporting

Certain incidents will require notification to external Regulatory authorities under NT and Commonwealth legislation. This includes requirements below; additional requirements may apply as conditions of approval of the DPD Project.

8.3.2 Reportable incident – Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)

Reportable Incidents, defined as *"…an incident arising out of operations for the activity that is not within the parameters of the environmental performance standards in the environment plan in force for the activity"*, will be reported to DITT in accordance with Part 3 of the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 which requires the following:

+ The operator of an activity must give notice of a reportable incident (either oral or written), with all material details of the incident that are reasonably available to the operator, to the Designated Authority as soon as possible after the first occurrence of the incident.
+ The operator must give a written report of the incident to the Designated Authority:
    - if the Designated Authority specifies a reasonable period for giving the report — within that period; or

  - in any other case — as soon as practicable after the first occurrence of the incident.
+ The report must set out fully:
  - all the material facts and circumstances of the incident that the operator knows or is able, by reasonable search and inquiry, to find out; and
  - the action (if any) taken to avoid or mitigate any adverse effects of the incident on the environment; and
  - the corrective action that has been taken, or is proposed to be taken, to prevent another incident of that kind.
+ The operator must keep a record of reports of each reportable incident, and of the details, in each case, of any corrective action taken.

8.3.3 Reportable incident – Waste Management and Pollution Control Act 1998 (NT)

As per Part 3 Section 14 of the Waste Management and Pollution Control Act 1998 (WMPC Act 1998), incidents causing, or that may threaten to cause, pollution resulting in material environmental harm or serious environmental harm, will be reported to the NT EPA as soon as practicable after (and in any case within 24 hours after) becoming aware of the incident. An incident includes "*an accident, emergency or malfunction and a deliberate action, whether or not that action was taken by the person conducting the activity in the course of which the incident occurred*".

A notification to the NT EPA of an incident as per Part 3 Section 14 of the WMPC Act 1998 will specify:

+ the incident causing or threatening to cause pollution;
+ the place where the incident occurred;
+ the date and time of the incident;
+ how the pollution has occurred, is occurring or may occur;
+ the attempts made to prevent, reduce, control, rectify or clean up the pollution or resultant environmental harm caused or threatening to be caused by the incident; and
+ the identity of the person notifying.

8.3.4 Wildlife incident reporting

Any incident resulting in a significant impact to a species listed as threatened or migratory under the *Environmental Protection and Biodiversity Protection Act 1999* (EPBC Act 1999) is to be reported to DCCEEW as soon as practicable (and in any case within 24 hours) of becoming aware of the event occurring. For the Project Area, marine species listed as threatened or migratory under the EPBC Act include marine turtles (all species), dolphins, dugongs and crocodiles.

The report will contain:

+ time, location and description of the incident;
+ a summary of the response being undertaken; and
+ details of the relevant contact person.

Any occurrences of stranded, injured or entangled marine megafauna are also to be reported to NT Marine Wild Watch (1800 453 941) (DEPWS) as soon as practicable after observing.

8.3.5 Hydrocarbon/ hazardous substance spill reporting

External reporting requirements will include reporting to Darwin Port (for incidents within Darwin Port limits), NT EPA (as above) and the Australian Maritime Safety Authority (AMSA), including completion of a marine pollution report (POLREP). Oil spill reporting is to follow any additional reporting requirements outlined within the DPD Project Oil Pollution Emergency Plan (BAS-210 0026).

8.3.6 Corrective actions

Corrective actions identified from environmental assurance activities and incident investigations will be derived in collaboration with contractors. For this CEMP, corrective actions and contingency processes are described as per the Barossa Project Environmental Compliance Assurance Plan (BAA-200 0635) and Barossa Health, Safety & Environment Management Plan for Execute (BAA-200 0003).

CEMP non-conformances will be addressed and resolved by a systematic corrective action process as outlined in Santos' Management System. Santos' incident and action tracking management system (HSE Toolbox) will be used to track corrective actions in the following instances:

+ Where there has been or potentially been a reportable incident
+ Where there has been a non-compliance in accordance with a statutory plan
+ Where any corrective action requires notification to an external regulatory or statutory body
+ Where there are corrective actions from formal audits (Contractor Pre-Start Audit, external regulator audit etc.).

Once entered, corrective actions, time frames and responsible persons (including action owners and event validators) will be assigned. Corrective action 'close out' will be monitored using a management escalation process.

Environmental corrective actions identified through compliance assurance activities are to be promptly managed to ensure timeframes for external reporting are met and that decision making is made visible.

8.3.7 Continuous improvement

For this CEMP, continuous improvement will be driven by the list below and may result in a review of the CEMP, with changes applied in accordance with **Section 8.6.2**.

+ Improvements identified from the review of business-level HSE key performance indicators
+ Actions arising from Santos and departmental HSE improvement plans
+ Corrective actions and feedback from HSE audits and inspections, incident investigations and after-action reviews
+ Opportunities for improvement and changes identified during pre-activity reviews and MoC documents
+ Actions taken to address concerns and issues raised during the ongoing stakeholder management process (**Section 9**).

Identified continuous improvement opportunities will be assessed in accordance with the MoC process (**Section 8.6.2**) to ensure any potential changes to this CEMP are managed in a controlled manner.

8.4 Emergency preparedness and response

Emergency preparedness and response arrangements, applicable to activities covered by this CEMP, including for oil spill response, will be included in Santos and Contractor procedures.

8.4.1 Contractor emergency and oil spill response plans

DPD Project contractors are responsible for having comprehensive Emergency Response Plans (ERPs) that address emergency response actions associated with all credible incidents for the activity. These will describe the interface arrangements between Contractor and Santos Incident Management structures and cover all aspects of emergency response including technical, logistical and medical support.

Contractor ERPs will outline roles and responsibilities of contractor personnel for emergency events. The ERPs are accepted by Santos and reviewed on an annual basis by the contractor or if a significant change has occurred to the incident management or emergency response arrangements.

Scenario-based drills are performed to test the emergency response arrangements and updates are made to improve the ERPs, if required.

Contractor vessels undertaking activities covered by this CEMP are required, where applicable to vessel class, to have Shipboard Oil Pollution Emergency Plans (SOPEP) and/or Shipboard Marine Pollution Emergency Plans (SMPEPs) outlining hydrocarbon/ hazardous substance spill response arrangements, including response actions and equipment requirements. Vessels are required to conduct regular spill response drills as per arrangements detailed in these plans.

8.4.2 Santos incident management and oil spill response arrangements

Santos maintains Incident and Crisis Management Teams (IMT and CMT) and support arrangements to respond to all-hazard incidents, including oil spill incidents, at its sites and for activities under its control or influence, including activities covered under this CEMP. Santos' crisis and incident management arrangement are outlined within the Crisis, Incident Management & Emergency Response Procedure (SMS-HSS-OS05-PD01) and Incident Management Plan – Upstream Offshore (SO-00-ZF-00025). IMT and CMT training and exercise requirements, including OPEP exercises, are included within an annual training and exercise plan and schedule.

Specific oil spill response support strategies and arrangements for hydrocarbon spill scenarios covered in this CEMP will be outlined within the DPD Project Oil Pollution Emergency Plan (BAS-210 0026). This will include roles and responsibilities and response strategies / resources applicable for responding to worst case spill scenarios for DPD activities covered by this CEMP. The arrangements within the OPEP will provide support to, and interface with, response activities undertaken by onsite personnel (e.g., vessel oil spill response activities), as well as response activities coordinated by designated NT Control Agencies.

8.5 Reporting and notifications

Environmental reporting for the DPD Project construction activities will include reports between Subcontractors and Contractors, Contractors and Santos, and Santos and Stakeholders, including Regulatory authorities. Reports will be delivered within agreed upon timeframes. **Table 8-2** outlines an initial assessment of reporting requirements relevant to this CEMP.

External reporting requirements may be dictated by approval conditions associated with the DPD Project and finalisation of this CEMP will include all relevant external regulatory reporting requirements.

A detailed schedule of reporting requirements and submission dates for the DPD Project will be developed as per the Barossa Project Environmental Compliance Plan (BAA-200 0635).

Table 8-2: Summary of reporting requirements

Report/ Notification	Responsibility	Content	Frequency	Recipient
Pre-start				
OVID inspection reports	Santos Marine Assurance Team	Provides a summary of the findings of the support vessel inspection which assesses compliance with relevant international (e.g. MARPOL 73/78), Australian and Santos requirements.	Prior to commencement of the activity	Santos
Pre-start contractor audit	Santos Barossa Team	Confirmation of compliance with CEMP commitments relating to operational procedures and processes that Santos require to be in place prior to the commencement of the activity.	Prior to commencement of the activity	Santos
Pre-start notifications	Santos Barossa Team / Contractors	Details on DPD Project commencement to meet requirements of stakeholders (including Regulatory authorities)	Prior to commencement of the activity	Various stakeholders
Execution and completion				
Regular Stakeholder updates	Santos Barossa Team	Regular updates on DPD Project during planning and execution as per Stakeholder Management Plan (refer **Section 9**)	Throughout planning and execution	Various stakeholders
Contractor environmental execution audit	Santos Barossa Team	Confirmation of compliance with CEMP commitments relevant to execution of the activity.	Prior to completion of the activity	Santos
Vessel Daily Reports	Contractor Vessel Master	Update on day's activities, including any identified non-conformance against this CEMP, and any issues that may need addressing.	Daily	Santos

Report/ Notification	Responsibility	Content	Frequency	Recipient
Vessel Environmental Reports/Checklists	Contractor Vessel Master	Compliance against key regulatory and contractual commitments (including CEMP commitments). Reporting of fuel usage, vessel discharges and emissions etc.	Weekly/ Monthly[1]	Santos
HSE Meetings Records	Contractor and Santos Barossa Team	Monthly, dedicated HSE meetings are held with the offshore and Perth-based management (including contractor management) and advisors to address targeted health, safety and environment incidents and initiatives. Minutes of these meetings are produced and distributed as appropriate.	Monthly	Santos
Completion notifications	Santos Barossa Team /Contractors	Details on DPD Project completion to meet requirements of stakeholders (including Regulatory authorities)	Following completion of the activity	Various stakeholders
Unexpected Finds Notification	Contractor and Santos Barossa Team	Notification by Contractor of potential unexpected find of heritage value. Further notification to Maritime Archaeologist and NT Heritage Branch, as required, following Unexpected Finds Protocol.	Dependent upon occurrence of unexpected find of cultural value	NT Heritage Branch
Environmental Monitoring Reports	Santos Contractor and Santos Barossa Team /Environmental Monitoring Contractor	Reporting on the outcomes of environmental monitoring activities (including water quality and benthic habitat monitoring) associated with the DPD Project construction activities.	Various dependent upon program	Santos DEPWS DITT NT EPA DCCEEW (if required)

Report/ Notification	Responsibility	Content	Frequency	Recipient
Environmental Performance/ Compliance Assurance Report	Santos Barossa Team	Provides a summary of compliance performance, including the environmental performance objectives, standards and measurement criteria within this CEMP and any other conditions of approval on the DPD Project.	At completion of the activity and not less than annually	DITT NTEPA (DEPWS) DCCEEW (if required)
Incident reporting				
Incident Report – Internal	Contractor and Santos Barossa Team	Provides framework for Internal notification of incidents including spills. The first report contains tools for assessing the severity of the incident and escalating as per the incident notification procedure. Incident reporting will also be undertaken through Santos' online EHS Toolbox system.	Incident specific	Santos
Incident Report – Reportable Environmental Incident (P(SL)(MoE) Regs 1999)	Santos Barossa Team	Reporting of Reportable Incidents as per Part 3 of the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (P(SL)(MoE) Regs 1999) (Refer **Section 8.3.2**)	Incident specific	DITT
Incident Report – Reportable Environmental Incident (WMPC Act 1998)	Santos Barossa Team	Reporting of Reportable Incidents as per Part 3 of the Waste Management and Pollution Control Act 1998 (WMPC Act 1998) (Refer **Section 8.3.3**)	Incident specific	NT EPA
Incident Report – Wildlife Incidents	Santos Barossa Team	Reporting of incidents involving EPBC Act species and reports of stranded, injured or entangled marine megafauna (Refer **Section 8.3.4**)	Incident specific	DCCEW DEPWS

Report/ Notification	Responsibility	Content	Frequency	Recipient
Incident Report – Hydrocarbon/ hazardous substance spill	Contractor and Santos Barossa Team	Reporting of NT oil spill incidents to Darwin Port (within port limits), AMSA and NT EPA. Additional oil spill reporting requirements as stated within the DPD Project Oil Pollution Emergency Plan (BAS-210 0026)	Incident specific	Darwin Ports AMSA NT EPA
Incident Report – Egress into wreck exclusion zone	Santos Barossa Team	Reporting of any egress into or disturbance of the exclusion zones of the Booya and Catalina 6 wrecks	Incident specific	Darwin Ports Harbour Master

1. As per the Barossa compliance assurance plan

8.6 Document management

This CEMP will be revised based on conditions of environmental approvals and/or licences and submitted to the appropriate regulator, for review and approval as required, prior to DPD Project implementation (i.e., commencement of construction activities).

8.6.1 Information management and document control

This CEMP, as well as any approved management of change (MoC) documents, are controlled documents and current versions will be available on Santos' document control system and made available to Project contractors.

As per the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)* the CEMP and all records associated with monitoring and reporting against CEMP commitments will be maintained for a period of five years. This includes revisions of the CEMP, and subordinate EMPs, written reports relating to environmental performance (monitoring, audit and review), records of emissions and discharges, records of calibration and maintenance of monitoring devices and records of reportable incidents.

The management and transfer of environmental assurance evidence between Santos and the primary construction contractor will be undertaken as per the Barossa Project Gas Export Pipeline (GEP) Environmental Compliance Assurance Plan (ECAP) Evidence Management and Transfer Procedure (BAS-210 0050).

8.6.2 Management of change

Following regulatory review and approval of this CEMP any changes to Project activities as described in this document, which have the potential to materially increase environmental impacts and risks, will be evaluated and controlled following the impact and risk assessment process followed in **Section 6**. The documentation and approval of management of change (MoC) assessments will follow the process outlined within the Santos Management of Change Procedure (SMS-LRG-OS01-PD04). MoC records will be retained and details of MoCs outlined within Regulatory compliance/performance reports.

As per the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cth)*, if a significant new environmental effect or risk is identified, or a significant increase in environmental effect of risk identified, which is not already provided for in the CEMP, a revision of the plan will be submitted to DITT as soon as practicable after the occurrence or identification of the significant effect or risk.

If there is a change in the petroleum instrument holder, or operator for the activity, a revision of the CEMP will be submitted to DITT as soon as practicable after the change.

8.6.3 Reviews

This CEMP addresses a temporary construction activity. Following approval, the CEMP will be reviewed annually, or as required in response to regulatory requirements and any changes to impacts, risks or management actions raised in Santos' assurance processes, incident response, stakeholder engagement or contractor engagement. These changes will be evaluated through the MoC process, and significant updates required to be communicated to regulators will be sent for review.

9 Stakeholder consultation

The stakeholder engagement approach used for the Project is in accordance with Santos's corporate approach to stakeholder engagement and industry leading standards and practice. The approach recognises and is aligned with the NT EPA's Guidance for Proponents – Stakeholder Engagement (NT EPA 2021a), the NT EPA's guidance for Preparing a Supplementary Environmental Report (NT EPA 2021b) and the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement (IAP2 2015).

Due to the iterative nature of the stakeholder process all relevant details have been contained in one document, the SER (BAS-210 0020), to contain updates to one location. The SER provides an outline of the objectives, process and key stakeholders consulted for the DPD Project. Additionally, the Stakeholder Engagement Plan (SEP) is attached to the SER. It details all consultation undertaken to date and information on future engagement activities.

In preparing the SER, and project management plans, Santos has considered and assessed each submission individually, and taken into consideration the issues raised when engaging with stakeholders to assess potential impacts and proposed management measures.

The SER provides a summary of the issues raised relevant to the Project and Santos' assessment and response to these issues. A full register, with all submissions and responses, is provided as an attachment to the SER.

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Attachment 1 Santos Environment, Health and Safety Policies

Environment, Health & Safety

Policy

Our Commitment

Santos is committed to being the safest gas company wherever we have a presence and preventing harm to people and the environment

Our Actions

We will:

1. Integrate environment, health and safety management requirements into the way we work
2. Comply with all relevant environmental, health and safety laws and continuously improve our management systems
3. Include environmental, health and safety considerations in business planning, decision making and asset management processes
4. Identify, control and monitor risks that have the potential for harm to people and the environment, so far as is reasonably practicable
5. Report, investigate and learn from our incidents
6. Consult and communicate with, and promote the participation of all workers to maintain a strong environment, health and safety culture
7. Empower our people, regardless of position, to "Stop the Job" when they feel it necessary to prevent harm to themselves, others or the environment
8. Work proactively and collaboratively with our stakeholders and the communities in which we operate
9. Set, measure, review and monitor objectives and targets to demonstrate proactive processes are in place to reduce the risk of harm to people and the environment
10. Report publicly on our environmental, health and safety performance

Governance

The Environment Health Safety and Sustainability Committee is responsible for reviewing the effectiveness of this policy.

This policy will be reviewed at appropriate intervals and revised when necessary to keep it current.

Kevin Gallagher

Managing Director & CEO

Status: APPROVED

Document Owner:	Jodie Hatherly, General Counsel and VP Legal, Risk and Governance		
Approved by:	The Board	Version:	3

20 August 2019 Page 1 of 1

Attachment 2 Summary of management actions

Management Action Reference	Management Action
Planned Events	
DPD-MA01	Intertidal and shoreline construction is in pre-disturbed area (DLNG footprint) with no public access
DPD-MA02	Installation of the pipeline within pre-agreed route, with minimal incursions into the shipping channel (as defined in consultation with the regional harbour master)
DPD-MA03	Anti-snag protection for mechanical support structures
DPD-MA04	Activity vessels equipped and crewed in accordance with Australian maritime requirements
DPD-MA05	Development and implementation of communication plan (including applicable notifications) for relevant stakeholders (including recreational and commercial fishing bodies and tourism operations) to minimise adverse impacts on other marine users
DPD-MA06	Implementation of cautionary zones around DPD Project vessel to mitigate against adverse interactions
DPD-MA07	One vessel will act as a surveillance vessel within the operational area during gas export pipeline installation and trenching activity
DPD-MA08	The proposed pipeline route will be marked on marine charts, in the same way that the existing pipelines are gazetted and marked on marine charts
DPD-MA09	Construction activities undertaken in accordance with Santos HSE management and marine vessel vetting processes
DPD-MA10	Causeway/s will be temporary structure/s and will be removed following trenching and pipeline installation
DPD-MA11	Pipeline will not be installed in the vicinity of the jewfish aggregation area within the Charles Point Wide RFPA
DPD-MA12	Trenching, stabilisation and freespan correction/ prevention will only be undertaken at identified areas (using standard positional accuracy measures used in the industry)

Management Action Reference	Management Action
DPD-MA13	Overflow from the TSHD will be undertaken through the adaptive management processes There will be 'environmental valve', 'green valve' where available (attached to O/F to reduce air entrained, to reduce billowing and facilitates sediment sinking) as standard which will be used as a first step
DPD-MA14	Standard operating procedure for spoil disposal will be used.
DPD-MA15	Spoil will not be disposed of in a single location, to avoid developing a single large mound.
DPD-MA16	Spoil will only be placed *in situ* within a short section of trenching within intertidal zones and will be removed subsequently where accessible by BHD and SHB for offshore disposal
DPD-MA17	When available, the base case is for the DP pipelay vessel to be used to install as much of the pipeline as depth allows DP vessel can be used in deeper water from KP23 (Territorial water boundary) to ~KP91.5 where the shallow water pipelay (<20 m) and associated anchoring will begin
DPD-MA18	Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, trenching and other support activities in the vicinity of sensitive habitats and nearshore heritage or sacred sites
DPD-MA19	Trained and competent anchor handling operators will be used
DPD-MA20	Anchors exclusion areas will be implemented to avoid sensitive habitats and heritage sites
DPD-MA21	Objects identified as cultural heritage objects that cannot be avoided will be managed as per NT Heritage Branch requirements
DPD-MA22	Differential global positioning system (DGPS) will be operational on the pipelay vessels to maintain accurate vessel position during installation
DPD-MA23	+ DGPS used to confirm ILT foundation structure position during installation + Underwater positioning system (USBL/ transponders) and ROV to confirm installation location and positioning (within required location accuracy to reduce disturbance to the seabed)

Management Action Reference	Management Action
DPD-MA24	Installation plan will be developed and include: + requirement for trained and experienced vessel crews + pipe to be installed in trench as per approved design
DPD-MA25	Span-specific rectification plans developed that include: + pre-span method selection + real-time monitoring of span rectification + post-rectification inspections
DPD-MA26	Permanent rock installation will be limited to only those pipeline sections requiring stabilization and/or anchor protection, as informed by a quantitative risk assessment
DPD-MA27	Causeway/s will be temporary structure/s and will be removed following trenching and pipeline installation
DPD-MA28	Adaptive management process will be implemented as defined within the TSDMMP (BAS-210 0023) which will include environmental monitoring of water quality with management measures applied if water quality exceeds trigger levels
DPD-MA29	Continuous monitoring of anchor wire tensions to prevent anchor drag on seabed and wire length measurement of the winch will be monitored to prevent anchor drag
DPD-MA30	Pre-lay surveys will confirm the nature of the seabed within the ILT foundation location to ensure the structure is installed on bare area of the seabed. Post-lay surveys will allow verification of the impact assessment
DPD-MA31	Where practicable rock installation will not exceed seabed level within practical installation tolerances.
DPD-MA32	Restrict disturbance to within the onshore Project Area and existing DLNG site area
DPD-MA33	Establish appropriate access restrictions into the onshore Project Area

Management Action Reference	Management Action
DPD-MA34	Direct stormwater runoff from the open trench to filter through the rock causeway, when present
DPD-MA35	Leave trench open at both ends to allow any fauna to egress freely
DPD-MA35	Install geotextiles under primary construction area (i.e., site pad)
DPD-MA36	Return area to natural grade to match existing topography
DPD-MA37	All personnel to complete the DLNG HSE site induction
DPD-MA38	Maintain larger batters on trench entry and exit suitable for fauna to exit the trench or include fauna ladders or similar
DPD-MA39	Implement ASS and groundwater management and monitoring requirements within the ASSDMP (BAS-210-0049). The ASSDMP includes requirements for: + Soil stockpiling, laboratory testing and treatment, dependent upon location of work and encountering of ASS + Groundwater laboratory testing and treatment, if groundwater is reached Maintenance of testing and inspection records
DPD-MA40	Plan onshore works to minimise the amount of time soil is exposed to the air
DPD-MA41	Trench inspections to be performed daily to check for trapped wildlife
DPD-MA42	Insert caps on ends of pipe if the pipe is to be unattended for periods >12 hours; to prevent fauna ingress.
DPD-MA43	Ensure any native vertebrates injured by DPD construction activities are referred to an appropriate wildlife carer group or veterinarian
DPD-MA44	Limit vehicles to access roads, prepared site pad or defined boundaries within the onshore Project Area/DLNG disturbance
DPD-MA45	Use water truck for dust suppression
DPD-MA46	Establish and implement vehicle speed controls

Management Action Reference	Management Action
DPD-MA47	Wet parking area will be monitored daily, with photographs taken.
DPD-MA48	Observation and shut-down zones for marine fauna have been developed based on noise modelling results and standard protocols
DPD-MA49	Vessel inductions for all crew will address marine fauna risks and the required management controls
DPD-MA50	Vessel and helicopter contractor procedures will comply with Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA51	Personnel trained in marine fauna observation (MFO) will be present on pipelay, dredge and rock installation vessels during daylight hours, including one crew member with MFO training on the bridge at all times
DPD-MA52	All marine fauna interactions and observations will be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW
DPD-MA53	Soft-start procedures for rock breaking (BHD) for night-time activities where observation is not possible
DPD-MA54	Vessels will adhere to Port of Darwin vessel speed limits
DPD-MA55	Maintenance of vessel, vehicle and equipment combustions engines and vessel incinerators as per planned maintenance system
DPD-MA56	Observation and shut-down zones for marine fauna have been developed based on noise modelling results for trenching and standard protocols and include: + Observation (150 m) and exclusion (50 m) zones for marine mammals and turtles. + Observation zone monitored for 10 minutes prior to commencing trenching. A Marine Megafauna Observation and Adaptive Management Protocol will be included within the MMNMP (BAS-210 0045)
DPD-MA57	Soft start (ramp-up) of hydraulic tools (rock breaking) by BHD Soft start (ramp-up) of trenching equipment, where practicable, will apply to the CSD and TSHD
DPD-MA58	Pipelay vessels will have enclosed pipe welding decks

Management Action Reference	Management Action
DPD-MA59	Shielding, where practicable, and/or orienting operational lights (excluding navigational lighting) on vessels to limit light spill to the environment
DPD-MA60	Housekeeping measures will be adopted, including requiring all crew to keep shutters on windows closed at night, to limit light emissions from vessels
DPD-MA61	Vessel searchlights will only be operated in an emergency situation.
DPD-MA62	Santos will document vessel light spill on Darwin Harbour turtle nesting beaches as part of the DPD Project's environmental monitoring program
DPD-MA63	Vessels will comply with relevant Marine Orders with respect to planned discharges, including: + Marine Order 91 – Marine Pollution Prevention: Oil, which implements Annex I of the MARPOL + Marine Order 96 – Marine Pollution Prevention: Sewage, which implements Annex IV of the MARPOL
DPD-MA64	Santos Marine Assurance Process
DPD-MA65	Protection/screening of abstraction hose end to prevent fauna entrainment
DPD-MA66	Backflush water will be discharge onto existing disturbed shore crossing construction site so that it drains into the intertidal area and solids disperse with tidal movement, minimising turbidity effects
DPD-MA67	Where possible, and dependant on the progress of shore crossing rock installation at time of FCGT activities, backflush water will be discharged onto installed rock, to baffle the flow of discharged backflush water
DPD-MA68	Atmospheric emissions from combustion, incinerators and ODS managed in accordance with standard maritime practice (MARPOL) MARPOL standards include no incineration in harbour
DPD-MA69	Monitoring and reporting of fuel consumption and calculated GHG emissions

Management Action Reference	Management Action
DPD-MA70	Use of low sulphur diesel
DPD-MA71	Pipeline installation procedures Maintenance requirements for pipelaying equipment to minimise risk of operational failure Redundancy in nearshore pipelay vessel anchors Pipelay vessel will have redundancy in station keeping capabilities in operating in DP2 (as a minimum)
DPD-MA72	Chemical selection procedure for all chemicals planned to be release to the marine environment
DPD-MA73	Calibrated chemical dosing system in place to ensure accuracy of chemical dosing
DPD-MA74	If contingency use and discharge of treated seawater is required, the lowest required concentration of treated chemical will be evaluated and used (up to a maximum of 550 ppm) in order to meet pipeline preservation requirements.
DPD-MA75	Pipeline dewatering of treated seawater will be through valve orientated vertically to promote dispersion and direct discharge away from seabed
DPD-MA76	In the unlikely event that the pipeline requires contingency filling and subsequent dewatering of treated seawater in response to a wet buckle event and prolonged repair, water quality monitoring at the discharge location will be conducted to confirm the concentration and dispersion of treatment chemicals.
Unplanned Events	
DPD-MA07	One vessel will act as a surveillance vessel within the operational area during gas export pipeline installation
DPD-MA50	Vessel and helicopter contractor procedures will comply with Part 8 of the Environment Protection and Biodiversity Conservation Regulations 2000, which includes controls for minimising interaction with marine fauna
DPD-MA51	Personnel trained in marine fauna observation (MFO) will be present on pipelay, dredge and rock installation vessels during daylight hours, including one crew member with MFO training on the bridge at all times

Management Action Reference	Management Action
DPD-MA52	All marine fauna interactions and observations will be appropriately recorded and reported to DEPWS/NT EPA and DCCEEW
DPD-MA63	+ Vessels will comply with relevant Marine Orders, including: + Marine Order 95 – Marine Pollution Prevention: Garbage
DPD-MA65	Protection/screening of abstraction hose end to prevent fauna entrainment during water winning activities
DPD-MA77	Implementation of Santos approved standards and procedures for outboard lifts
DPD-MA78	All lifting and winching equipment will undergo inspection, testing and certification as per applicable Laws, Codes and Standards
DPD-MA79	Dropped object recovered where safe and practicable to do so
DPD-MA80	Identification of no lift zones where relevant in proximity to subsea assets and infrastructure as documented in relevant lifting and operational procedure/s
DPD-MA81	No outboard lifting operations will be completed in Company defined "no lifting zones" which will be identified in navigational systems
DPD-MA82	Emergency response implemented to minimise potential for impacts in the event a dropped object causes a loss of containment from the existing Bayu-Undan GEP
DPD-MA83	Pipeline installed along pre-approved route, which is designed where practicable to avoid the potential for impact to habitat / cultural seabed features or assets from a dropped object.
DPD-MA84	Vessels equipped with effective anti-fouling coatings as required for class
DPD-MA85	Ballast water management will comply with MARPOL requirements (as applicable to class), Australian Ballast Water Management Requirements and *Biosecurity Act 2015*
DPD-MA86	Apply risk-based IMS management for vessels and immersible equipment – vessel and immersible equipment mobilised from outside of the Project Area/Darwin Harbour must be assessed as having a low risk of IMS prior to coming onto activity

Management Action Reference	Management Action
DPD-MA87	Vessels having suitable anti-fouling coating (marine growth prevention system) in accordance with the *Protection of the Sea Act 2006*
DPD-MA88	Inductions to include observing marine fauna (e.g., crocodiles and shorebirds)
DPD-MA89	The TSHD shall be fitted with pre-sweeping mechanisms / chain curtains to mitigate turtle entrapment (fauna strike – unplanned)
DPD-MA90	Inspection and maintenance for all equipment containing chemicals/ hydrocarbons and chemical/ hydrocarbon storage areas
DPD-MA91	Santos chemical selection procedure applied for chemicals
DPD-MA92	ROV operations undertaken in accordance with good industry practice (in relation to hydraulic fluid control)
DPD-MA93	Procedures for helicopter refuelling
DPD-MA95	Chemical storage areas designed to contain leaks and spills and inspected routinely
DPD-MA96	Spills will be managed in accordance with standard maritime practices as per vessel shipboard oil pollution emergency plan (SOPEP)
DPD-MA97	Spill clean-up kits available in high-risk areas
DPD-MA98	Bunding/secondary containment
DPD-MA99	Vessel-specific bunkering procedures and equipment consistent with Santos marine vessel vetting requirements including: + Use of bulk hoses that have quick connect 'dry break' couplings + Correct valve line-up + Defined roles and responsibilities, and the specific requirement for bunkering to be completed by trained personnel only + Visual inspection of hoses prior to bunkering to confirm they are in good condition + Testing of the emergency shutdown mechanism on the transfer pumps + Assessment of weather/sea state

Management Action Reference	Management Action
	+ Maintenance of radio contact with Vessel during bunkering operations + Bunkering checklist + Visual monitoring during bunkering + Ensuring deck drainage bungs are in place prior to bunkering + Marine Order 91 – Marine Pollution Prevention: Oil + Bunkering to commence in daylight hours
DPD-MA100	Vessel equipped and crewed in accordance with Australian maritime requirements
DPD-MA101	Safety exclusion zone around DPD Project vessels and Notice to Mariners will be issued for offshore works advising all major shipping traffic formally. In addition, pipelay vessels will have attendant vessels that may act as guard vessels for work within the harbour
DPD-MA102	No intermediate fuel oil (IFO) or heavy fuel oil (HFO) will be used in activity vessels working in the Project Area
DPD-MA103	Implement tiered spill response as per DPD Project specific OPEP in the event of an MDO spill
DPD-MA104	Santos to make oil spill tracking buoys available on primary project vessel/s with Santos CSR/s and/or at local supply base for immediate deployment to assist with tracking of an oil spill
DPD-MA105	Trenching will only occur within pre-programmed areas (using standard positional accuracy measures used in the industry)
DPD-MA106	Exclusion zones programmed on all primary vessels associated with the works to clearly indicate no entry zones and nearby pipelines – this will clearly identify areas for spud placement, anchor positioning and trenching activities
DPD-MA107	Navigation charts

Santos

Appendix 19: SER Contributors – Qualifications and Experience

Santos

SER Element	Key Roles	Organisation	Name	Qualifications	Experience (years)
SER Project Management	Barossa HSE Manager	Santos	Nick Phillips	BSc, MBA, MSc (OH&S)	20
	DPD Project Environmental Lead	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	DPD Project Consultation Lead	Santos	Mike Marren	BA (Journalism)	25
	SER Project Management	CDM-Smith	Lauren Elvidge	BSci (Marine Management), PostGradDip (EIA)	11
	SER Project Management	CDM-Smith	Julia Curran	BSc (Marine Management), PostGradDip (Env Manage)	15
SER Chapters	Author/Reviewer	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	Author/Reviewer	Santos	Mike Marren	BA (Journalism)	25
	Reviewer	Santos	Ben Haslam	BEng, MSc (Marine Technology)	25
	Reviewer	Santos	Andrew Lindsay	BSc (Microbiol/Biochem), BEng (Chemical Engineering)	30
	Reviewer	Santos	Peter Ivicevich	BEng (Mechanical Engineering)	20
	Reviewer	Santos	Xander van Beusekom	MIEAust, MSc (Engineering Geology)	20
	Author/Reviewer	Santos	Simon Golding	BEng(Hons)(Mechanical Engineering), CPEng	15
	Author	CDM-Smith	Lauren Elvidge	BSci (Marine Management),PostGradDip (EIA)	11
	Author	CDM-Smith	Dr Brenton Chatfield	BSc(Hons), GradDip(GIS, Aquaculture), PhD (Mar Sci)	20
	Author	CDM-Smith	Scott Mainey	BUEP	9
	Author	CDM-Smith	Julia Curran	BSc (Marine Management), PostGradDip (Env Manage)	15
	Author	CDM-Smith	Juliano Miranda	BSEP, BITBA	8
	Author	CDM-Smith	Linda Kirchner	BSc (Geology), GradDipEnvSc	36
	Author	CDM-Smith	John Herron	BAppSc, MEM	22
	Reviewer	ERIAS	Greg Terrens	BSc, MSc (Environmental Science)	30+
	Reviewer	Morgan Consultants	Ceri Morgan	BSc (Hons) (Environmental Science)	30
	Author/Reviewer	Xodus	Matthew Holding	BSc (Env Biology), GradCert (OHS)	15
	Reviewer	Xodus	Petrina Raitt	BSc (Environmental)	25
	Author	Xodus	Shaun Huxtable	BSc(Environ. Mgnt / Biol. Sci. MBA (Adv.)	12
	Modelling, analysis, reporting	RPS	Nuala Page	BEng (Env. Eng.), BCom (GenMgt HRMgt)	18

Sediment Dispersion Modelling Report	Modelling review, analysis, reporting	RPS	Dr David Wright	MSci (Physics), PhD (Marine Optics and Remote Sensing)	16
	Reviewer	AIMS	Dr Hemerson Tonin	BSc, MSc, PhD (Physical Oceanogaphy)	25
Treated Seawater Discharge Modelling Report	Project manager and lead modelling	RPS	Dr Sasha Zigic	BEng (Civil), PhD (Environmental Engineering)	25
	Analysis and reporting	RPS	Dr Ryan Dunn	BEnvSc, PhD (Environmental Science)	13
	Post processing and analysis	RPS	Wayne Lin	BEngSc, Masters (Engineering Science)	10
	Rebecca McGrath	RPS	Rebecca McGrath	BEng (Environmental Engineering)	20+
Pipeline Benthic Survey Report	Author	RPS	Axel Werner	BSc, MSc (Marine Science)	4
	Author	RPS	Natalie Robson	BSc (Marine Science)	5
	Author/Reviewer	RPS	Dr Garnet Hooper	BSc, MSc, PhD (Marine Benthic Ecology)	20+
	Reviewer	RPS	Jeremy Fitzpatrick	BSc (Zoology and Botany)	30+
	Reviewer	RPS	Dr Katharine Thorne	MEarth Sci, MSc, PhD (Oceanogaphy)	12
Traffic Impact Assessment	Project Manager	AECOM	Anwar Sayed	BEng, MSc (Civil Engineering), CPEng, RPEQ, RPEV	20
	Lead Author	AECOM	William Chen	BSc, MEng (Civil/Business)	5
	Author	AECOM	April Alcock	BEng (Hons) (Civil)	2
	Reviewer	AECOM	James Jentz	BEng (Civil) Grad Dip (Mun Eng)	30+
Darwin Harbour Lighting Technical Note	Lead Author	Pendoley Environmental	Dr Kellie Pendoley	BSc, MSc, PhD (Biology)	35+
Maritime Archaeology Heritage Assessment	Lead Author	Cosmos Archaeology	Connor McBrian	GradDip (Maritime Archaeology)	5
	Author	Cosmos Archaeology	Caroline Wilby	BA(Hons) (Archaeology)	20+
	Reviewer	Cosmos Archaeology	Cosmos Coreonos	GradDip (Maritime Archaeology)	30+
Underwater Noise Modelling Assessment	Author/Reviewer	Talis consultants	Granger Bennett	B.Eng Elec. Eng. MSc Elec Eng, MSc Eng Acoustics	30+
	Author/Reviewer	Talis consultants	Luke Adams	Bachelor of Science (BSc)	15+
	Author/Reviewer	Talis consultants	Renzo Karsdorp	Bachelor of Information Technology (BiT)	12+
	Author/Reviewer	Talis consultants	Phil Lucas	Bachelor of Technology (BTech)	35+
	Reviewer	RPS	Dr Jeremy Colman	BSc, PhD (Marine Ecology)	30+
Underwater Noise Modelling	Lead Author/ Modeller	JASCO Applied Sciences	Dr Steven Connell	BSPhy, PhD	2

Assessment - Rock Breaking	Reviewer/ QAQC	JASCO Applied Sciences	Dr Matthew Koessler	BSc(Hons), PhD	5+
	Reviewer/ Project Manager	JASCO Applied Sciences	Craig McPherson	BEng(Hons)	15+
Hydrocarbon Spill Modelling	Project manager and lead modelling	RPS	Dr Sasha Zigic	BEng (Civil), PhD (Environmental Engineering)	25
	Analysis and reporting	RPS	Dr Ryan Dunn	BEnvSc, PhD (Environmental Science)	13
	Post processing and analysis	RPS	Wayne Lin	BEngSc, Masters (Engineering Science)	10
	Reviewer	RPS	Rebecca McGrath	BEng (Environmental Engineering)	20+
Stakeholder Engagement Plan	Author	Santos	Mike Marren	BA (Journalism)	25
Offshore Construction Environmental Management Plan	Author	RPS	Samuel Billinghurst	BSc (Mar. Sci.e & Analytical Chem.), Msc (Mar. Sci.)	3
	Author	RPS	Axel Werner	BSc, MSc (Marine Science)	4
	Reviewer	RPS	Dr Katharine Thorne	MEarth Sci, MSc, PhD (Oceanogaphy)	12
	Reviewer	RPS	Rebecca McGrath	BEng (Environmental Engineering)	20+
	Reviewer	RPS	Pennie Ginn	BSc (Conservation Biology)	12
	Reviewer	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	Reviewer	Santos	Ben Haslam	BEng, MSc (Marine Technology)	25
	Reviewer	Santos	Andrew Lindsay	BSc (Microbiol/Biochem), BEng (Chemical Engineering)	30
	Reviewer	Santos	Peter Ivicevich	BEng (Mechanical Engineering)	20
	Reviewer	Santos	Xander van Beusekom	MIEAust, MSc (Engineering Geology)	20
	Reviewer	ERIAS	Greg Terrens	BSc, MSc (Environmental Science)	30+
	Reviewer	Morgan Consultants	Ceri Morgan	BSc (Hons) (Environmental Science)	30
Onshore Construction Environmental Management Plan	Author	RPS	Margaret McCormack	Bsc Hons (Environmental Engineering)	5
	Author	RPS	Pennie Ginn	BSc (Conservation Biology)	12
	Author	RPS	Axel Werner	BSc, MSc (Marine Science)	4
	Reviewer	RPS	Dr Katharine Thorne	MEarth Sci, MSc, PhD (Oceanogaphy)	12
	Reviewer	RPS	Giles Glasson	BSc (Env), PostGradDip (Env. Mgt), MBA	
	Reviewer	RPS	Rebecca McGrath	BEng (Environmental Engineering)	20+
	Reviewer	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	Reviewer	Santos	Ben Haslam	BEng, MSc (Marine Technology)	25

	Reviewer	Santos	Andrew Lindsay	BSc (Microbiol/Biochem), BEng (Chemical Engineering)	30
	Reviewer	Santos	Peter Ivicevich	BEng (Mechanical Engineering)	20
	Reviewer	Santos	Xander van Beusekom	MIEAust, MSc (Engineering Geology)	20
	Reviewer	Morgan Consultants	Ceri Morgan	BSc (Hons) (Environmental Science)	30
Trenching and Spoil Disposal Management and Monitoring Plan	Author	RPS	Samuel Billinghurst	BSc (Mar. Sci.e & Analytical Chem.), Msc (Mar. Sci.)	3
	Reviewer	RPS	Dr Katharine Thorne	MEarth Sci, MSc, PhD (Oceanogaphy)	12
	Reviewer	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	Reviewer	Santos	Mike Marren	BA (Journalism)	25
	Reviewer	Santos	Ben Haslam	BEng, MSc (Marine Technology)	25
	Reviewer	Santos	Andrew Lindsay	BSc (Microbiol/Biochem), BEng (Chemical Engineering)	30
	Reviewer	Santos	Peter Ivicevich	BEng (Mechanical Engineering)	20
	Reviewer	Santos	Xander van Beusekom	MIEAust, MSc (Engineering Geology)	20
	Reviewer	Morgan Consultants	Ceri Morgan	BSc (Hons) (Environmental Science)	30
	Reviewer	Xodus	Libby Howitt	BSc (Biology), MSc (Marine Ecology)	35+
Marine Megafauna Noise Management Plan	Author	RPS	Dr Rhianne Ward	BSc (Marine Biology), BSc Hons, PhD (Bioacoustics)	10
	Author	RPS	Shane Dickeson	BSc (Marine Biology), BSc Hons (Marine Science)	9
	Author	RPS	Alexandra D'Cruz	BSc (Marine Biology), BSc Hons (Marine Science)	3
	Reviewer	RPS	Rebecca McGrath	BEng (Environmental Engineering)	20+
	Reviewer	RPS	Pennie Ginn	BSc (Conservation Biology)	12
	Reviewer	RPS	Dr Katharine Thorne	MEarth Sci, MSc, PhD (Oceanogaphy)	12
	Reviewer	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	Reviewer	Santos	Ben Haslam	BEng, MSc (Marine Technology)	25
	Reviewer	Santos	Andrew Lindsay	BSc (Microbiol/Biochem), BEng (Chemical Engineering)	30
	Reviewer	Santos	Peter Ivicevich	BEng (Mechanical Engineering)	20
	Reviewer	Santos	Xander van Beusekom	MIEAust, MSc (Engineering Geology)	20
	Reviewer	CDM-Smith	Brenton Chatfield	BSc(Hons), GradDip (Aqua., GIS), PhD (Mar. Sci./GIS)	20

	Reviewer	Morgan Consultants	Ceri Morgan	BSc (Hons) (Environmental Science)	30
	Reviewer	Xodus	Libby Howitt	BSc (Biology), MSc (Marine Ecology)	35+
Acid Sulfate Soil and Dewatering Management Plan	Author	RPS	Adam Russell	BSc. (Hons) Environmental Geoscience.	10+
	Reviewer	RPS	Alan Foley	BSc. (Applied Chemistry)	18+
	Reviewer	RPS	Dr Katharine Thorne	MEarth Sci, MSc, PhD (Oceanogaphy)	12
	Reviewer	Santos	Dr Lachlan MacArthur	BSc (Hons), PhD (Marine Ecology)	20
	Reviewer	Santos	Ben Haslam	BEng, MSc (Marine Technology)	25
	Reviewer	Santos	Andrew Lindsay	BSc (Microbiol/Biochem), BEng (Chemical Engineering)	30
	Reviewer	Santos	Peter Ivicevich	BEng (Mechanical Engineering)	20
	Reviewer	Santos	Xander van Beusekom	MIEAust, MSc (Engineering Geology)	20
	Reviewer	Morgan Consultants	Ceri Morgan	BSc (Hons) (Environmental Science)	30