Santos

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

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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.

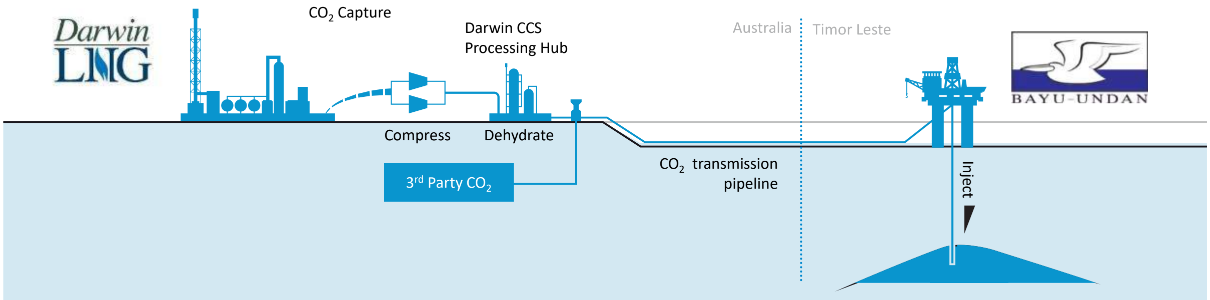

Figure 1-1 Proposed Bayu-Undan CCS project (uses the existing Bayu-Undan to Darwin gas pipeline)

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:	**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

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	+ proposal-specific data; + 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.	activities. A draft Trenching and Spoil Disposal Management and 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.	An assessment of the potential impact of contingency discharges of treated seawater has been undertaken and

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	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. 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.	the findings are discussed in **Section 8.5.2** with the modelling report provided as **Appendix 5**. 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.	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

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	Provide a detailed 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; and + Management actions to be applied if noise triggers are exceeded in accordance with the environmental decision-making hierarchy.	and existing activities. The underwater noise modelling reports are provided in **Appendix 8** and **Appendix 9**. A draft 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	The monitoring program in the draft 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**).

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	+ 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 TSDMMP includes a communications strategy for engaging with stakeholders to minimise and manage the potential for cumulative impacts from dredging activities in Darwin Harbour. A draft of 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.	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:

Environmental Factor	Additional Information Requested by NT EPA	Section of SER
	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.	+ 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. 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**.

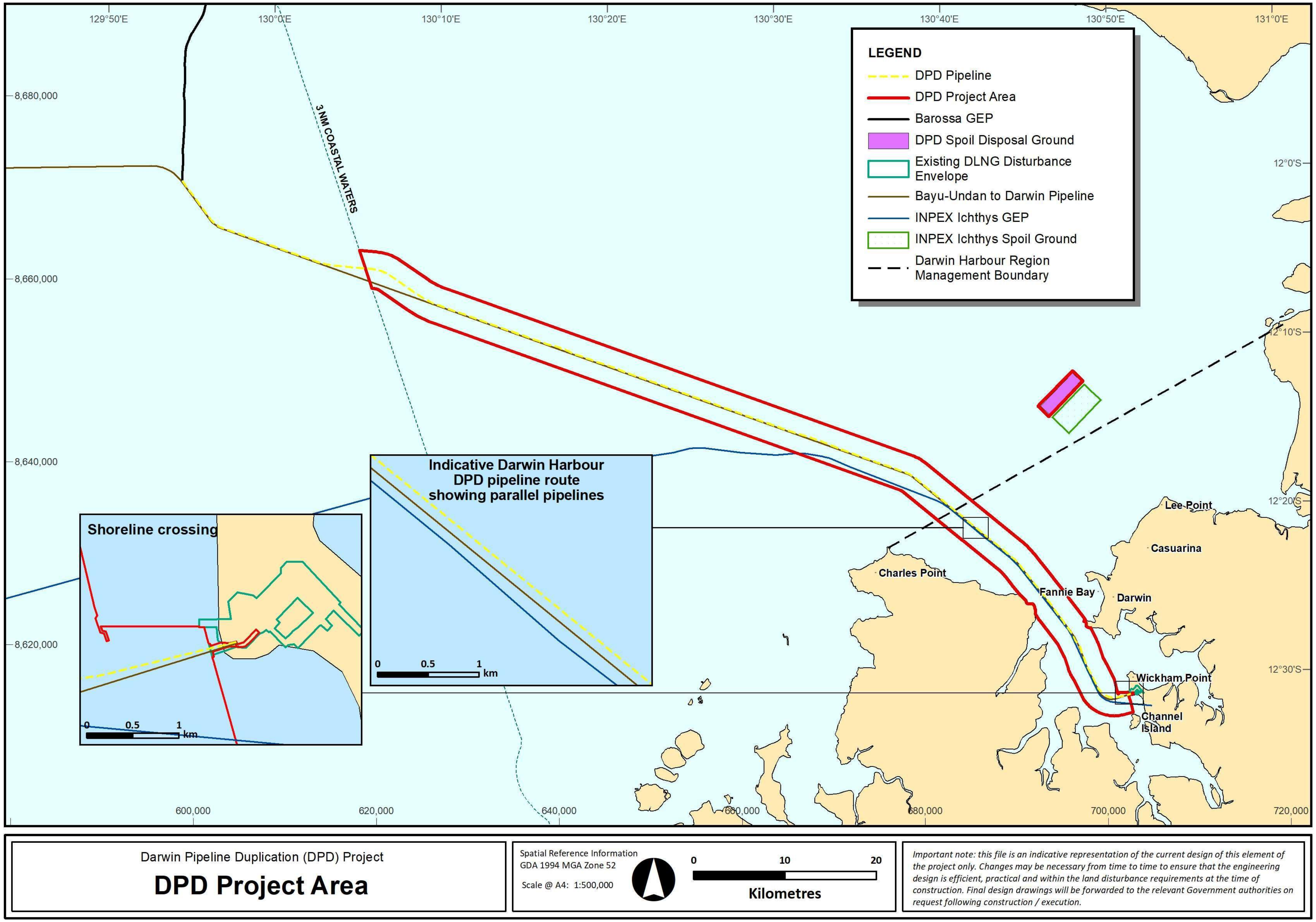

Figure 2-1 DPD Project area

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

<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 colspan="3">Construction Elements</td></tr>
<tr><td>Pipeline and route selection</td><td>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.</td><td>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.</td></tr>
<tr><td>Project area</td><td>The Project area is described and presented in Section 3.3 and Figure 3-1 of the referral.</td><td>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</td></tr>
</table>

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.

Submitted as part of referral		Updates since referral submission
Component	**Summary of referral elements**	
	required to protect crossings from anchor drag or over-trawling by commercial fisheries.	
Pipeline installation	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.	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.
Trench backfill / rock installation	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.	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)**.

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	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**	
	similar management 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.

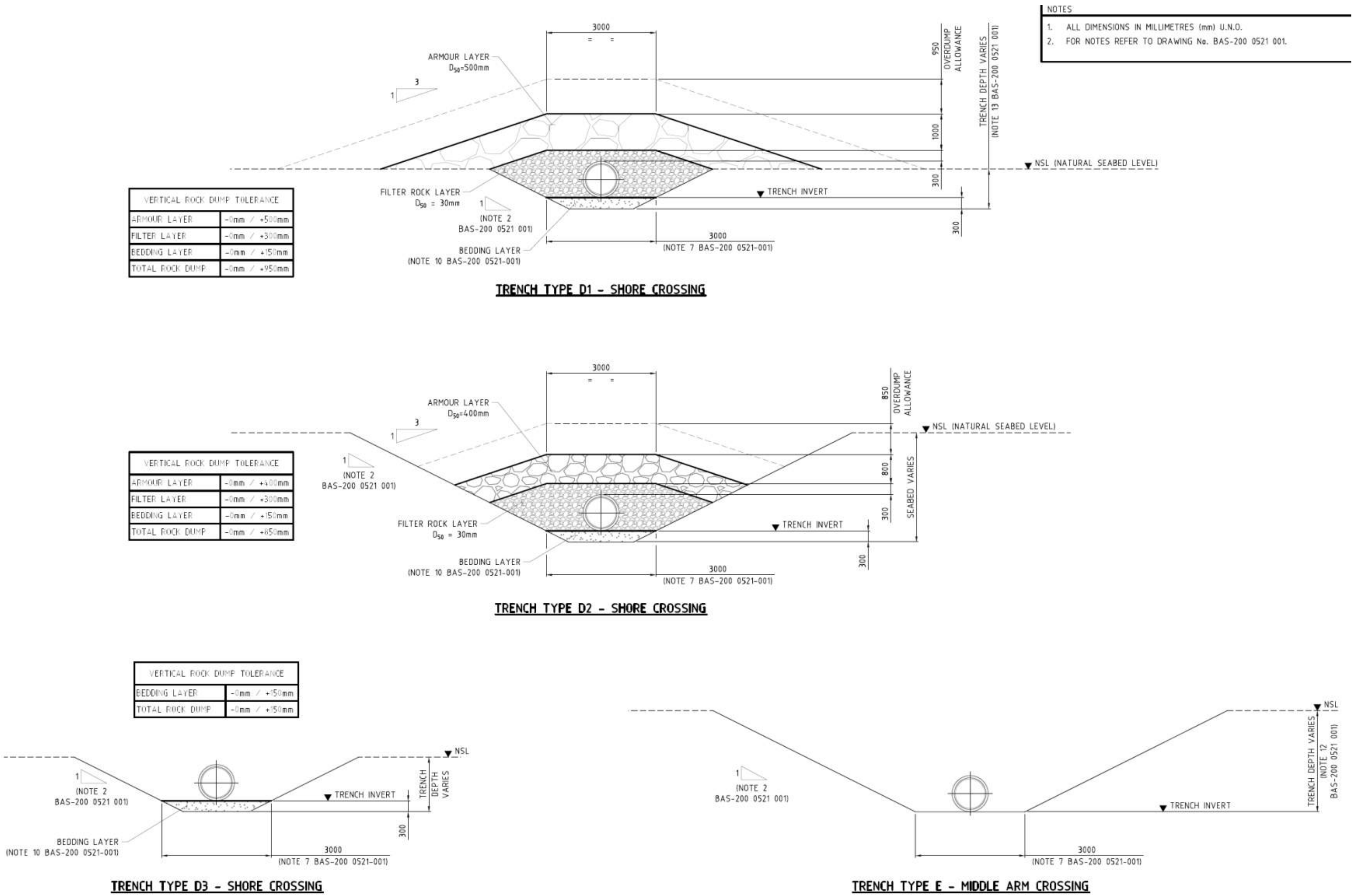

Figure 2-2 Indicative trench design – Middle Arm and shore crossing

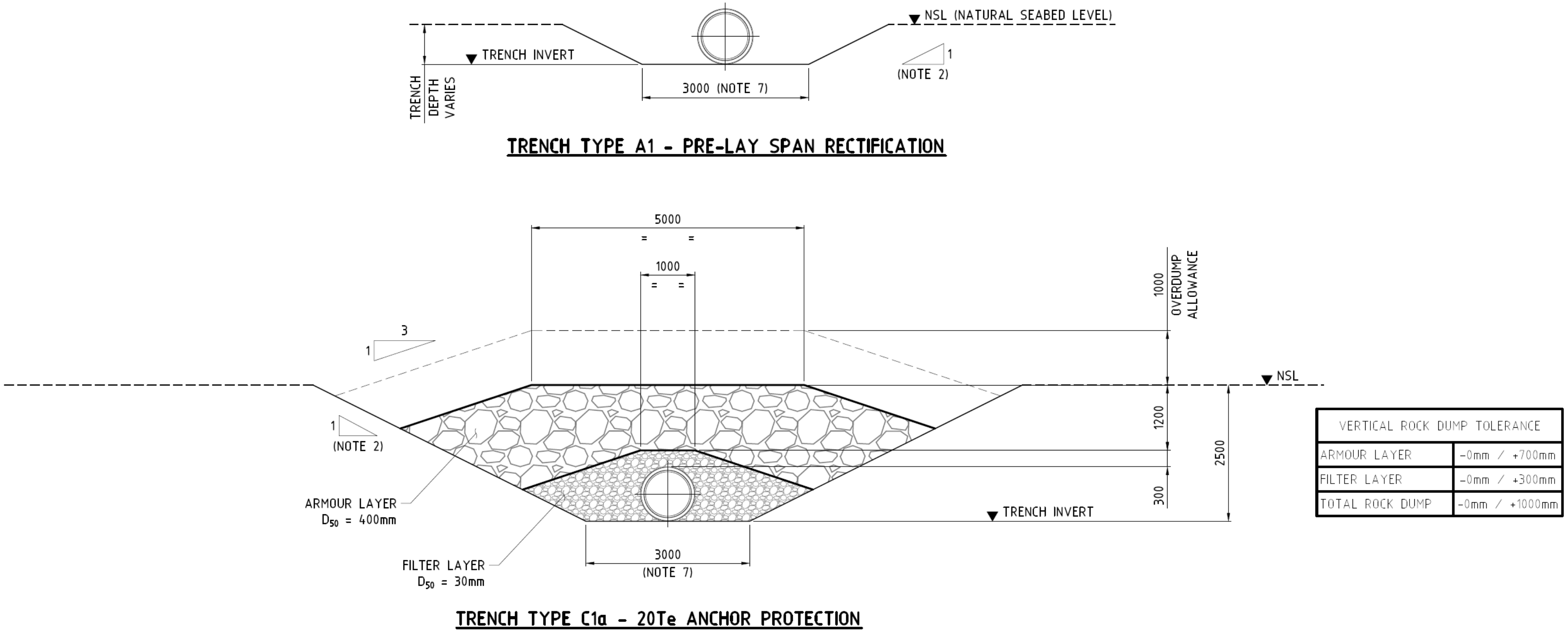

Figure 2-3 Indicative trench design – clearwater and anchor protection

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

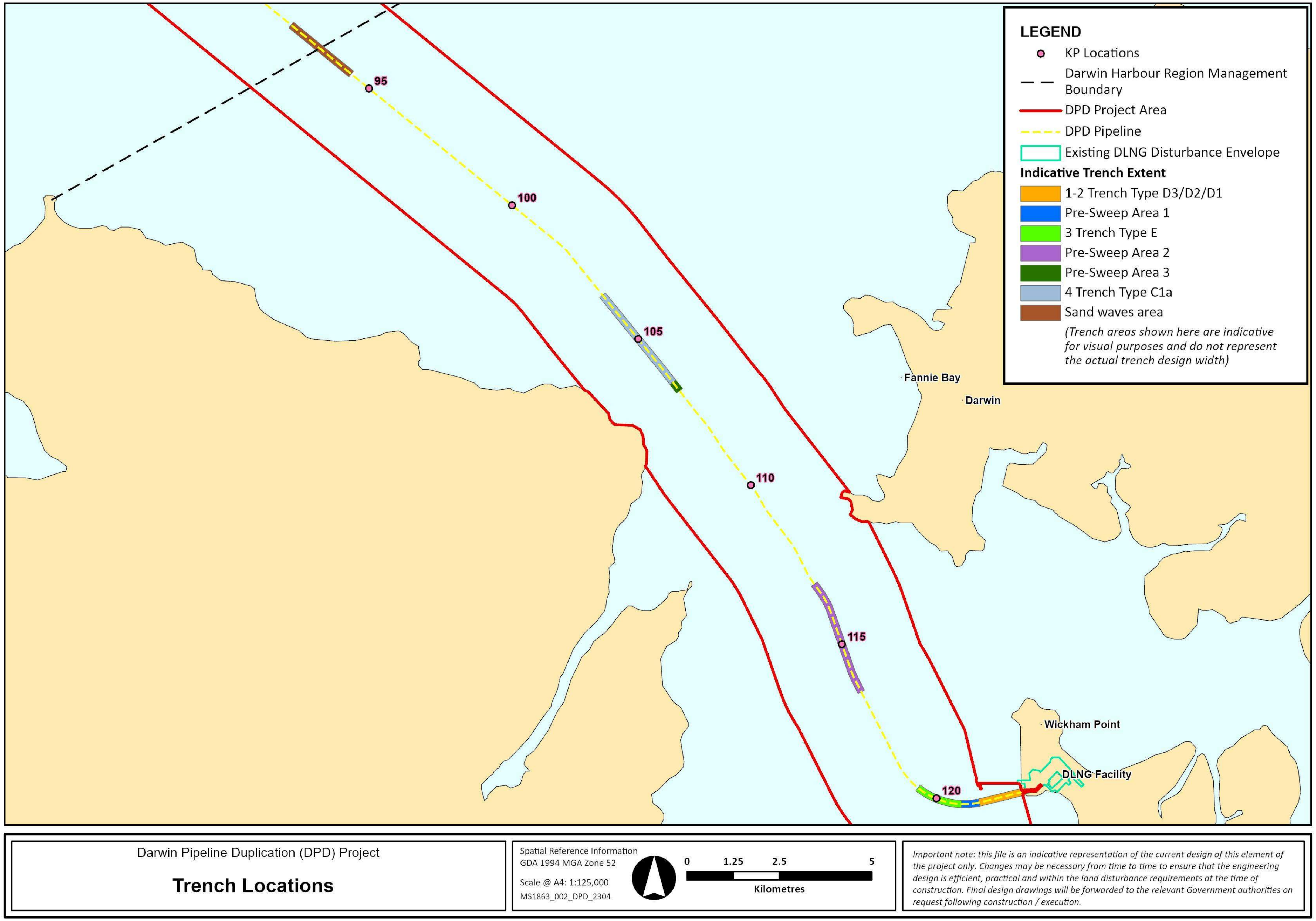

Figure 2-4 Proposed pipeline route with trenching, pre-sweep and sand waves sections and the proposed trenching vessel

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.

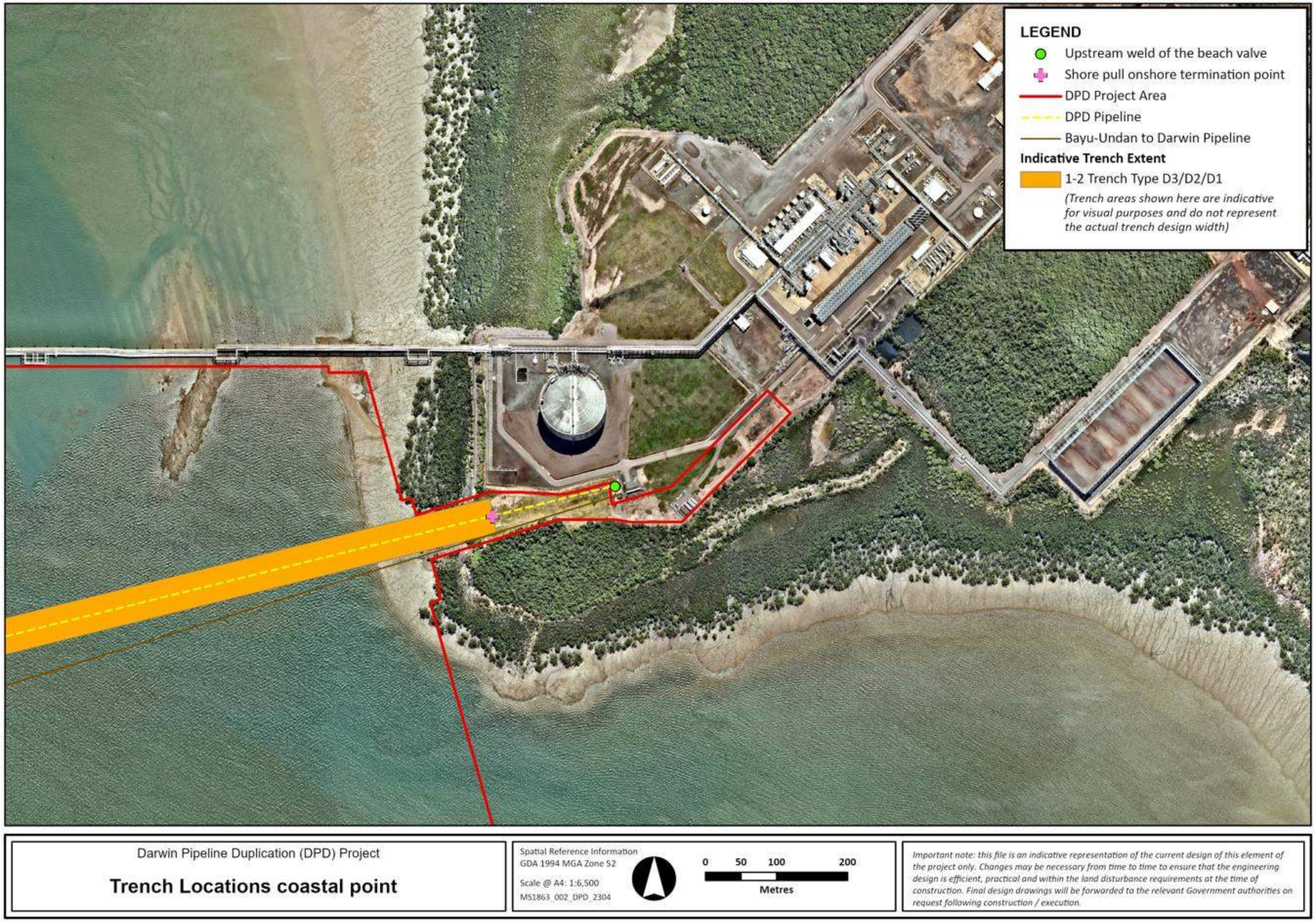

Figure 2-5 Proposed onshore and intertidal trench locations

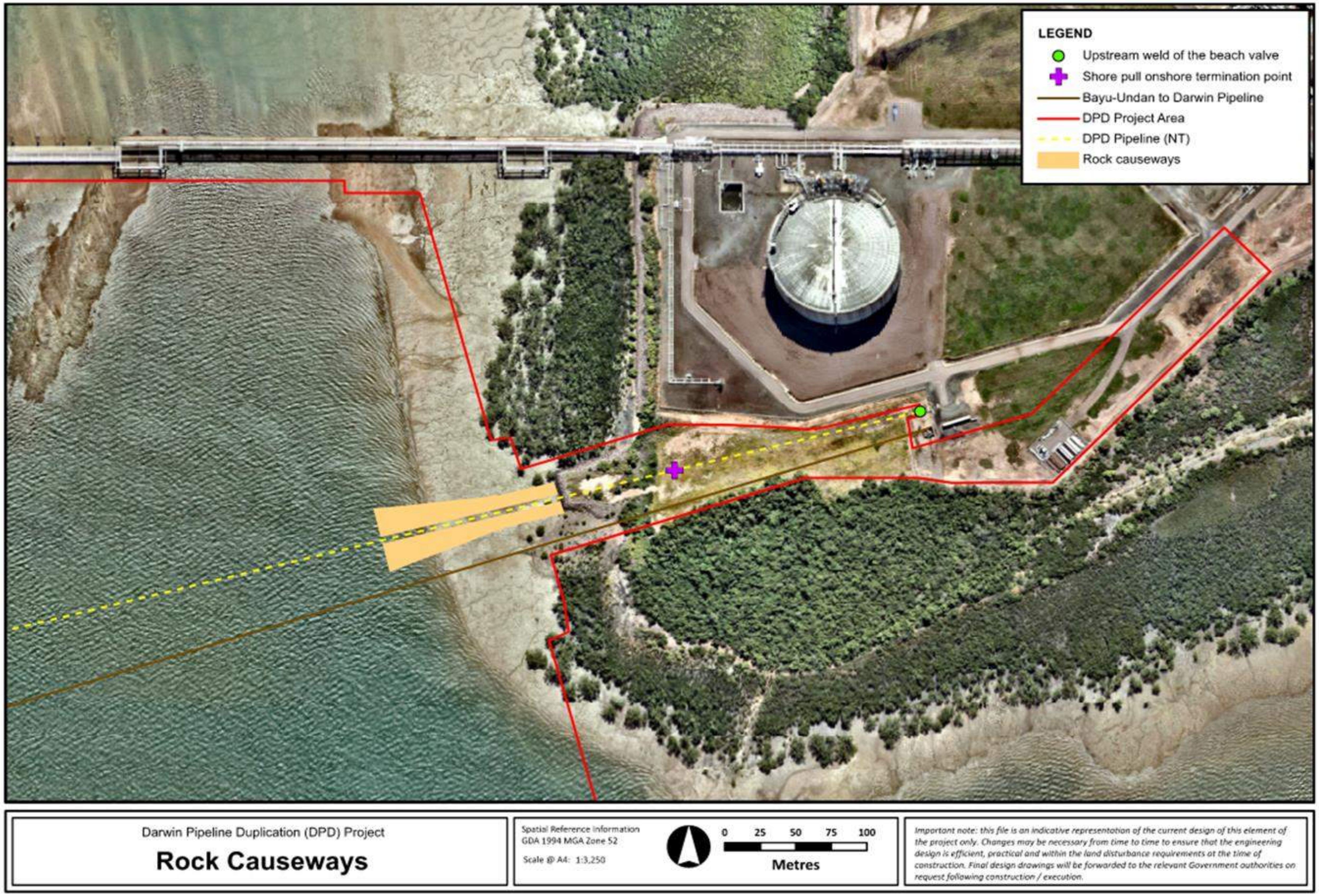

Figure 2-6 Temporary causeway location

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.

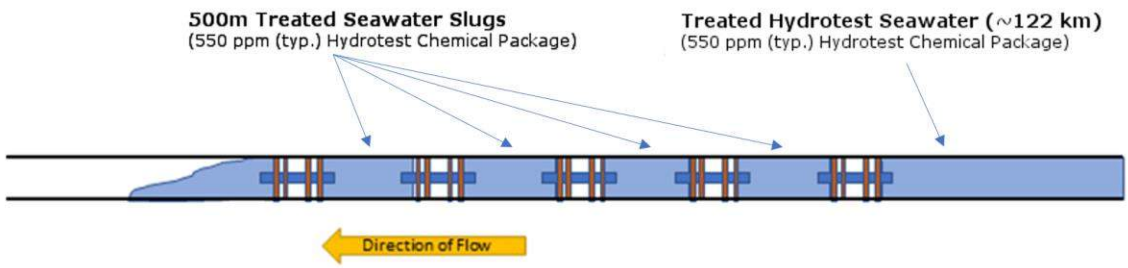

Figure 2-7 Schematic showing five pigs separated by 500 m

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.

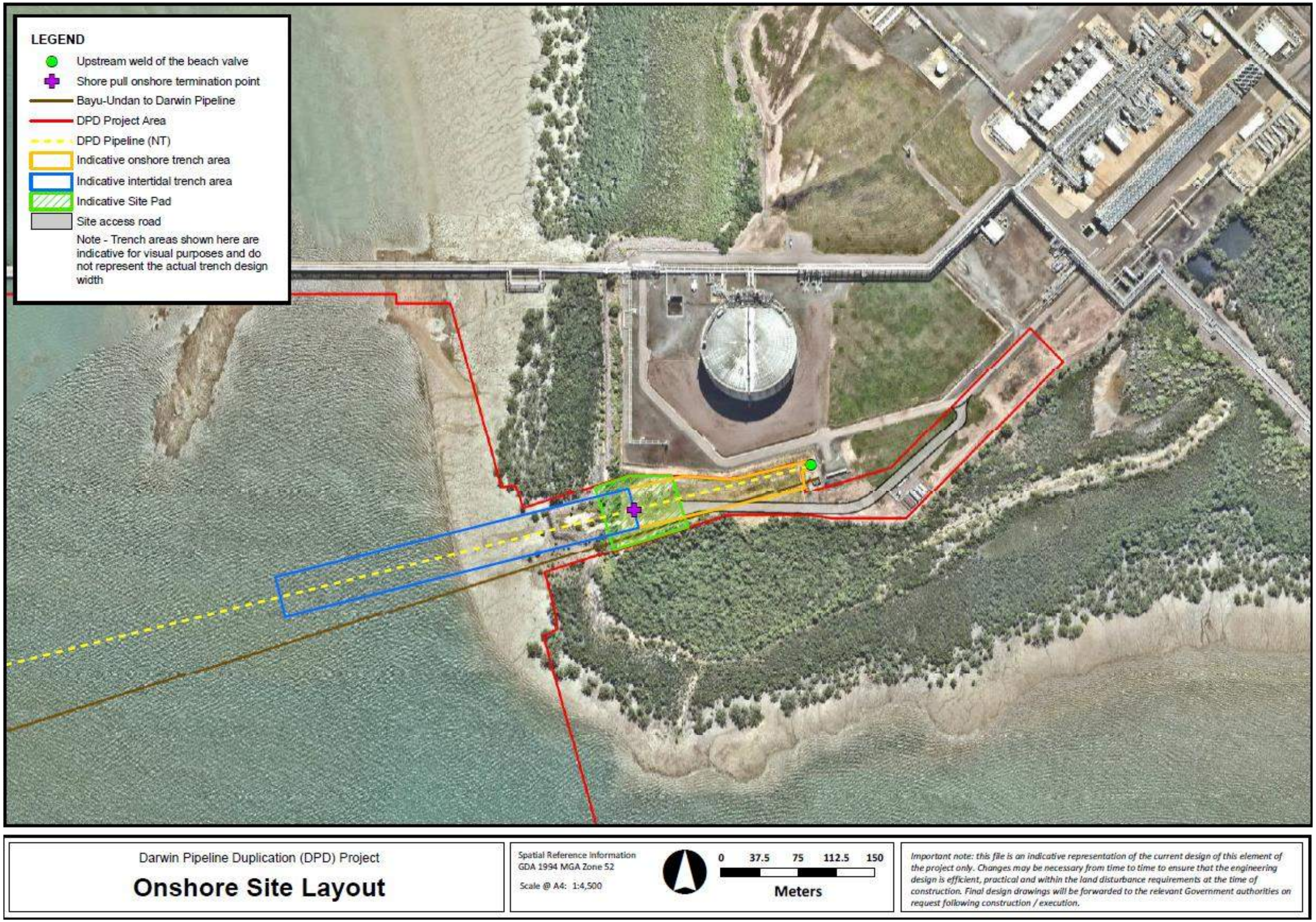

Figure 2-8 Indicative onshore site layout

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**).

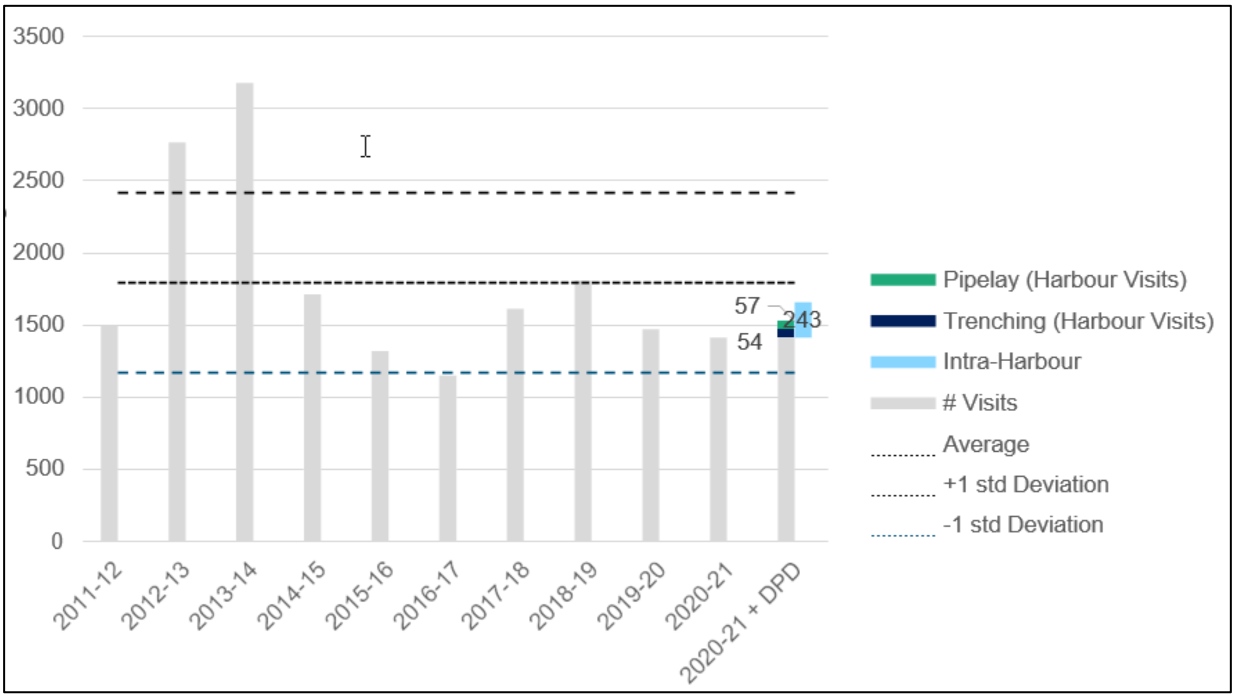

Figure 2-9 Annual harbour visits FY2011-12 to FY20-21

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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.

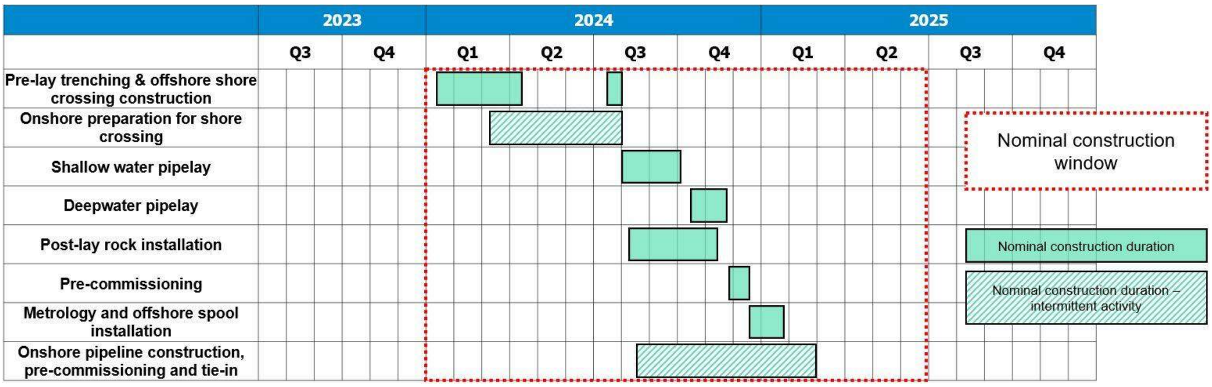


Figure 2-10 DPD Project execution schedule (Indicative)

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)

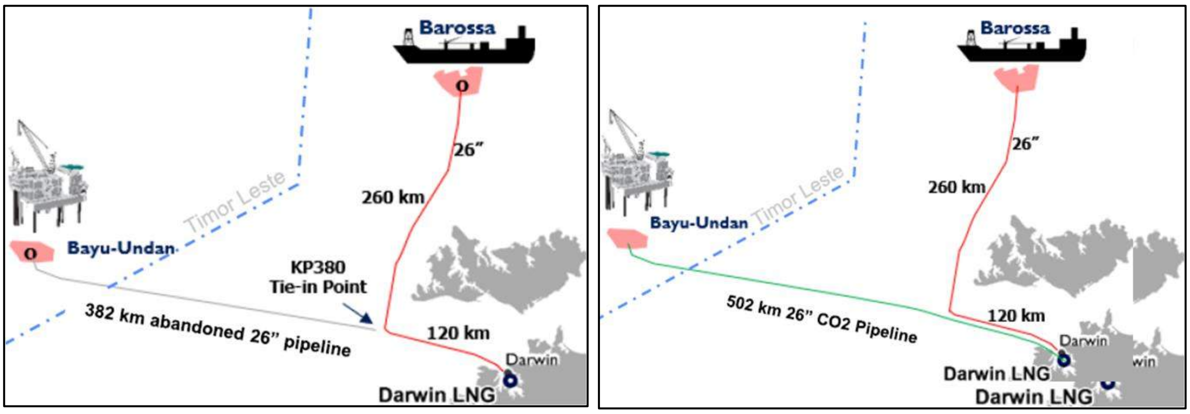


Figure 3-1 Options for the use of the existing pipeline for Barossa gas (A) or CCS service (B)

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

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
Construction phase			
Marine Environmental Quality	+ 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.	+ 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	+ 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.

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	+ 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.	+ 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
Coastal Processes		+ Additional decommissioning activities required for land-based section.	
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

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
			expansion capacity for DLNG facility.
Environmental benefits	+ Allows Bayu-Undan pipeline to be re-purposed for CO_2 transmissions 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.	+ Allows Bayu-Undan pipeline to be re-purposed for CO_2 transmissions 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.	+ Removes impacts and risks associated with the DPD Project 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
	+ 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. + Economic benefits and job creation associated with low carbon industry development.	+ Potential additional CO_2 sources for CCS could also include existing and/or future NT industry along with international imports. + 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.

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
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. + Refer **Section 15.2** for DPD Project environmental decision-making hierarchy assessment.	+ 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.
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.	+ 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.

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 15.3** for DPD Project waste management hierarchy assessment.		

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.

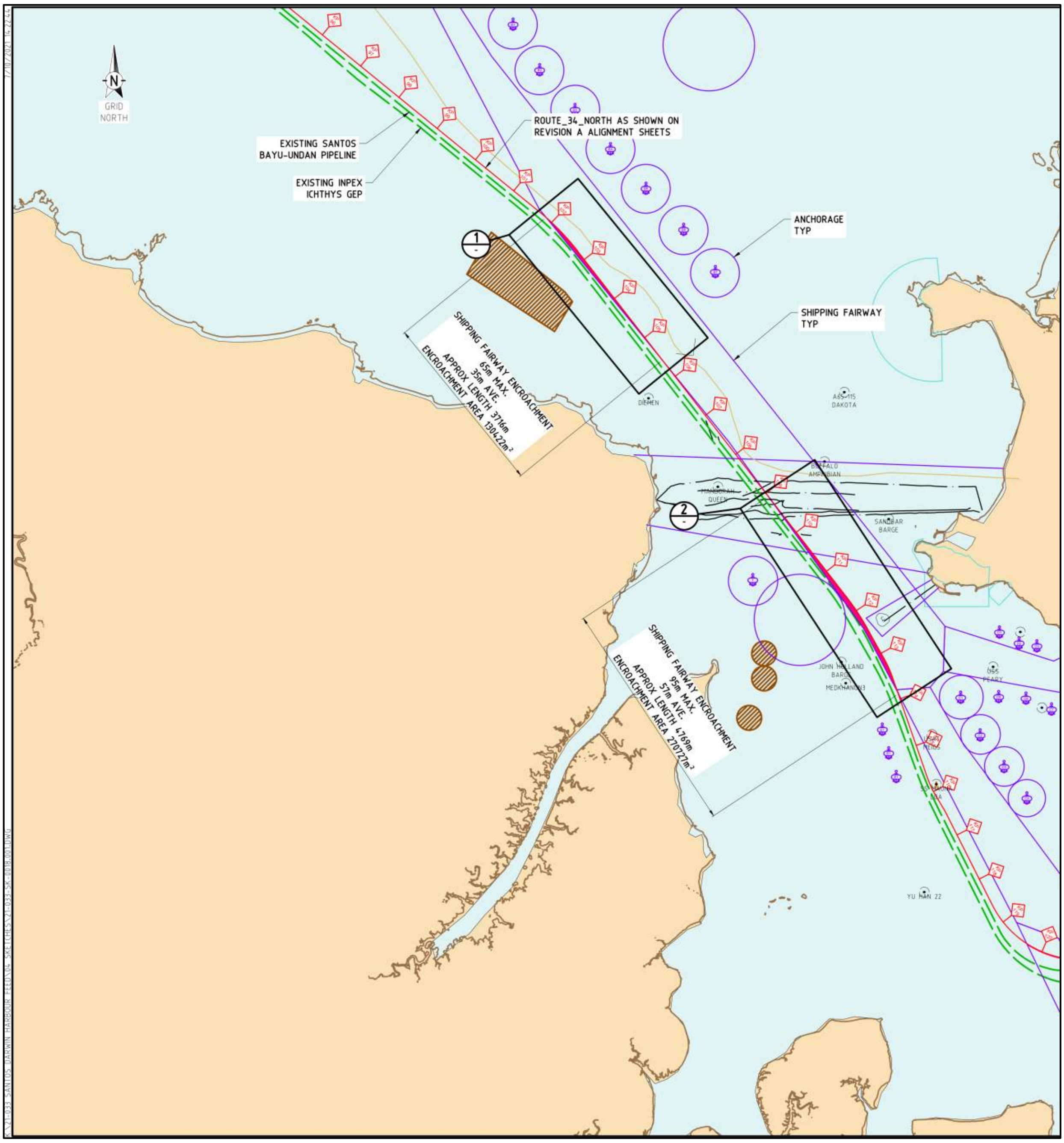


Figure 3-3 Section of the original DPD pipeline northern route, as described in the referral, showing shipping channel encroachment

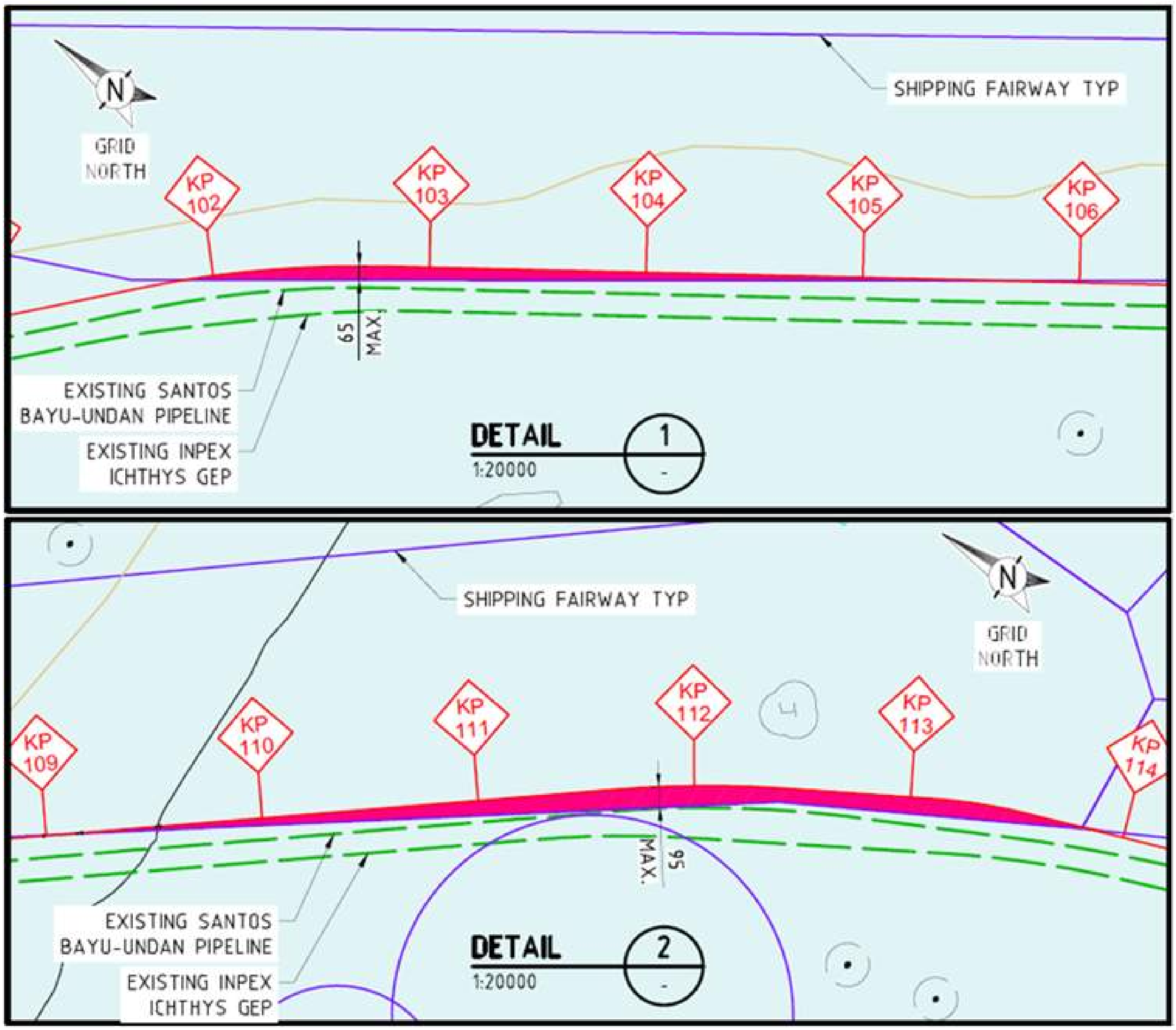
Original Route
Close-up of the two shipping channel encroachment areas, showing ~8,500 m length of shipping channel encroached and a maximum penetration of ~95 m into the channel.


Figure 3-4 Sections of the original DPD pipeline northern route showing encroachment into shipping channel in two areas

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.

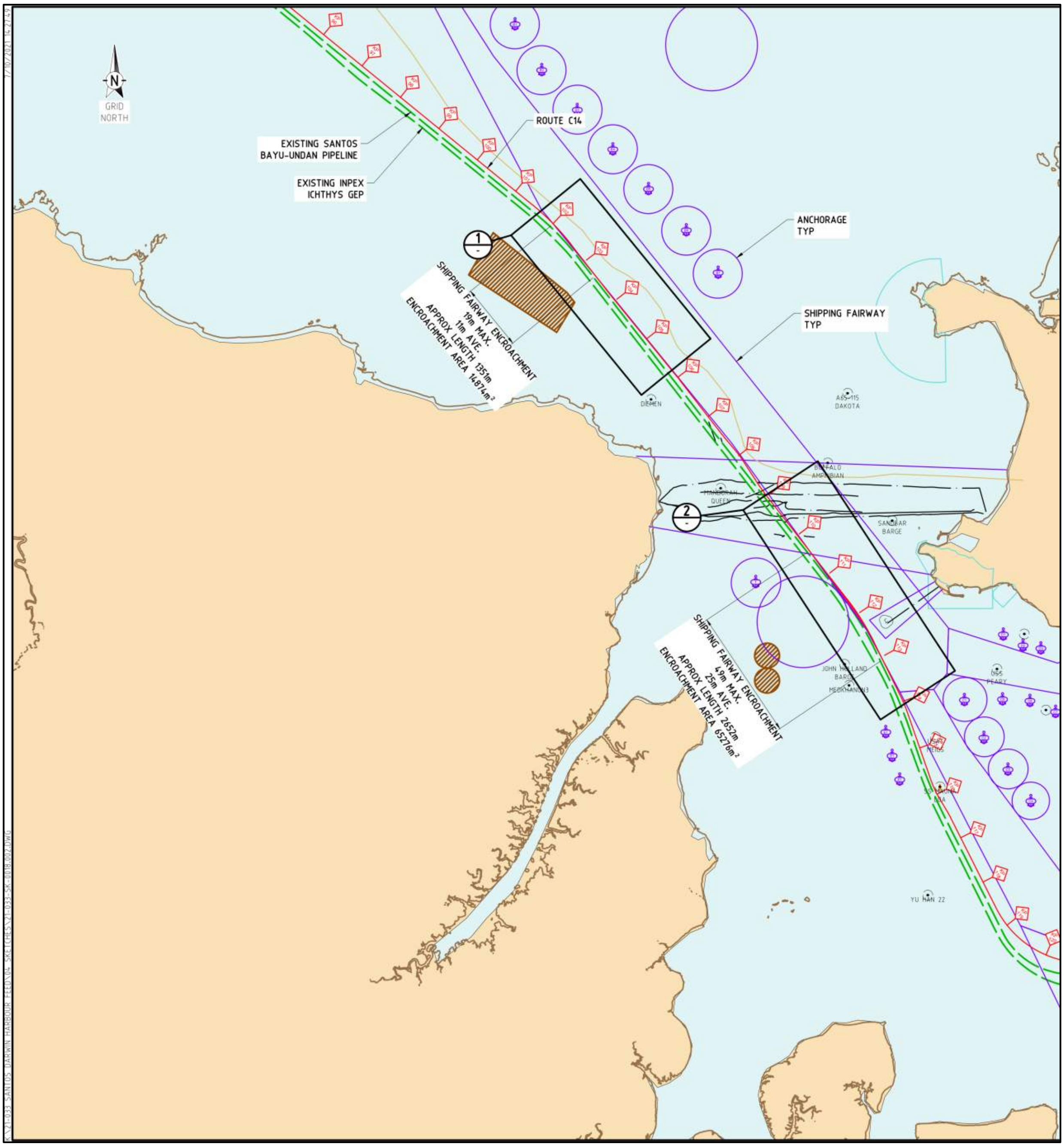


Figure 3-5 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 1), showing reduced shipping channel encroachment

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).

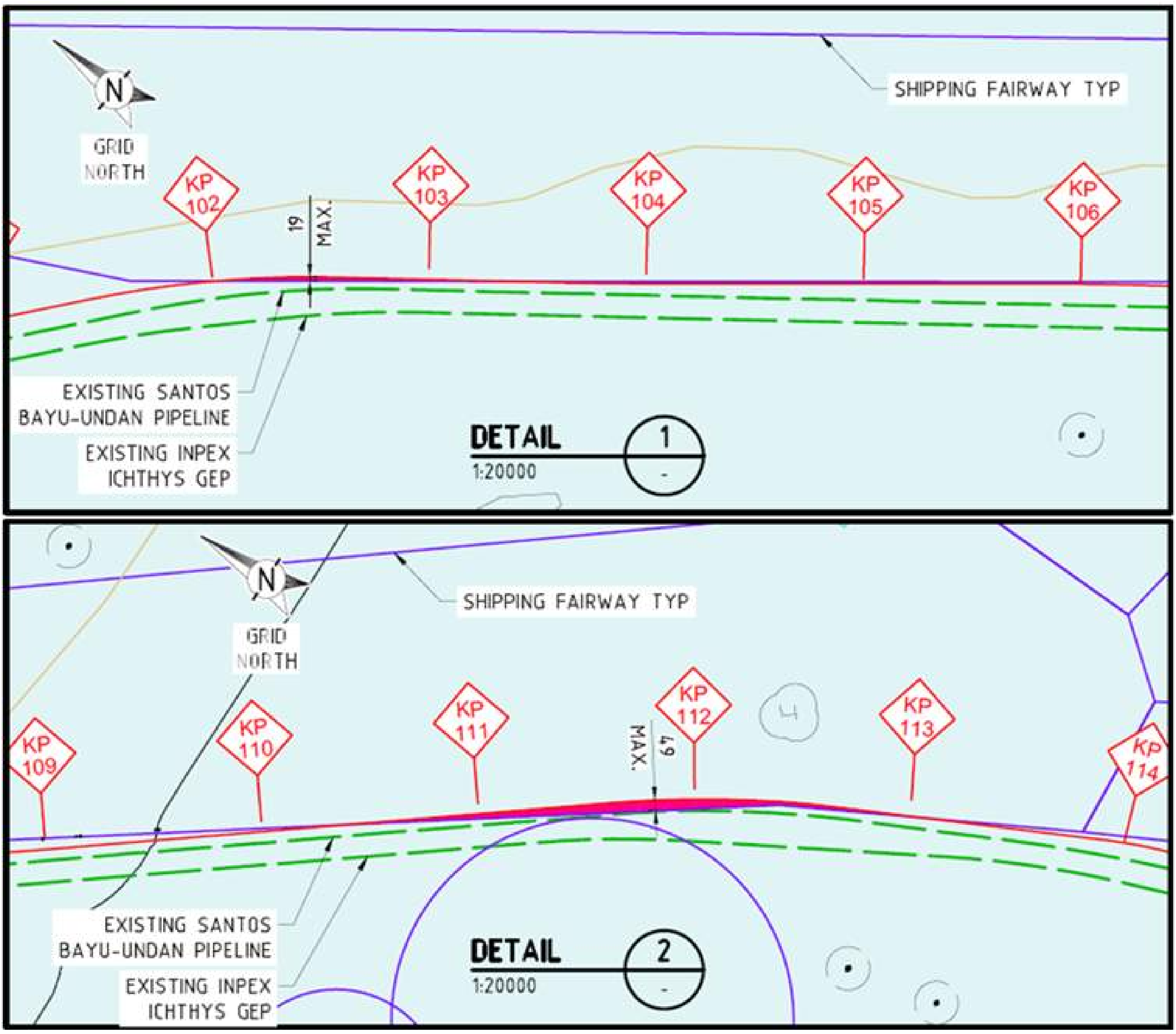


Figure 3-6 Sections of the revised DPD pipeline northern route (option 1) showing reduced encroachment into shipping channel in two areas

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.

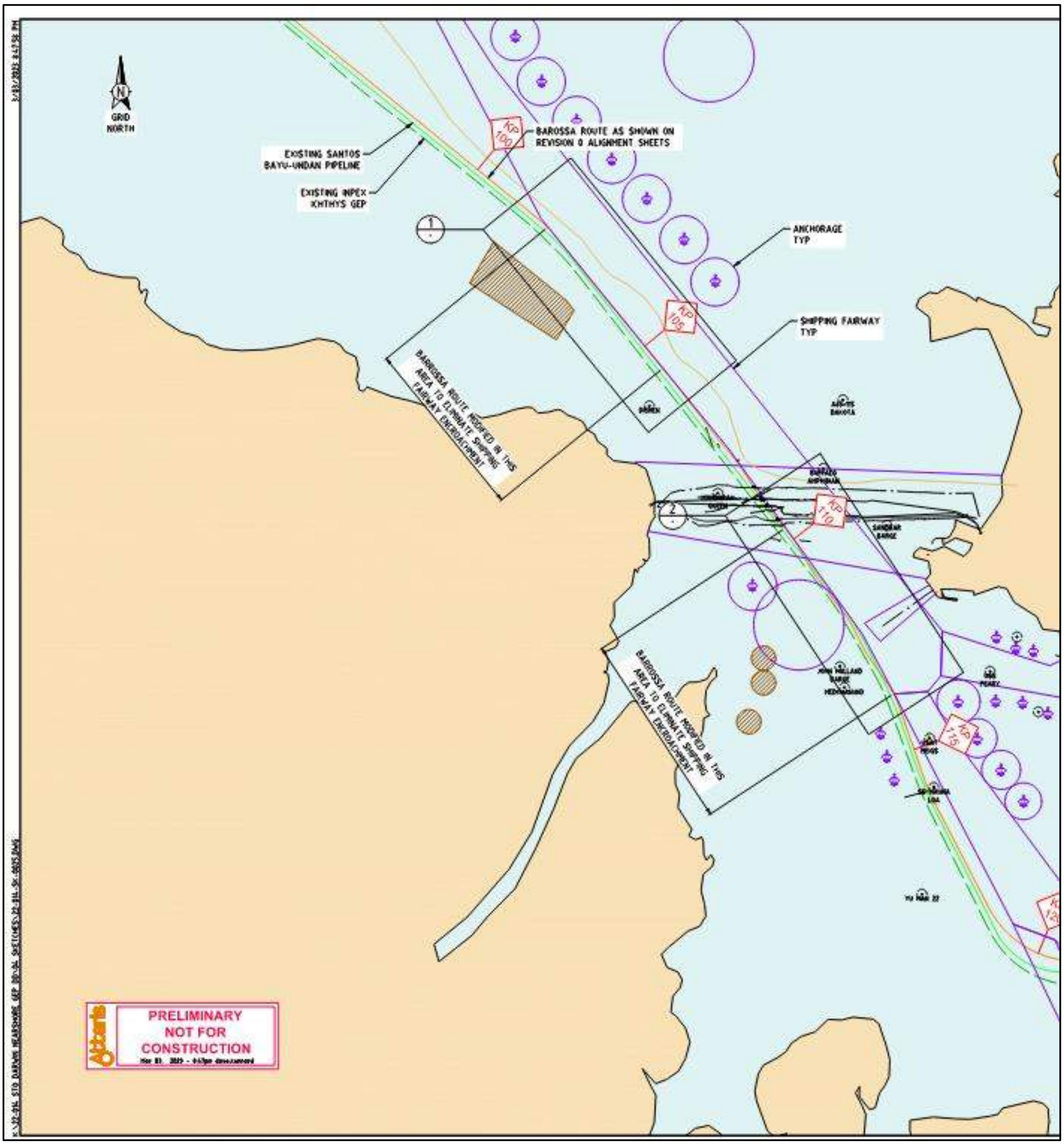


Figure 3-7 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 2), showing reduced shipping channel encroachment

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.

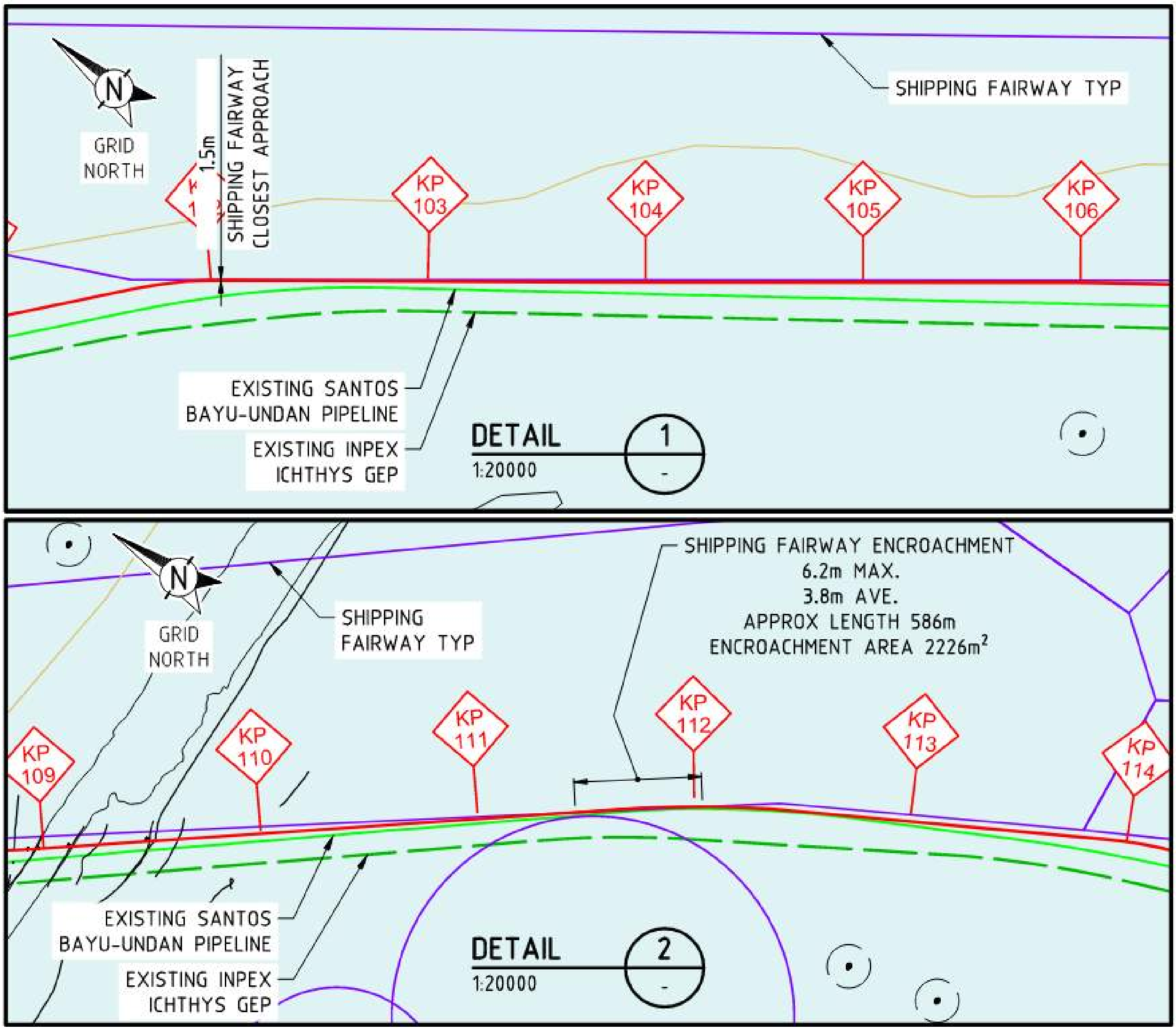


Figure 3-8 Sections of the revised DPD pipeline northern route (option 2) showing removed encroachment into shipping channel in the north and reduced encroachment in the south

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.

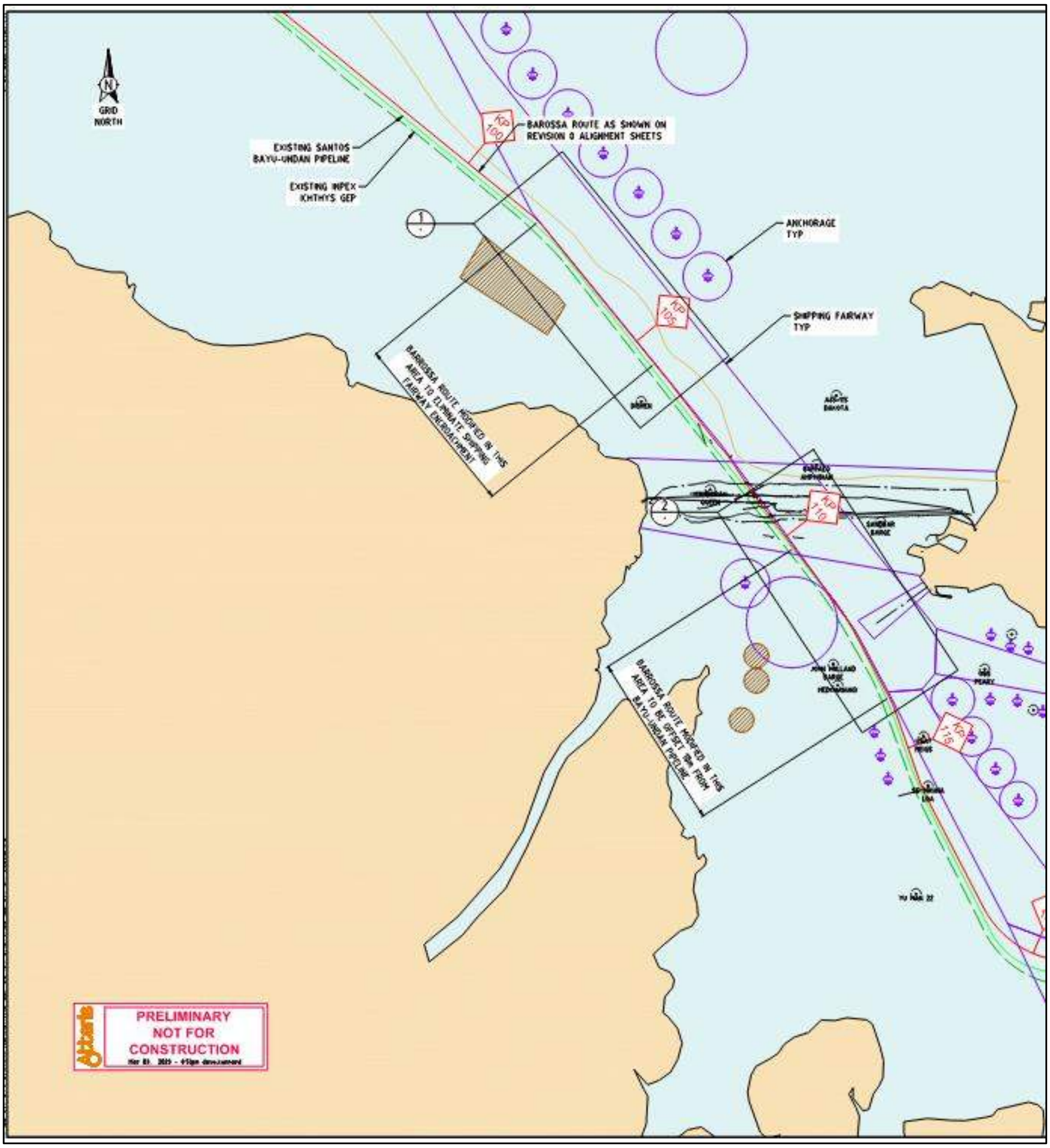


Figure 3-9 Section of the revised DPD pipeline northern route, following stakeholder engagement (option 3), showing removal of all shipping channel encroachment. This represents the final selected route.

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.

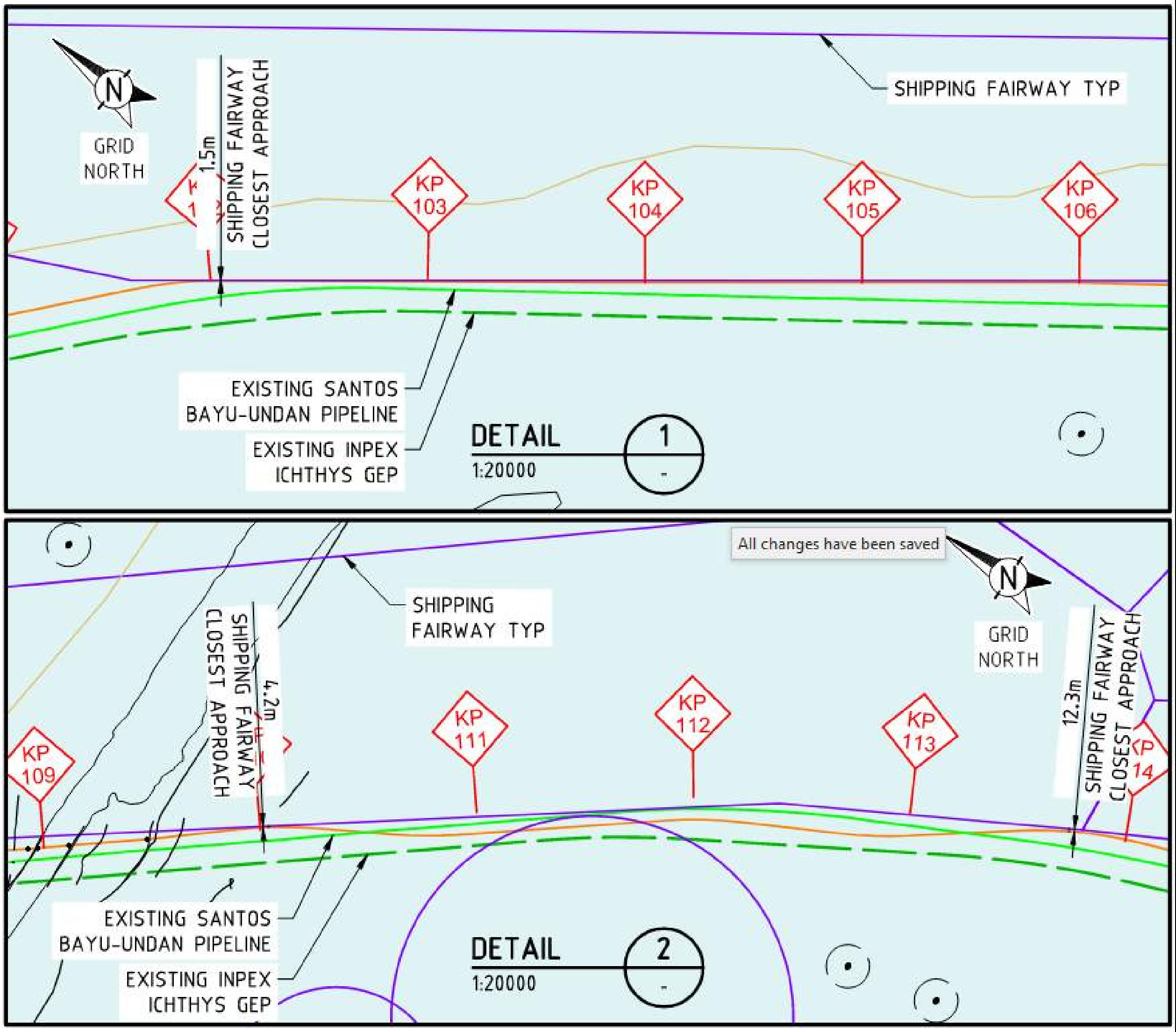


Figure 3-10 Sections of the revised DPD pipeline (option 3), following stakeholder engagement, showing removal of all shipping channel encroachment. This represents the final selected route.

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 draft 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 draft 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	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;		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.	
+ 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 draft 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	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	Atmospheric Processes

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
	Bruce Robertson - Institute for Energy Economics and Financial Analysis 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	Project's 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	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	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.	Atmospheric Processes

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
change, no further fossil fuel developments should be pursued.	Grusha Leema Julie Fraser – Australian Service Union Julie Fraser Peta Bailee Dina Rui - Jubilee Australia Research Centre Anonymous (submission 307)	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 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	Environment Centre NT (ECNT) Alice Nagy Australian Parents for Climate Action	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.	Atmospheric Processes

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
greenhouse gas methane, which will be emitted throughout the life cycle of the project. There are also potential leaks of emissions associated 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	Australian Parents for Climate Action Darwin and NT - volunteer group	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. 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.	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	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

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
+ More detail is required from Santos on the CCS project and how this will help reduce CO_2 emissions	The Australia Institute Grusha Leeman Julie Fraser – Australian Service Union Julie Fraser 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	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

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
impacts would occur should the climate risks come to bear.			
+ 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			
+ 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	Department of Industry, Tourism and Trade Julie Fraser – Australian Services Union Julie Fraser Robin Knox Kelly Lee Hickey	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	Community and Economy

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(pipe laying) to mitigate and minimise the negative impacts on tourism.	Naish Gawen (on behalf of many) (submissions 18-301) Anonymous (submission 307)	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.**	
+ 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	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

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
commercial fisheries in and adjoining the Project area.			
+ 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 (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.	Community and Economy
+ 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	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	Culture and Heritage

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
pipeline, preferably in partnership with Larrakia people, is required		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)*.	
+ 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. + The pre-referral tool located in the appendix does not appreciate potential impact to significant UCH sites not previously recorded.	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 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.	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	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	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**.	Marine Environmental Quality Marine Ecosystems Atmospheric Processes Coastal Processes Community and Economy Culture and Heritage

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
the harbour, as well as the process of industrialisation occurring within Darwin Harbour.	Dina Rui – Jubilee Australia Research Centre Anonymous (submission 307)	**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.	
+ 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.	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
+ 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	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	Community and Economy

Summary of key issues raised in submissions	Stakeholder	Santos' response and actions taken	Relevant Environmental Factor addressed in SER
it is optimally located in the context of other infrastructure within Darwin Harbour.		undertaken are provided in **Appendix 13**. Details of the final pipeline route selection and optimisation process is provided in **Section 3**.	
+ The NT EPA should have refused the DPD Project referral. + The DPD Project should be assessed at a higher level than a Supplementary Environmental 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.	Environment Centre NT (ECNT) Amateur Fisherman's Association of the Norther Territory (AFANT) 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	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
	Dina Rui - Jubilee Australia Research Centre Bruce Robertson - Institute for Energy Economics and Financial Analysis Peta Baillie		
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

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 draft 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.

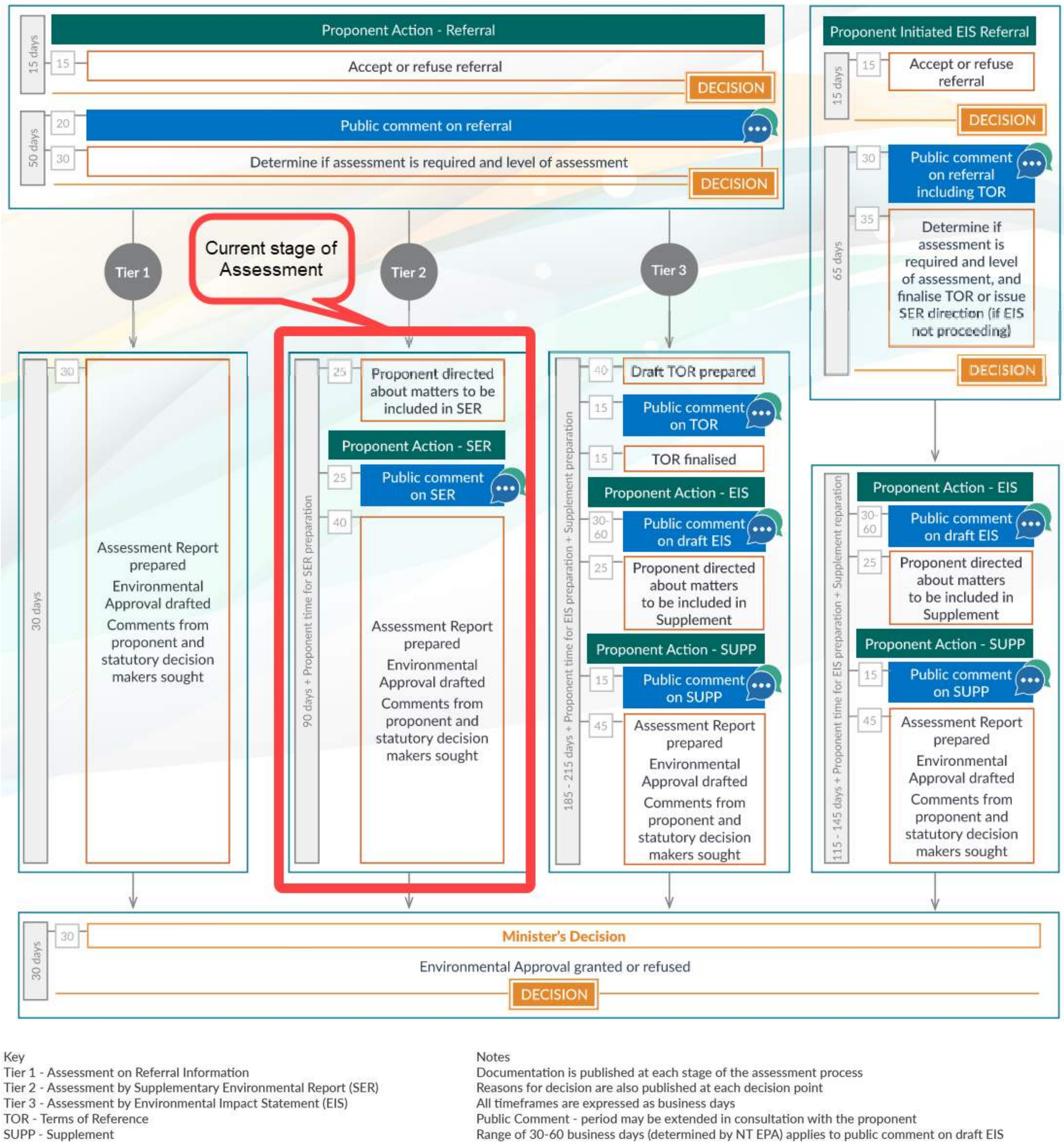

Figure 7-1 NT EP Act environmental approvals flowchart showing DPD Project position

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

Santos

+ 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

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 draft 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.

Santos

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.

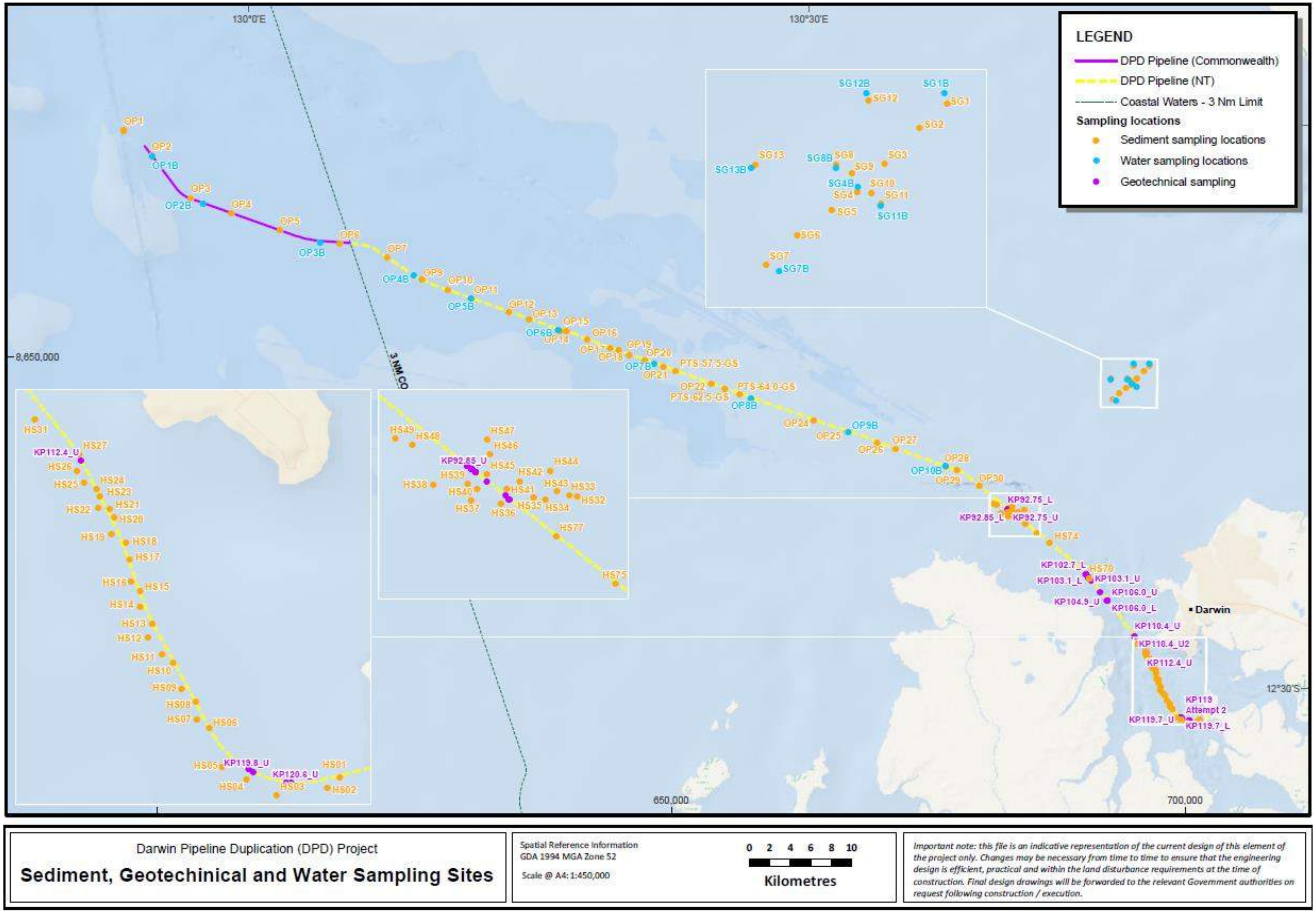

Figure 8-1 Sediment and water quality sampling sites (November 2021) and geotechnical sampling sites (January 2022) along the proposed Barossa Development pipeline route and at the proposed spoil ground (SG).

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.

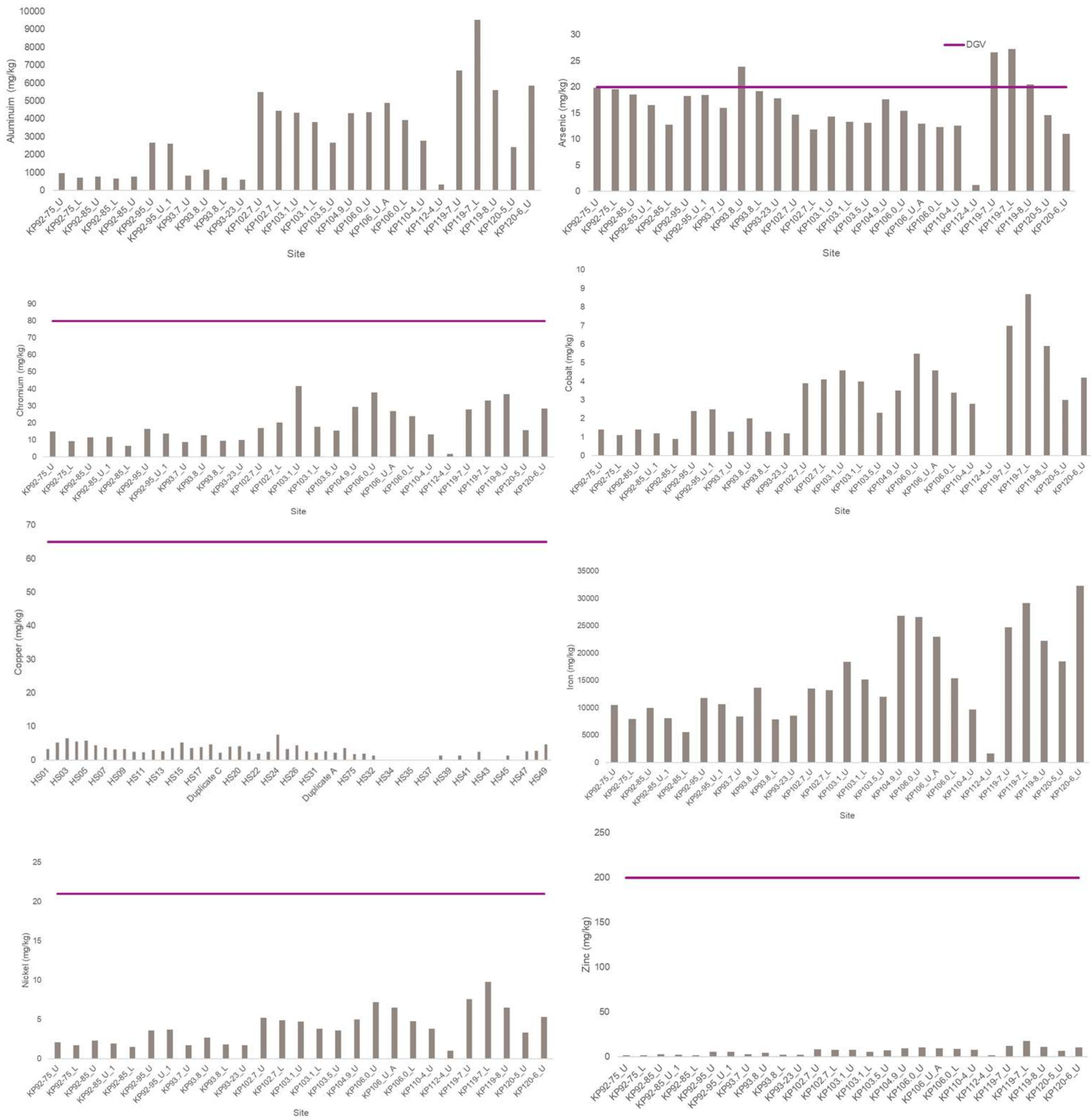

*Figure 8-2 Metal concentrations in comparison to the screening levels presented in the National Assessment Guidelines for Dredging, 2009 (CoA, 2009) (refer RPS, 2022a; **Appendix 6** for full details)*

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.

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.

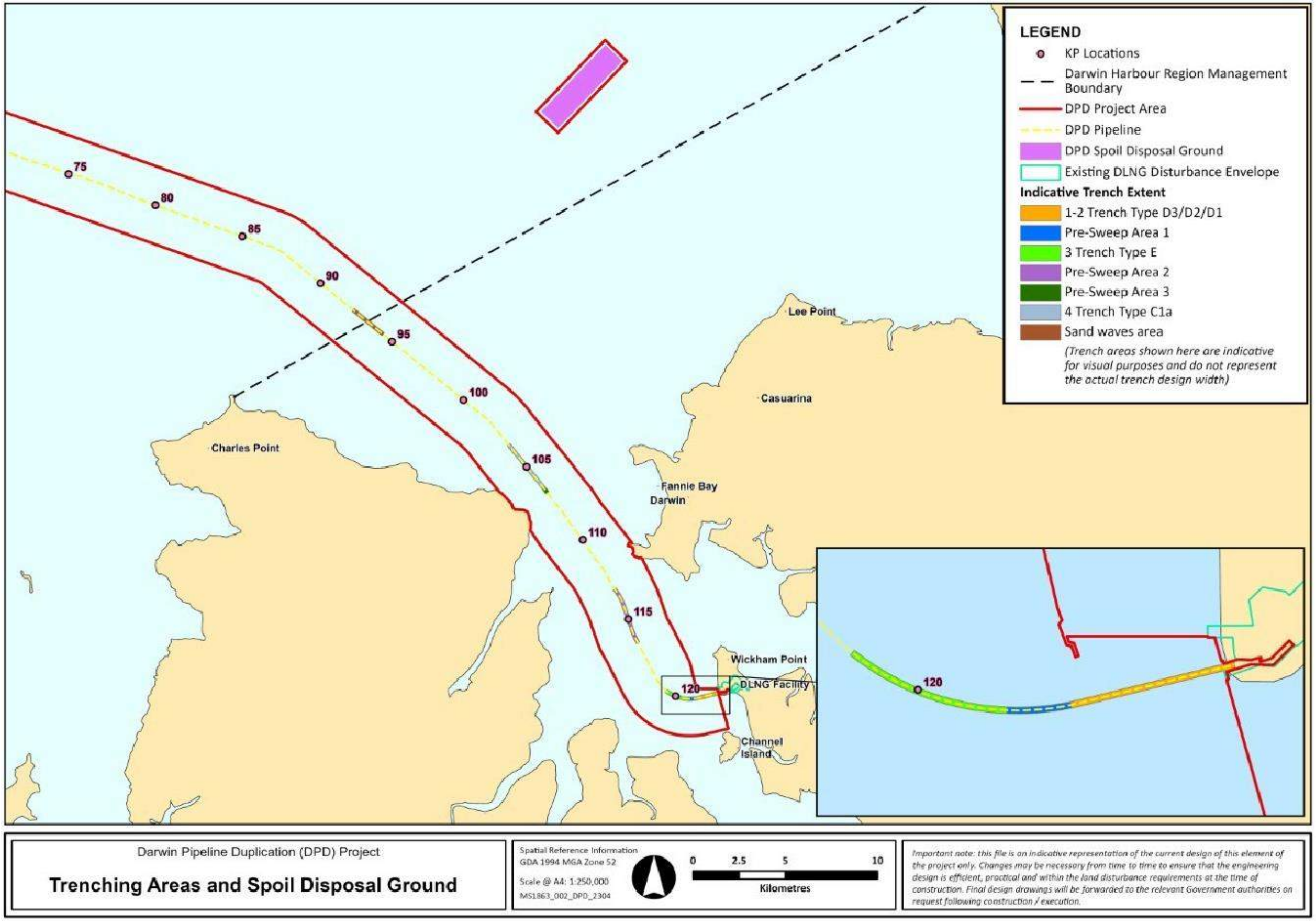

Figure 8-3 Trenching areas and spoil disposal ground

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	

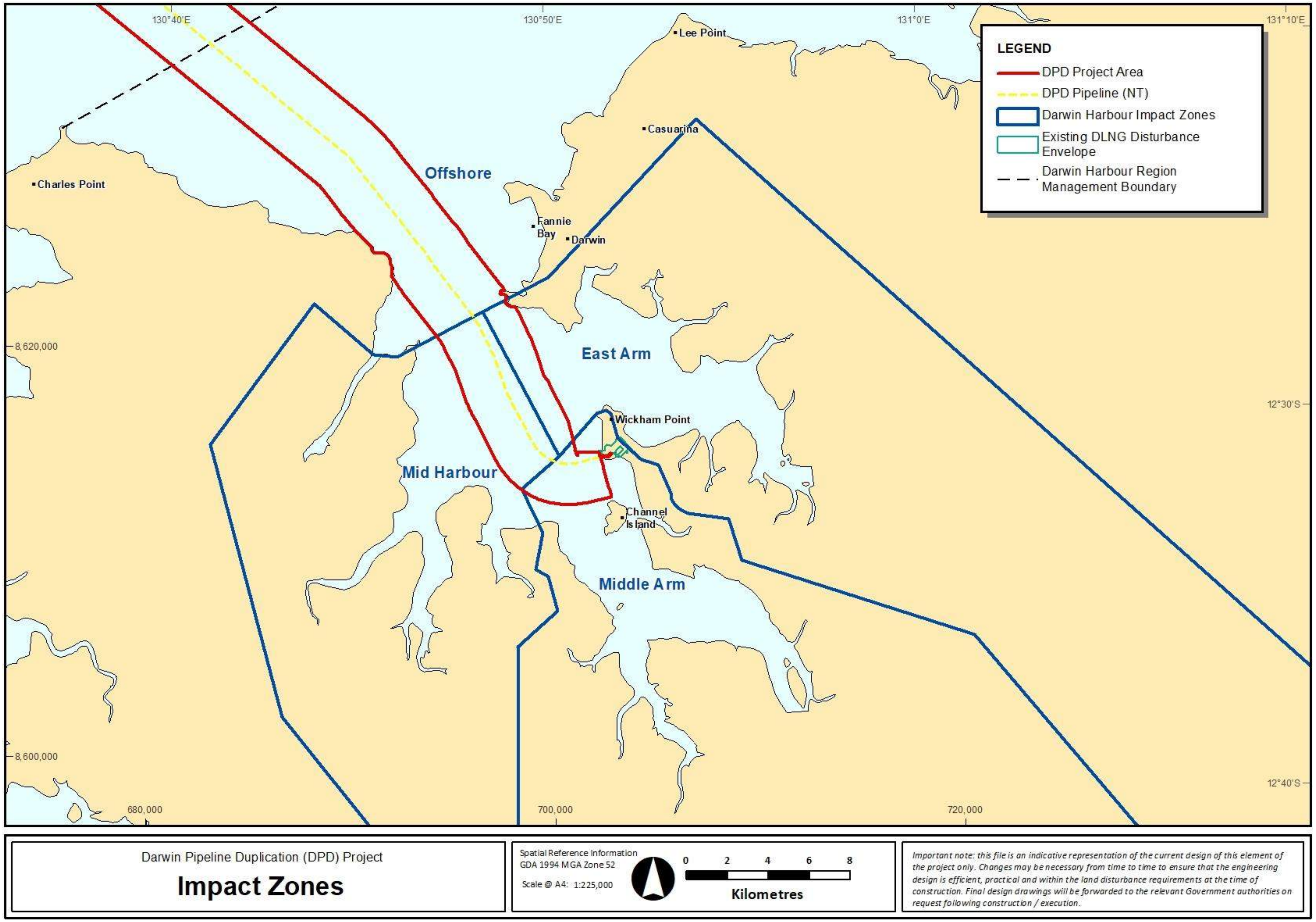

Figure 8-4 Proposed trenching impact reporting zones, based on INPEX (2010)

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**).

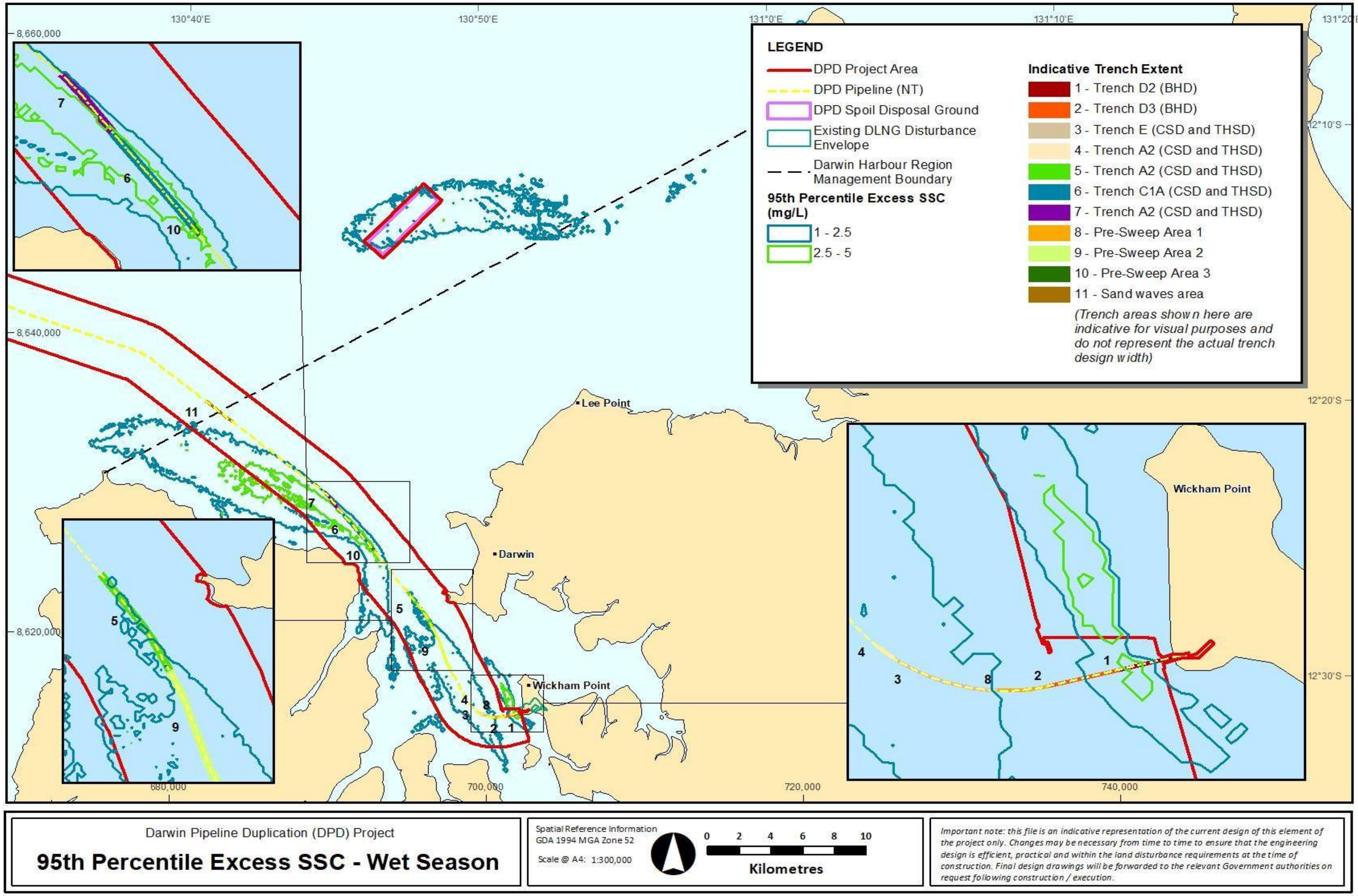

Figure 8-5 Predicted 95th percentile trenching-excess SSC for the trenching program transitioning into the summer/wet season (1st October to 9th November 2019)

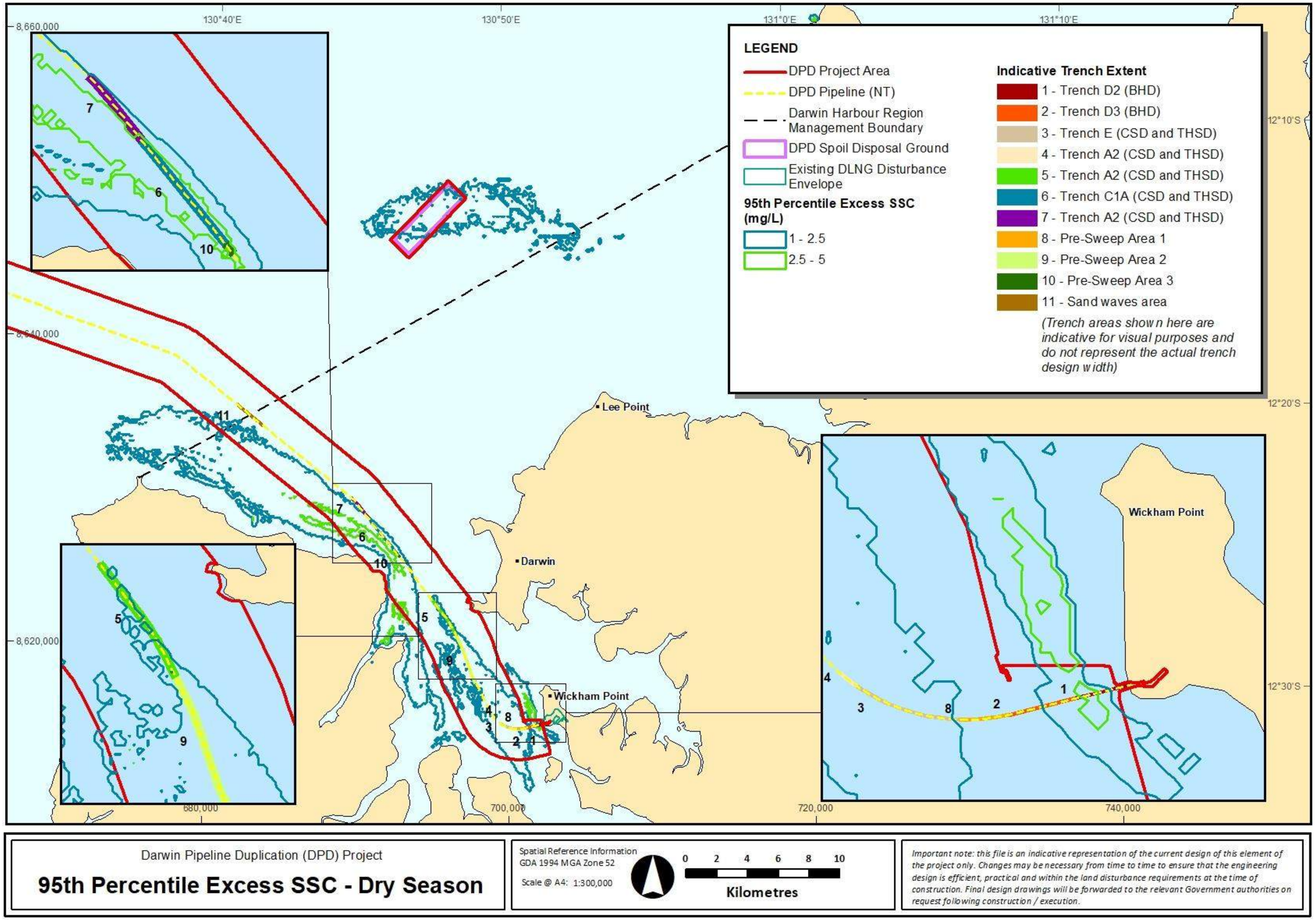

Figure 8-6 Predicted 95th percentile trenching-excess SSC for the entire trenching program transitioning into winter/dry season (1 April to 10 May 2019)

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.

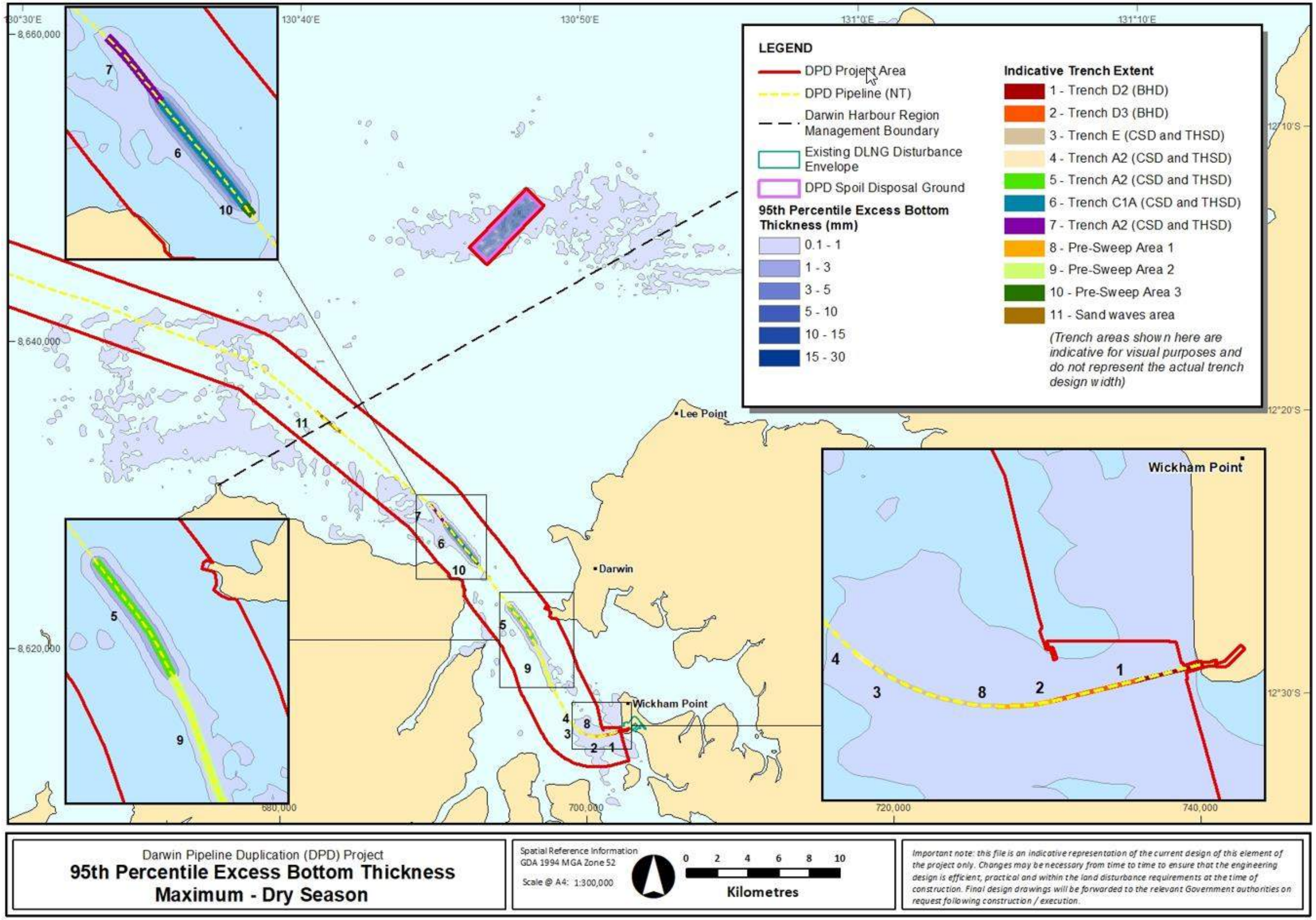

Figure 8-7 Predicted 95th percentile maximum trenching excess bottom thickness (mm) for the trenching program transitioning into winter/dry season (1st April to 10th May 2019)

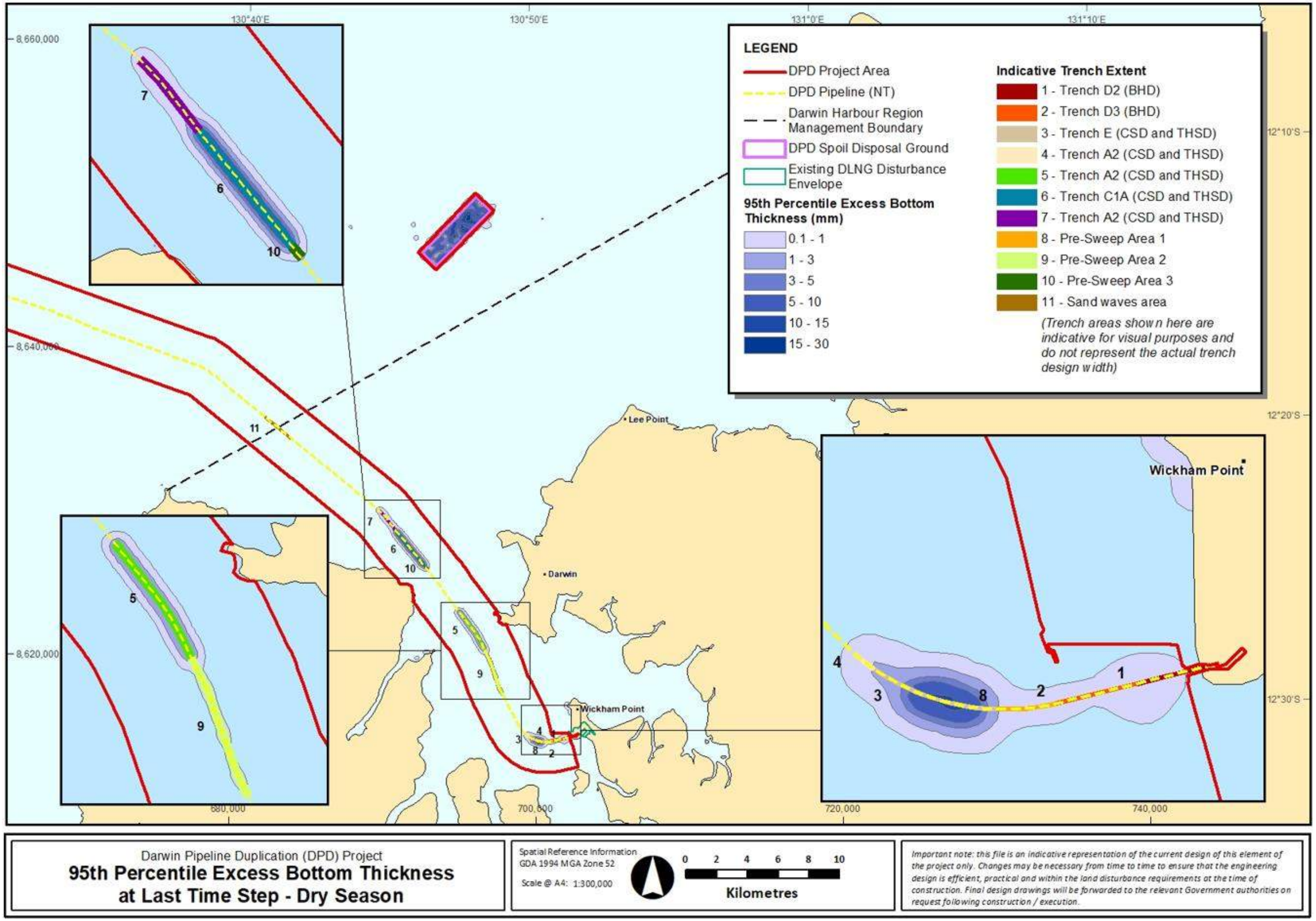

Figure 8-8 Predicted 95th percentile trenching-excess bottom thickness (mm) at the last time step of the trenching program transitioning into winter/dry season (1st April to 10th May 2019)

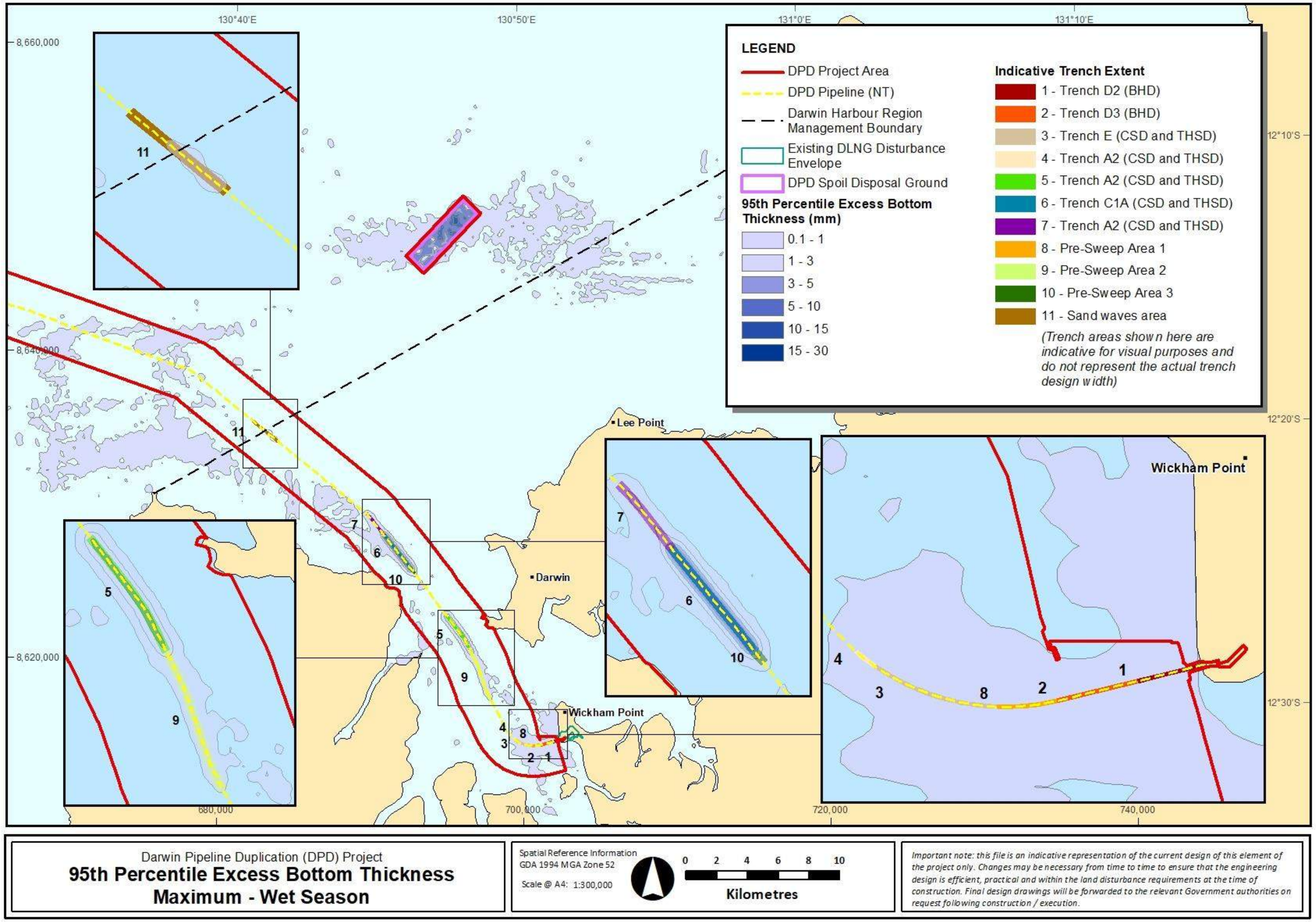

Figure 8-9 Predicted 95th percentile maximum trenching-excess bottom thickness (mm) for the trenching program transitioning into summer/wet season (1st October to 9th November 2019)

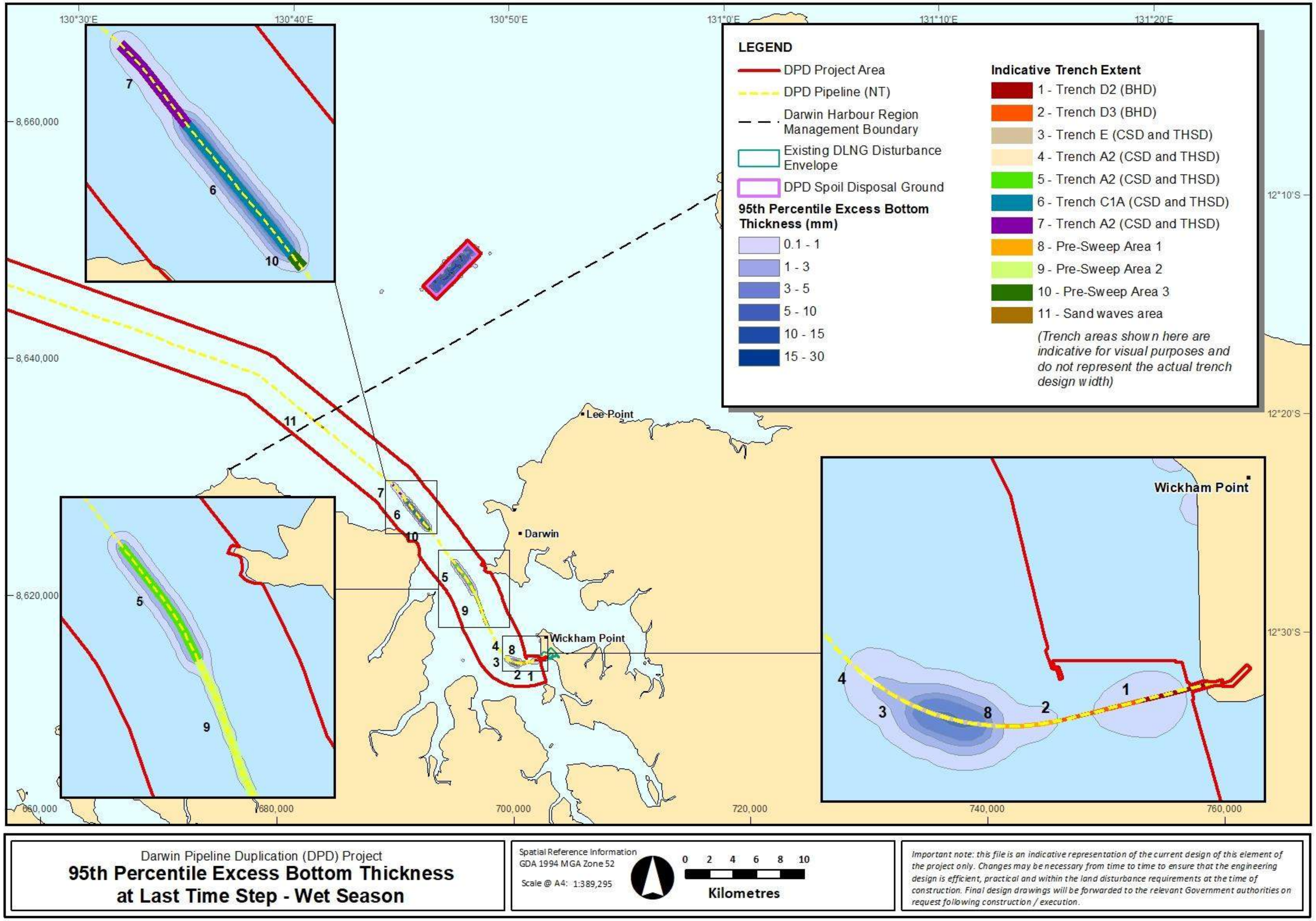

Figure 8-10 Predicted 95th percentile trenching excess bottom thickness (mm) at the last time step of the trenching program transitioning into summer/wet season (1st October to 9th November 2019)

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

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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).

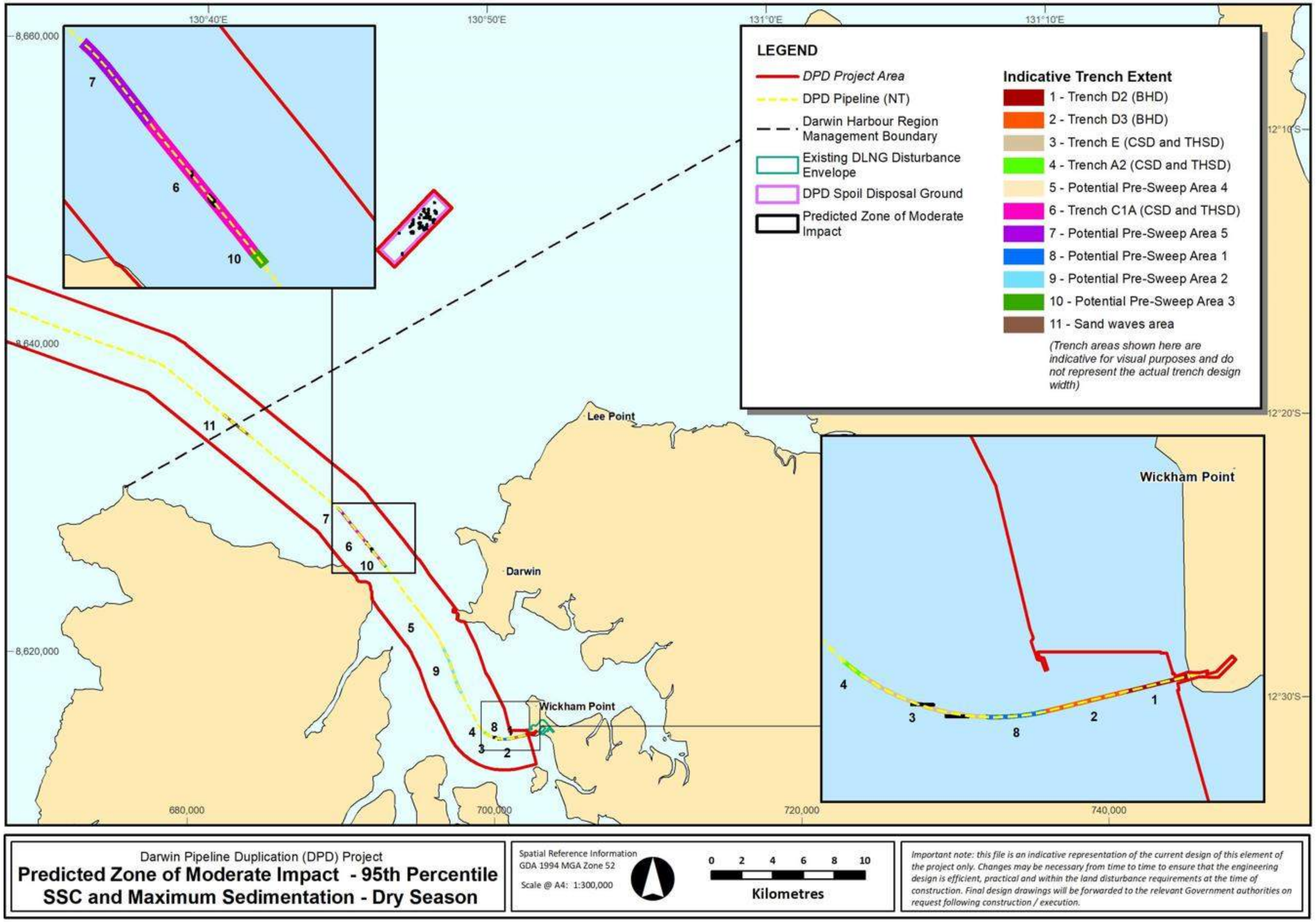

Figure 8-11 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into winter/dry season (1st April to 10th May 2019)

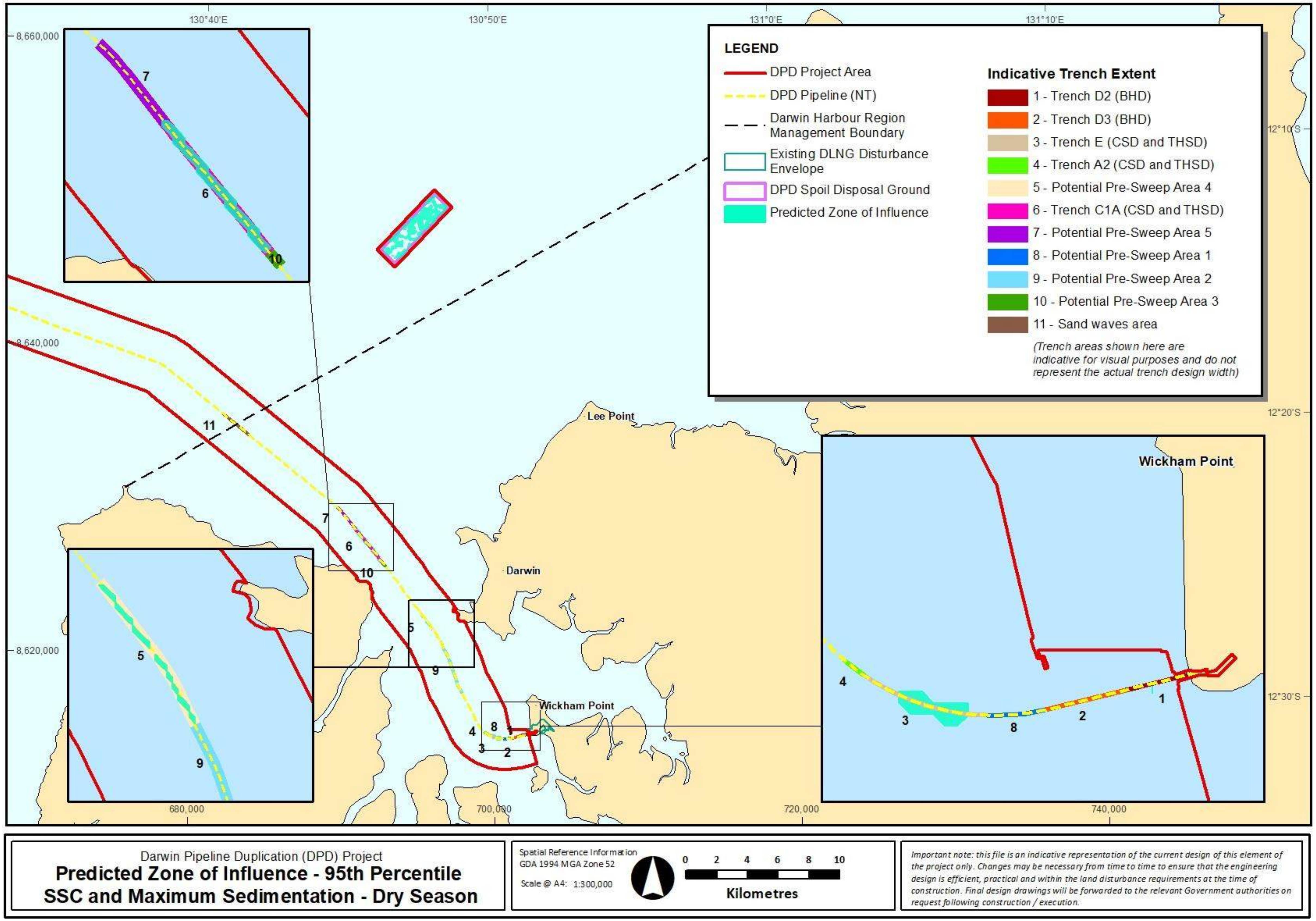

Figure 8-12 Predicted Zone of Influence following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into winter/dry season (1st April to 10th May 2019)

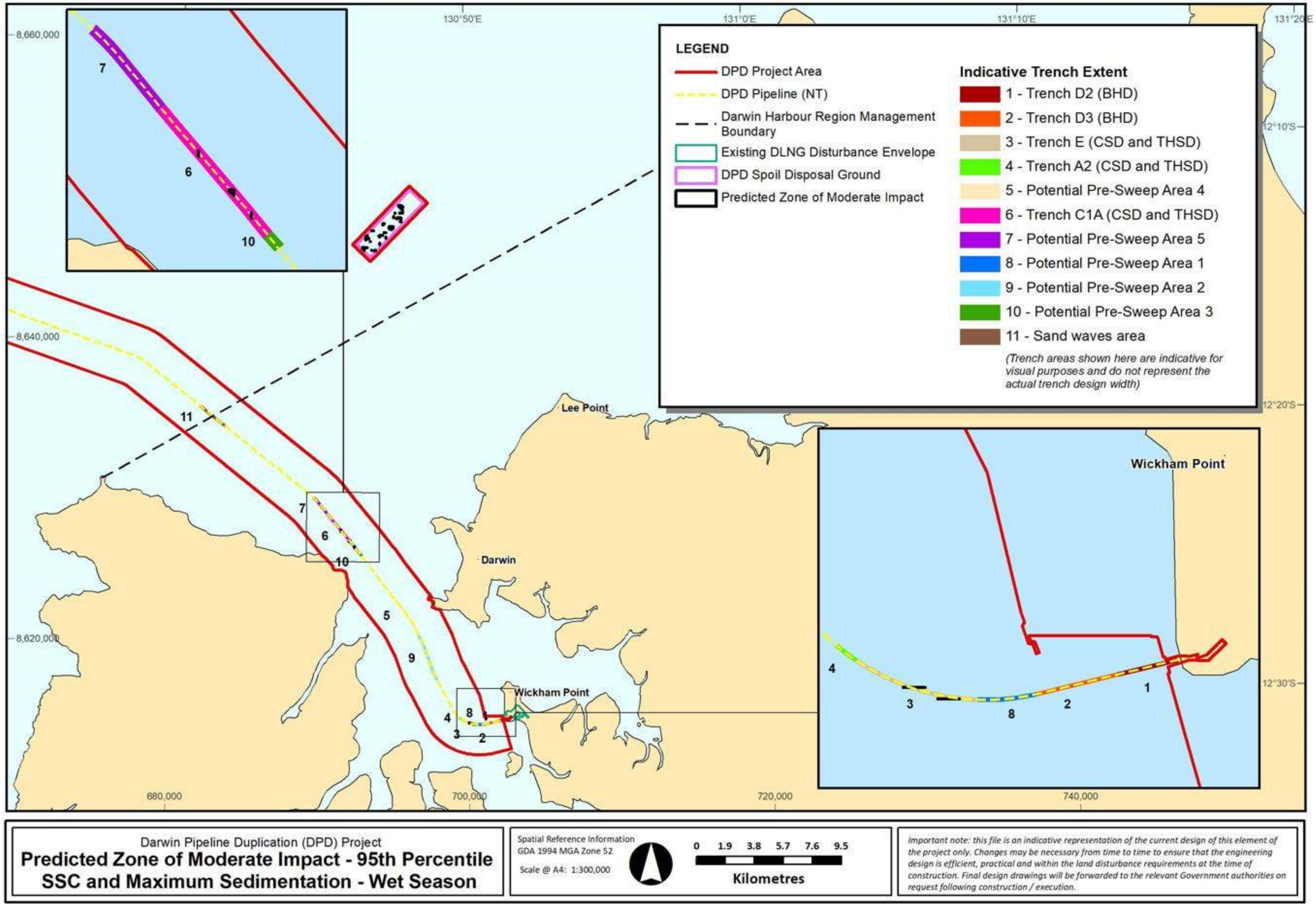

Figure 8-13 Predicted Zone of Moderate Impact following application of the appropriate spatial thresholds to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into summer/wet season (1st October to 9th November 2019)

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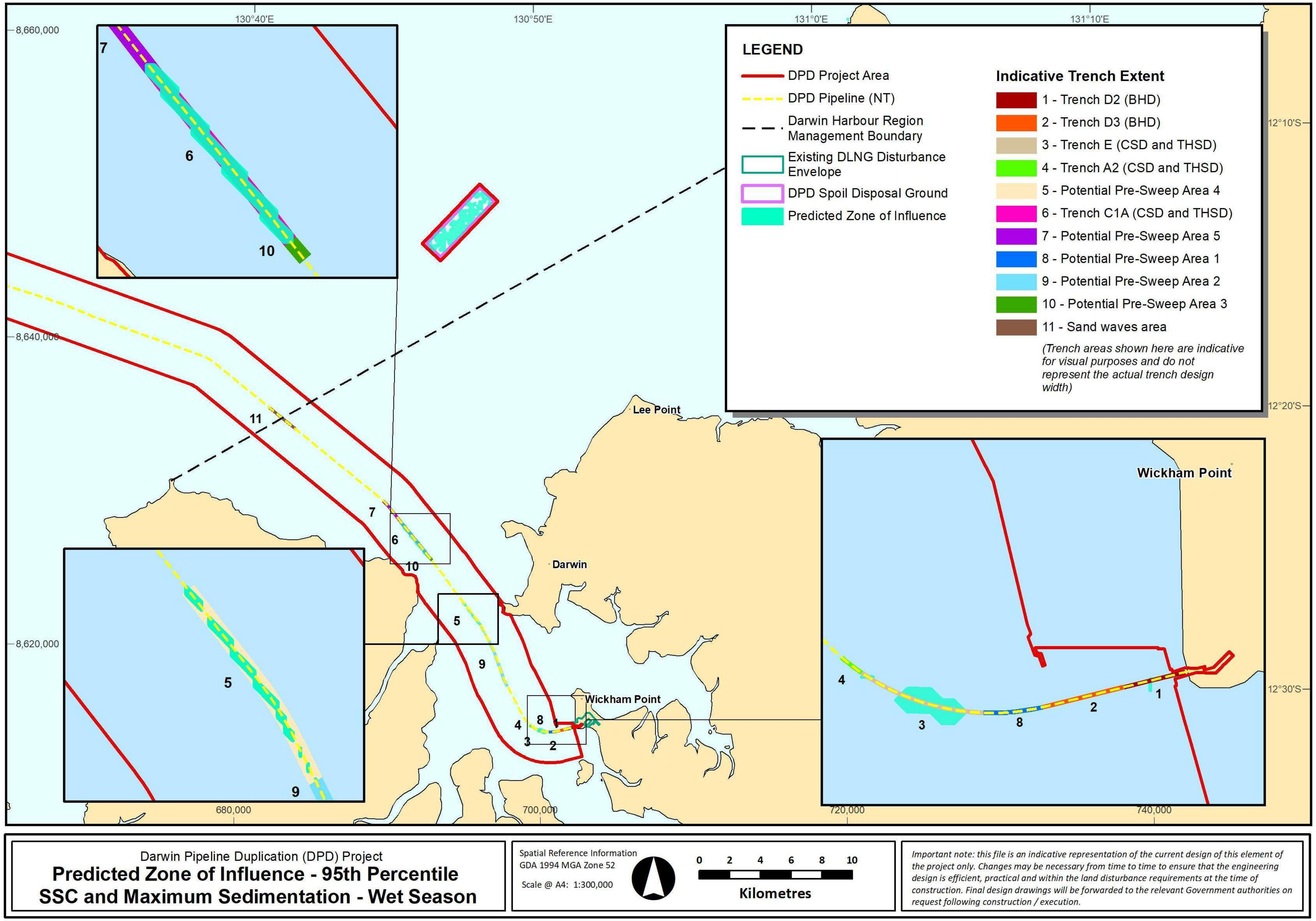

*Figure 8-14 Predicted Zone of Influence following application of the appropriate spatial thresholds (**Table** 8-2) to the 95th percentile SSC and maximum sedimentation throughout the entire trenching programme transitioning into summer/wet season (1st October to 9th November 2019)*

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

Species	Test	Type	NOEC ppm (or mg/L)
Heliocidaris tuberculate (echinoderm)	72 hr larval development	Chronic	1.25
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.

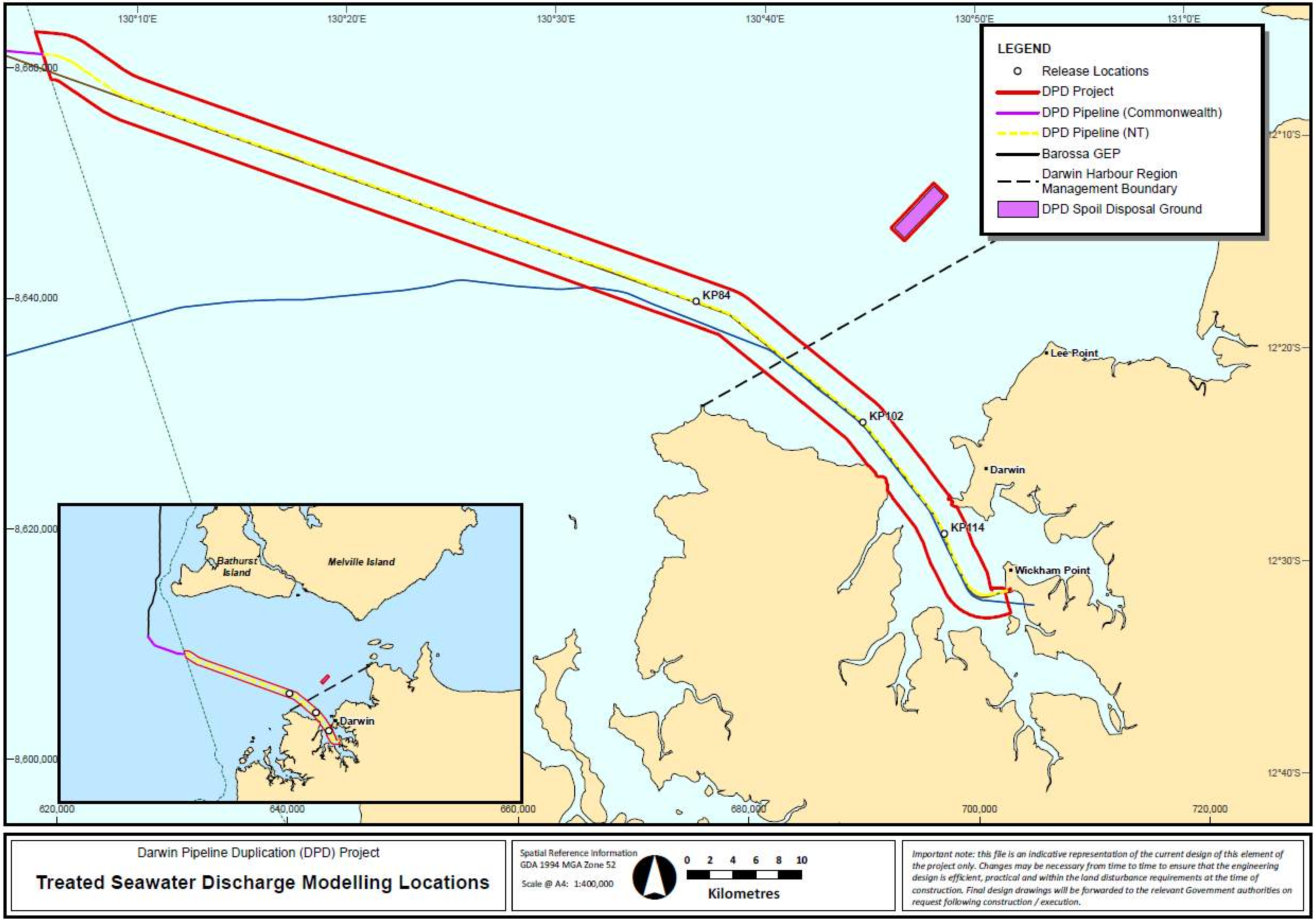

Figure 8-15 Contingency treated seawater discharge modelling locations

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.

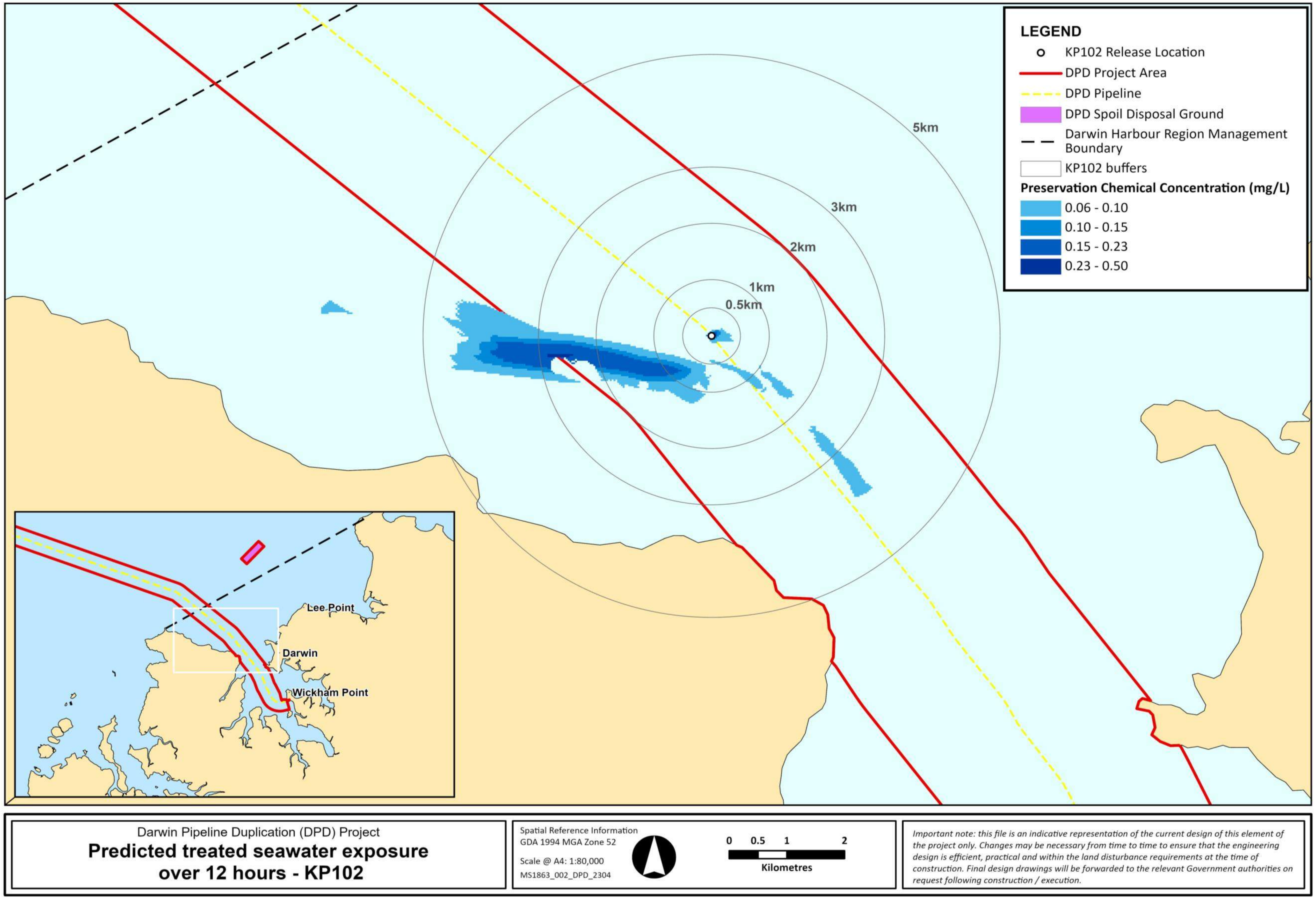

Figure 8-16 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP84 (based on 25 simulations with different metocean conditions)

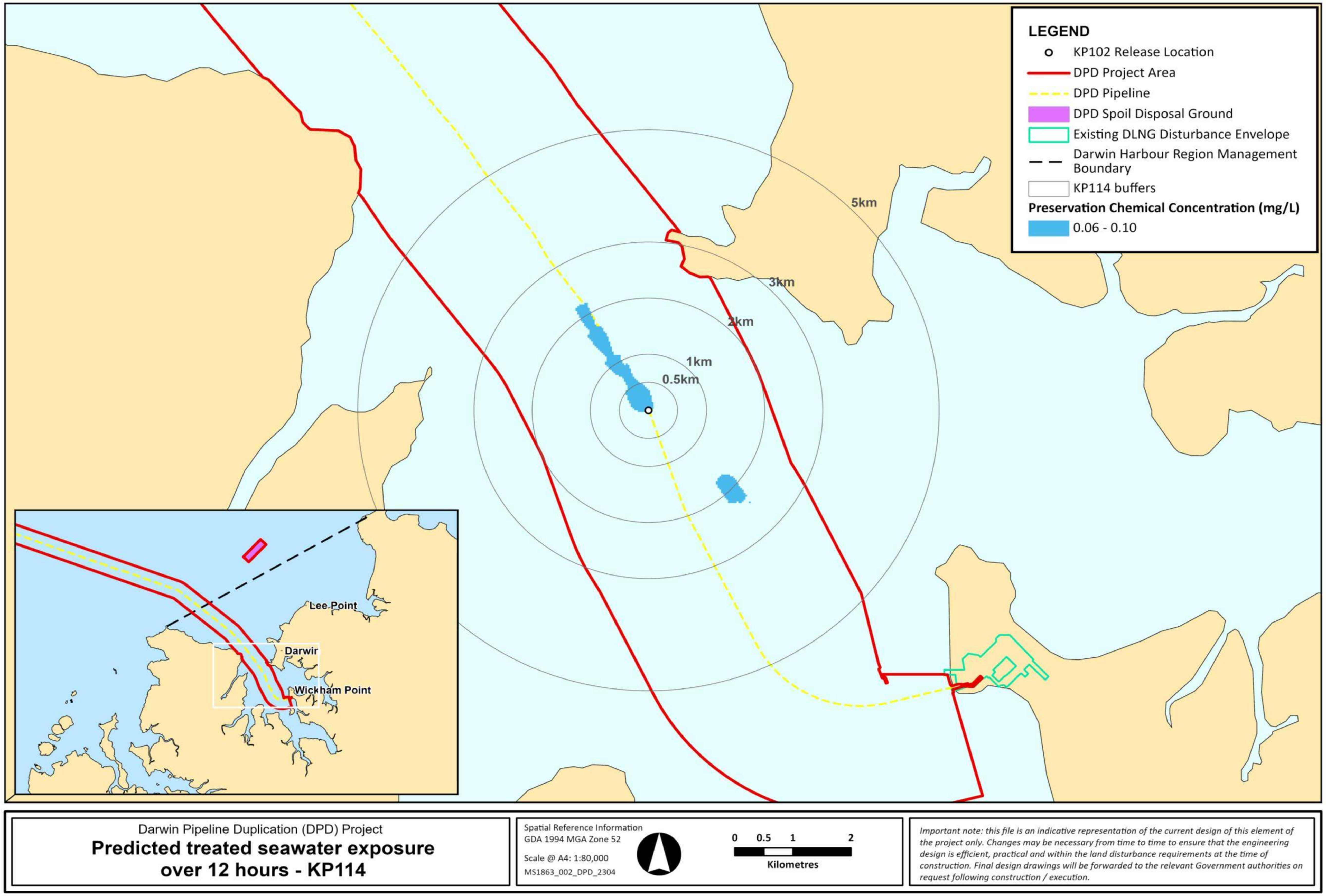

Figure 8-17 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP102 (based on 25 simulations with different metocean conditions)

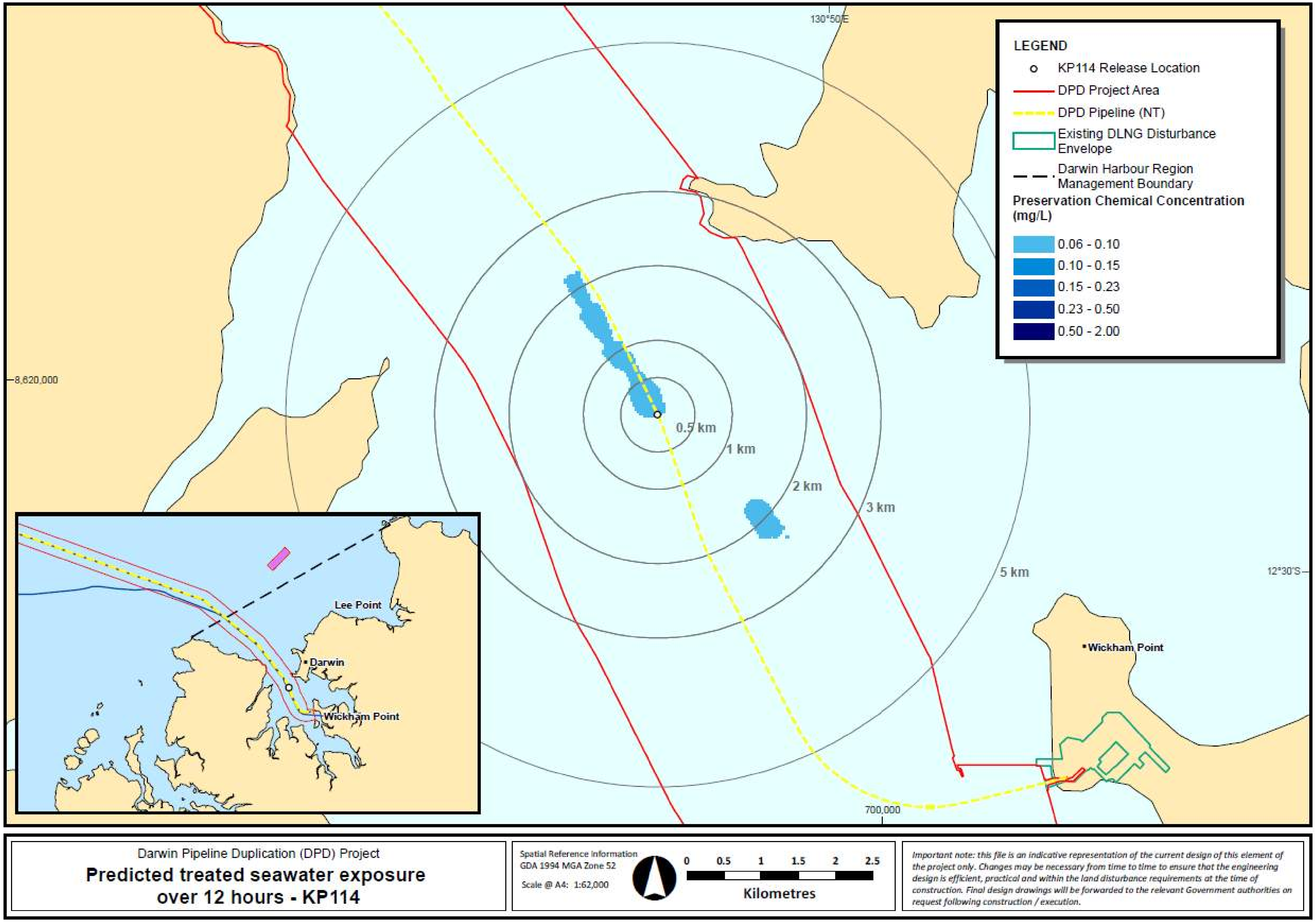

Figure 8-18 Predicted distribution and concentrations of the preservation chemical over a 12-hour exposure period during dewatering from KP114 (based on 25 simulations with different metocean conditions

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.

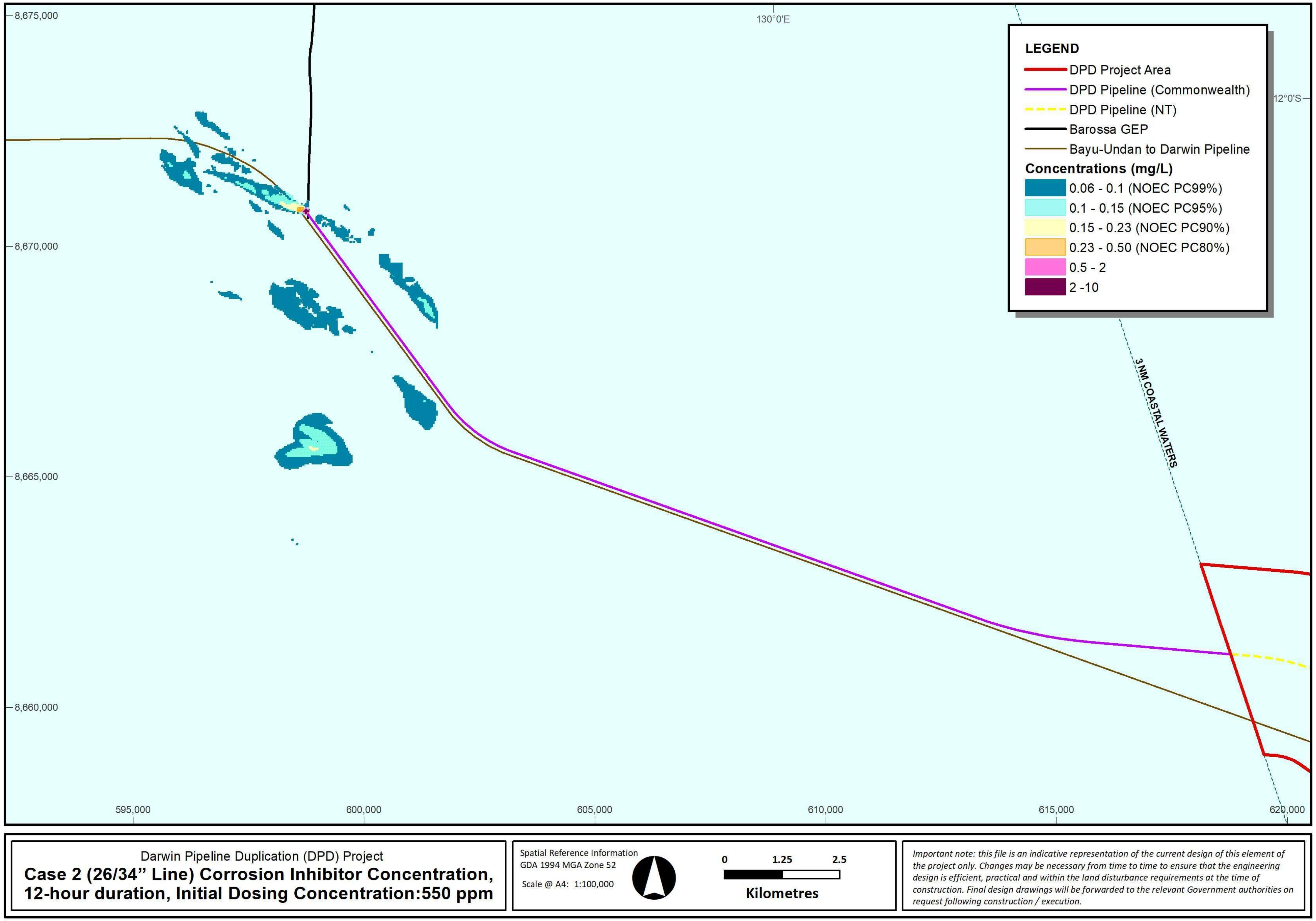

Figure 8-19 Predicted corrosion inhibitor concentrations assessed over a 12-hour continuous exposure period (calculated from 25 simulations)

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 (2.5^{th}-percentile species) and 2,260 ppb for insensitive species (97.5^{th}-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.

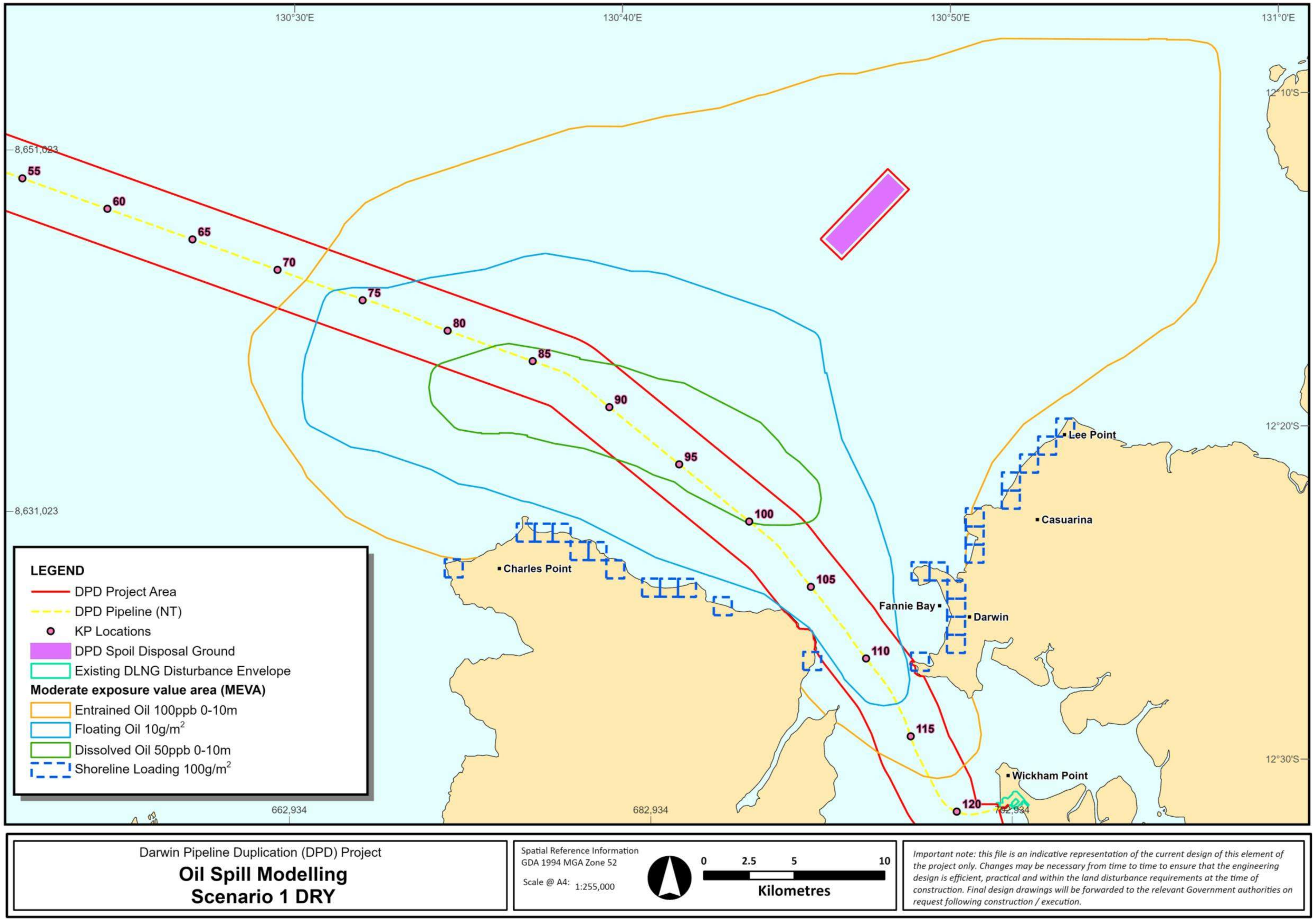

Figure 8-20 Stochastic MDO spill modelling (100 simulations) – Scenario 1 – dry season

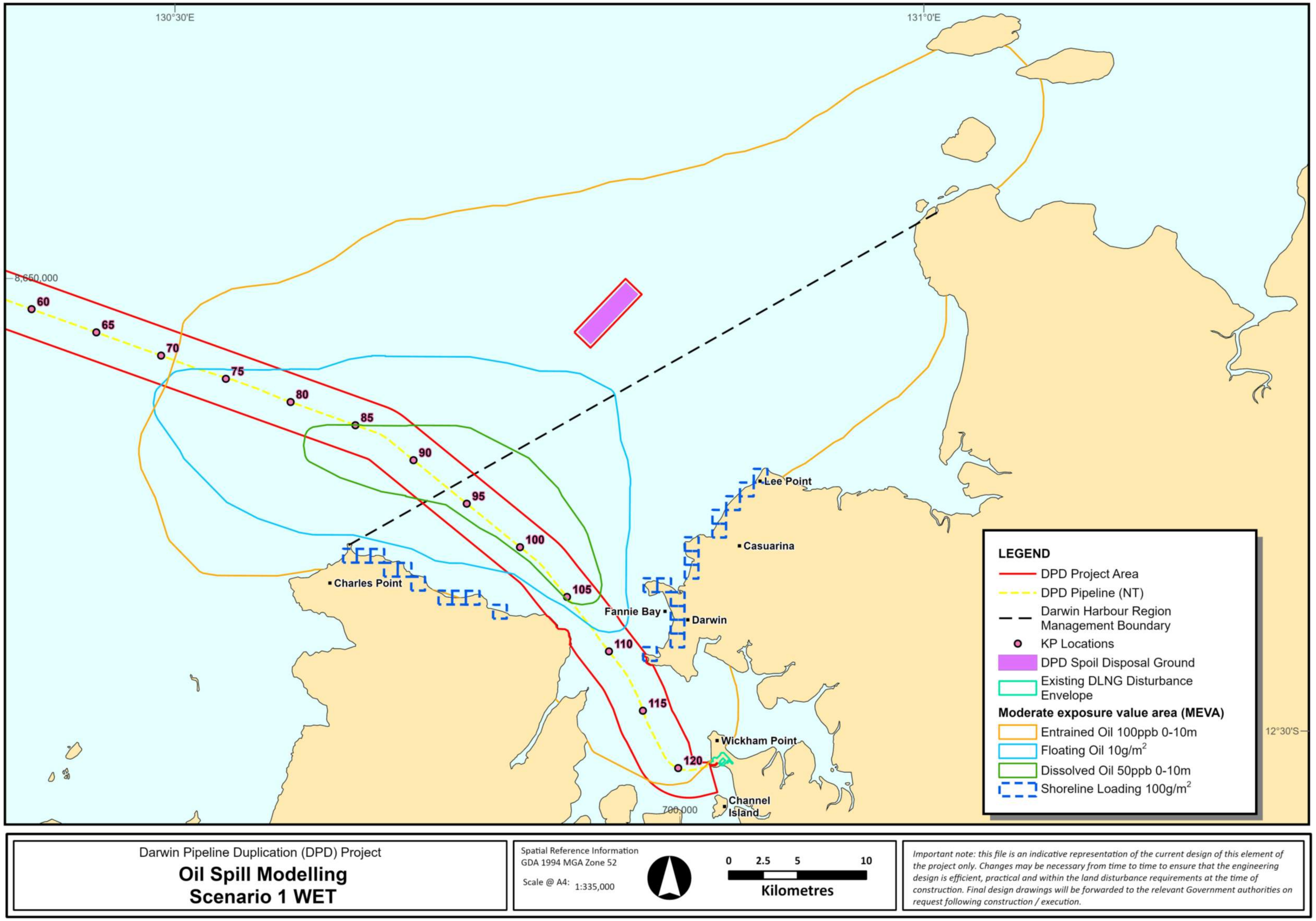

Figure 8-21 Stochastic MDO spill modelling (100 simulations)– Scenario 1 – wet season

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.

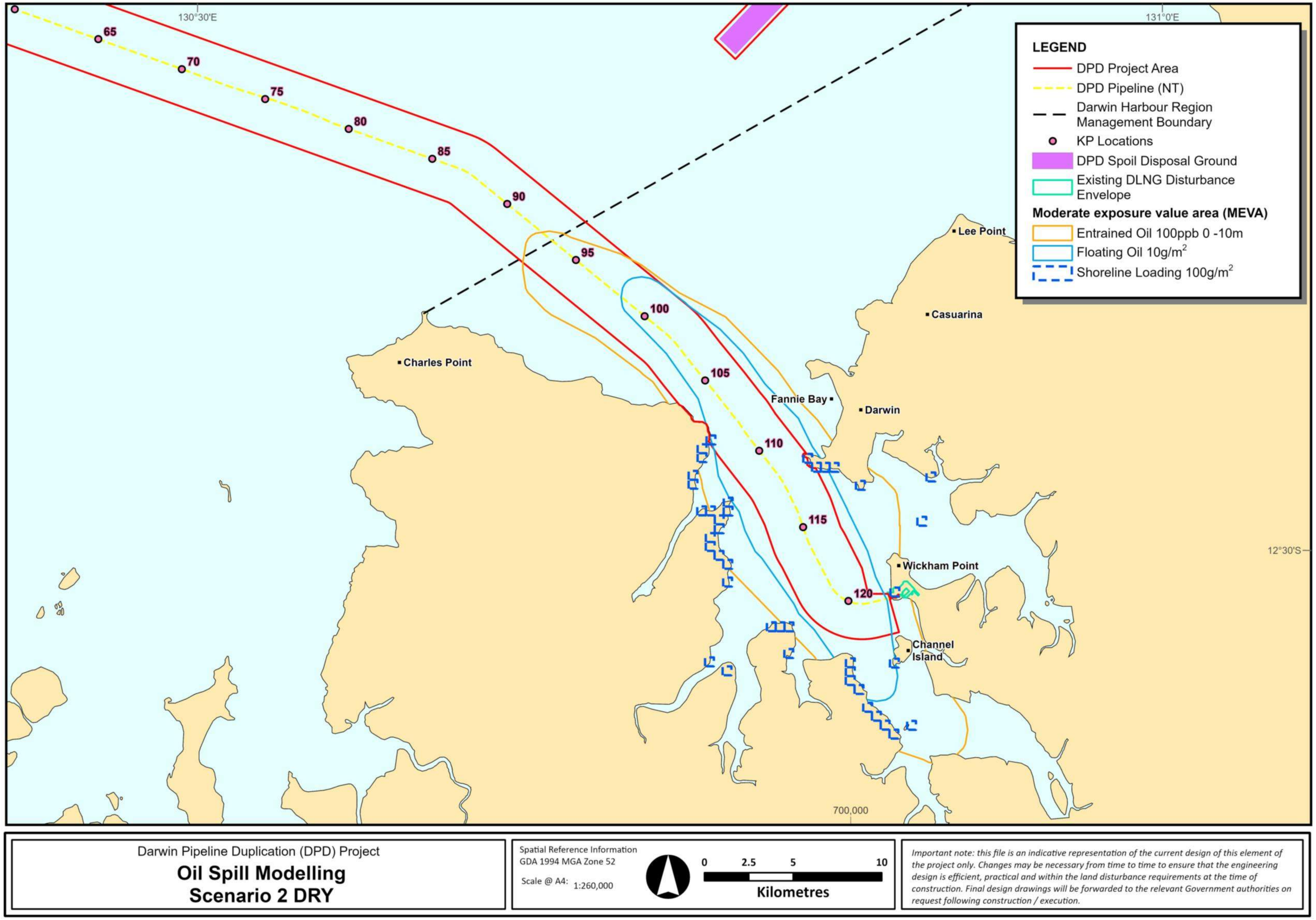

Figure 8-22 Stochastic MDO spill modelling (100 simulations)– Scenario 2 – dry season (Note: no dissolved oil exposure at MEVA [50ppb])

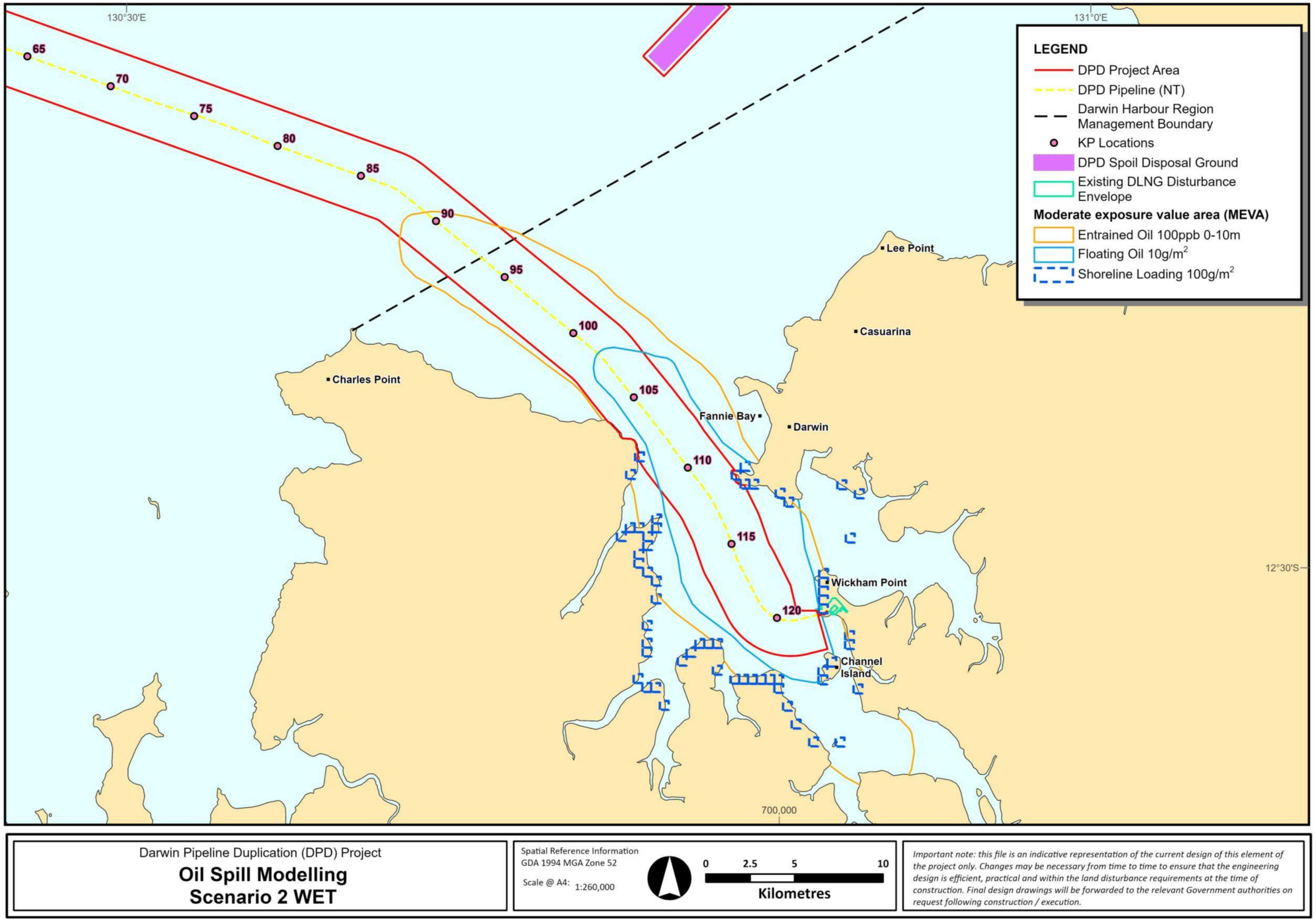

Figure 8-23 Stochastic MDO spill modelling (100 simulations)– Scenario 2 – wet season (Note: no dissolved oil exposure at MEVA [50ppb])

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.

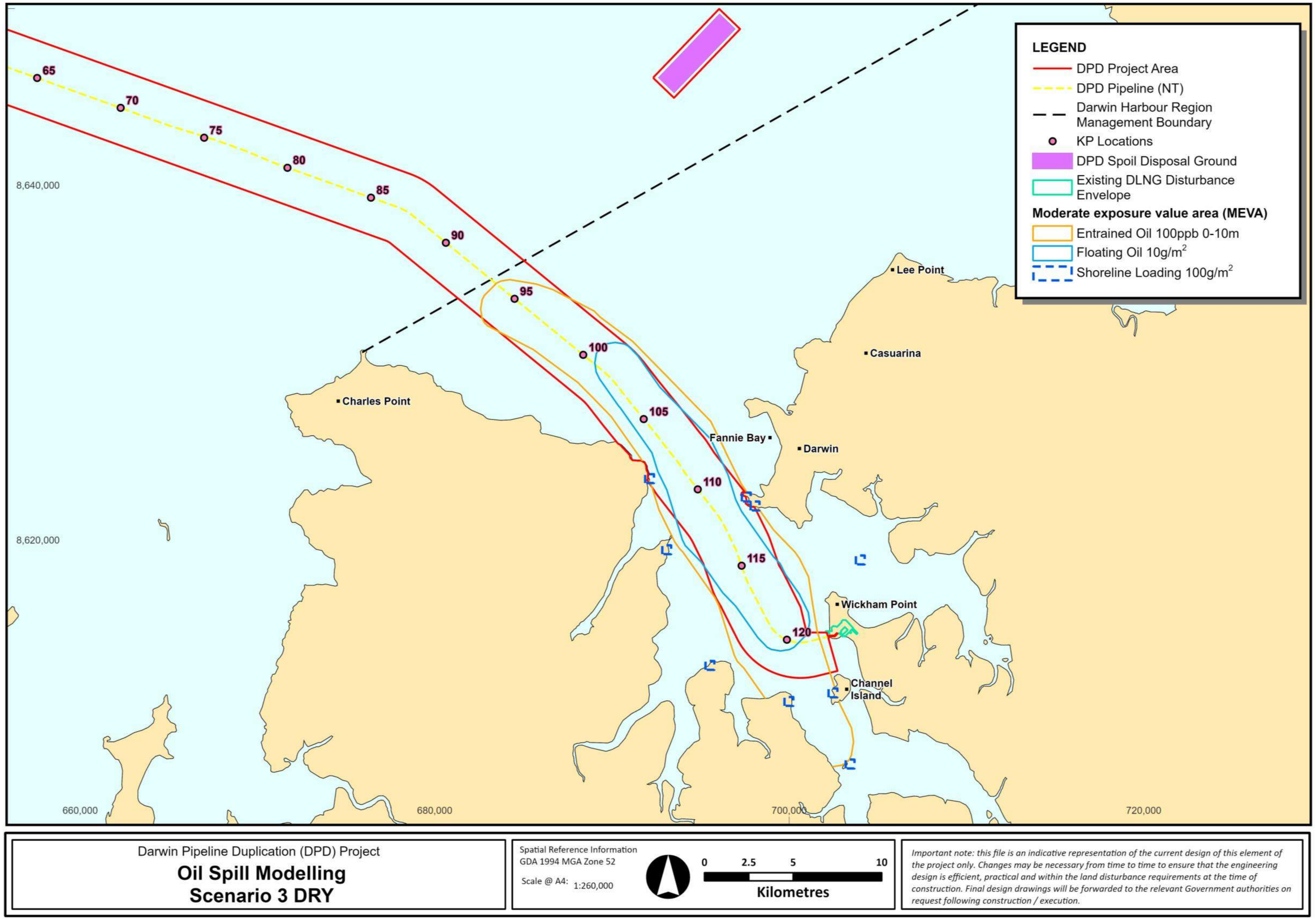

Figure 8-24 Stochastic MDO spill modelling (100 simulations)– Scenario 3 – dry season (Note: no dissolved oil exposure at MEVA [50ppb])

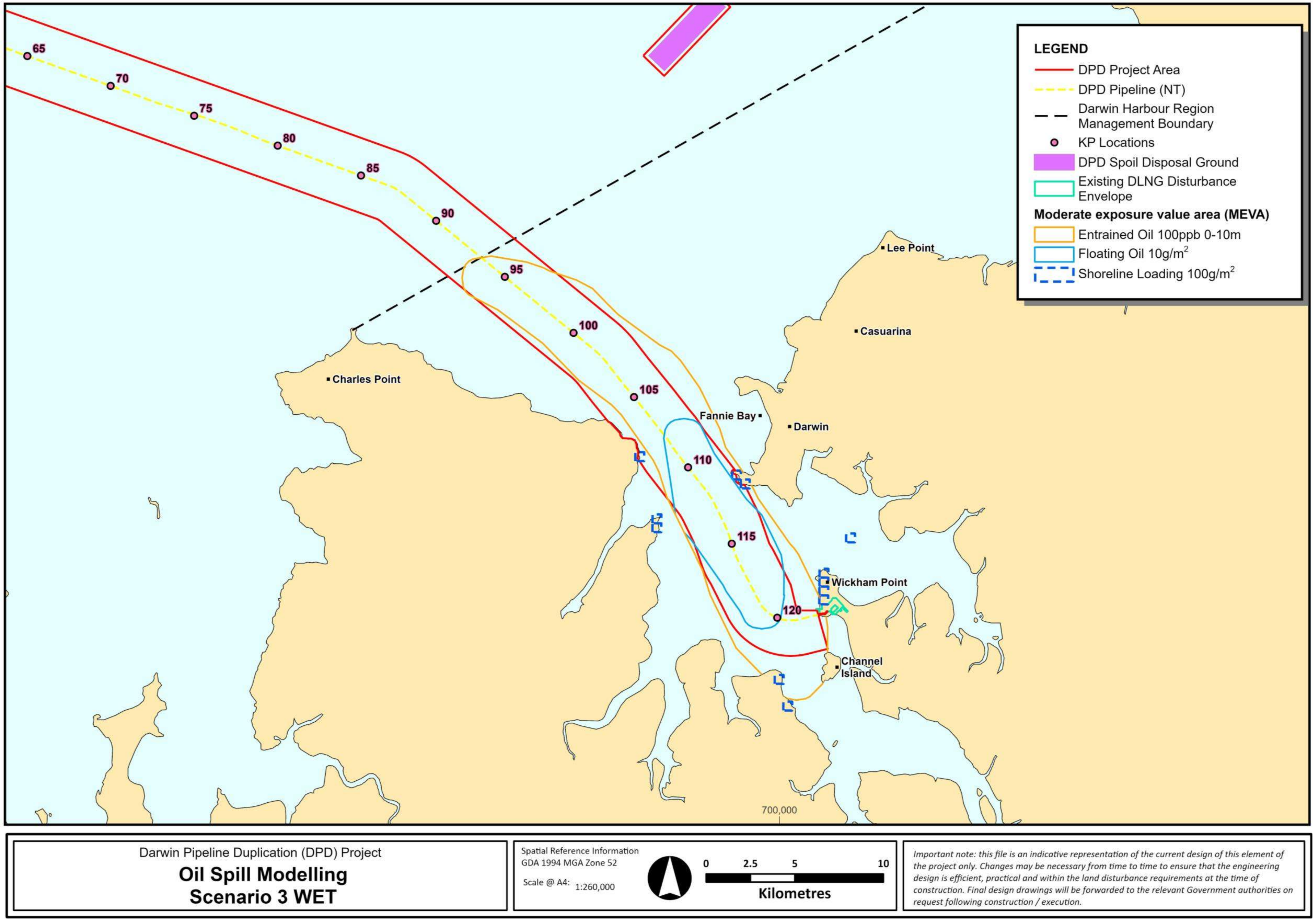

Figure 8-25 Stochastic MDO spill modelling (100 simulations)– Scenario 3 – wet season (Note: no dissolved oil exposure at MEVA [50ppb])

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.

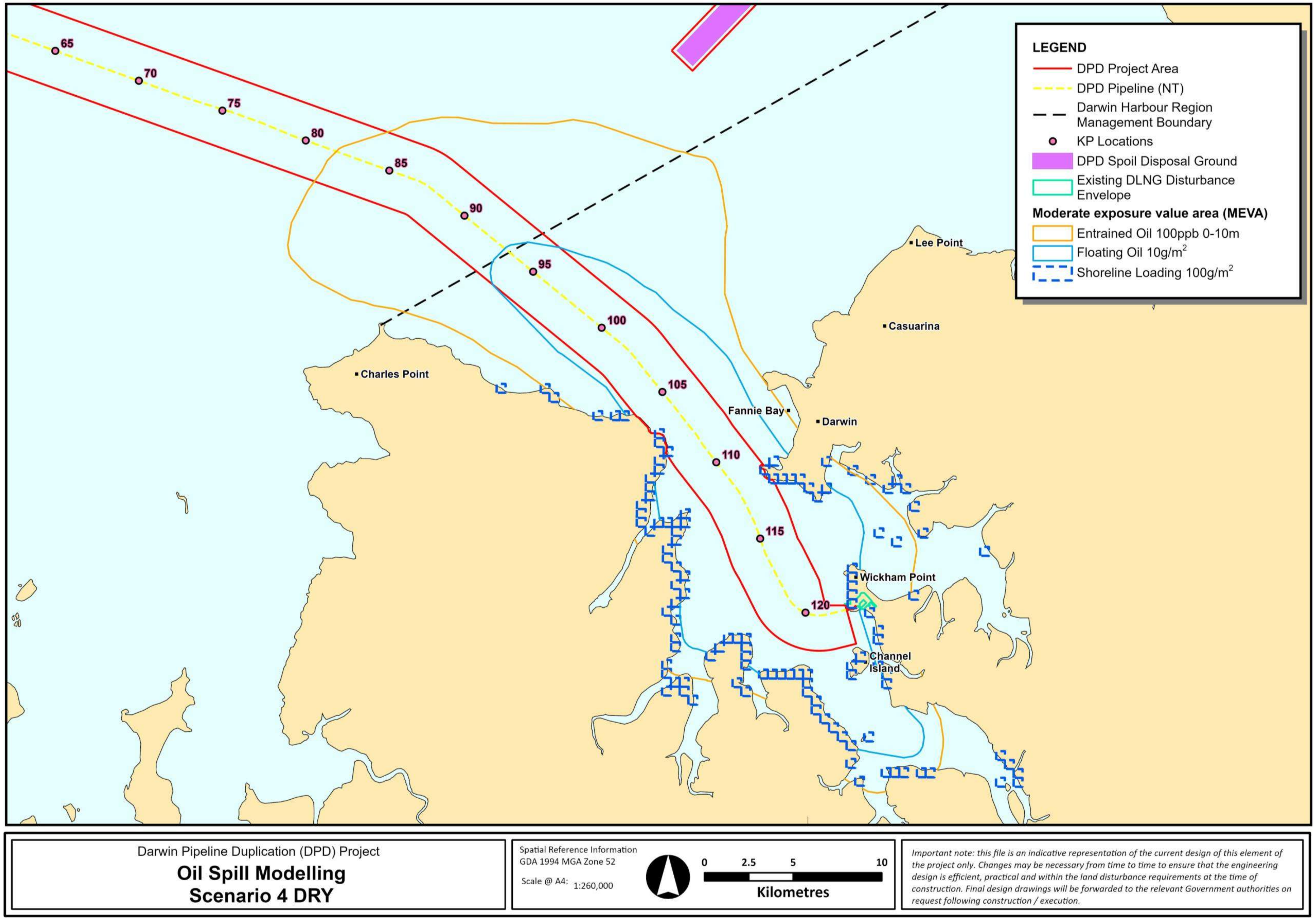

Figure 8-26 Stochastic MDO spill modelling (100 simulations)– Scenario 4 – dry season (Note: no dissolved oil exposure at MEVA [50ppb])

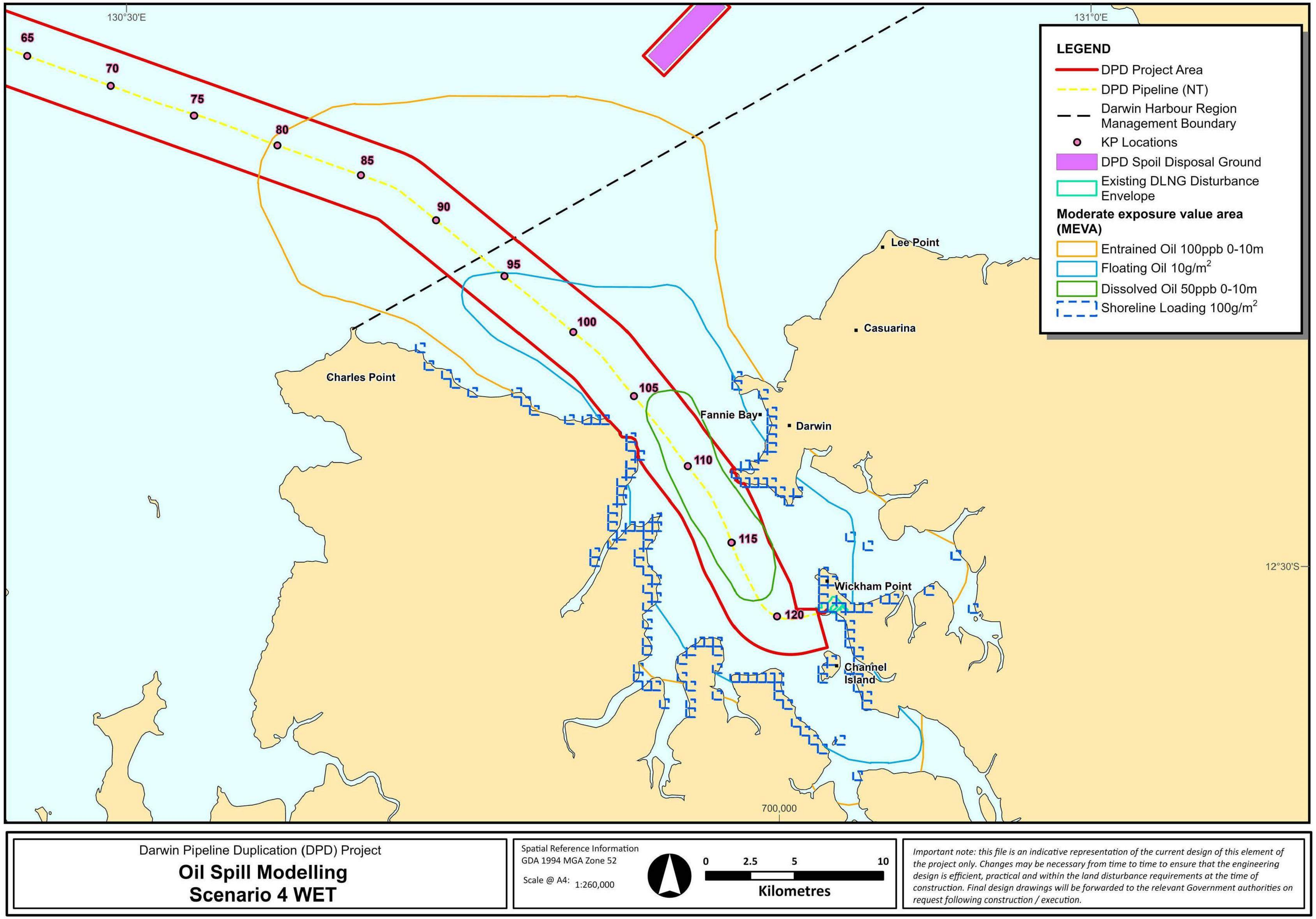

Figure 8-27 Stochastic MDO spill modelling (100 simulations)– Scenario 4 – wet season

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 draft 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**).

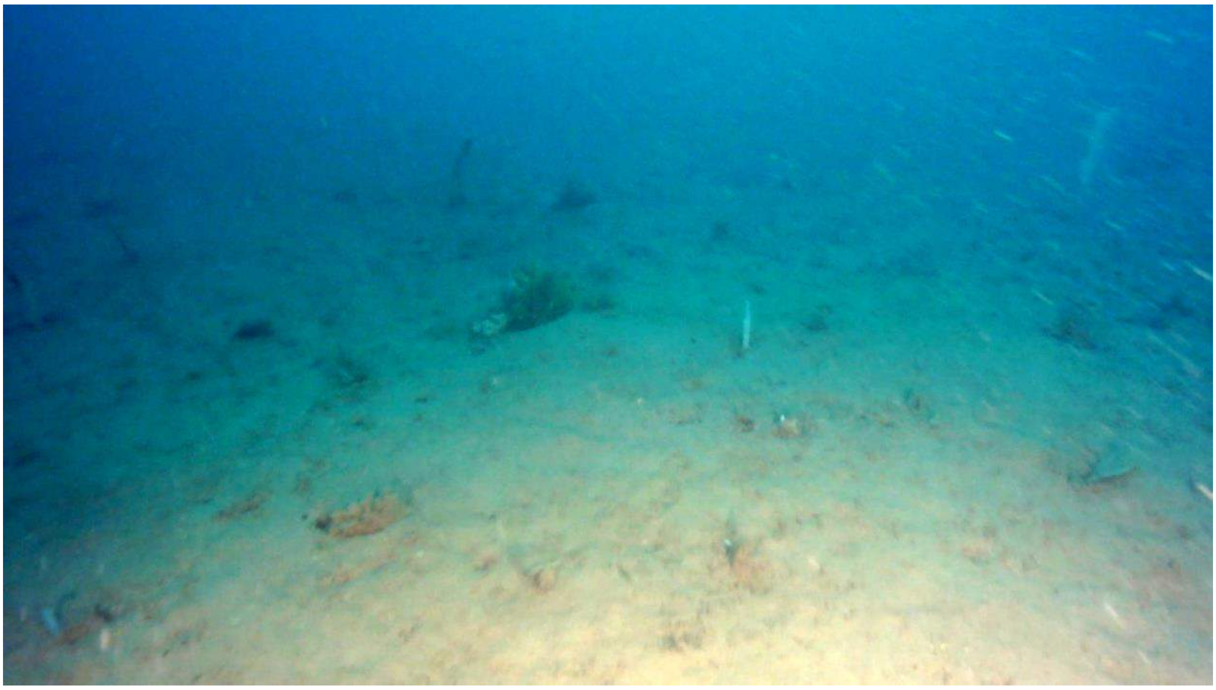

*Figure 9-1 Example image of silty shelly sand habitat with sparse soft corals within the RFPA (site RFPA3, refer **Appendix 6**)*

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**).

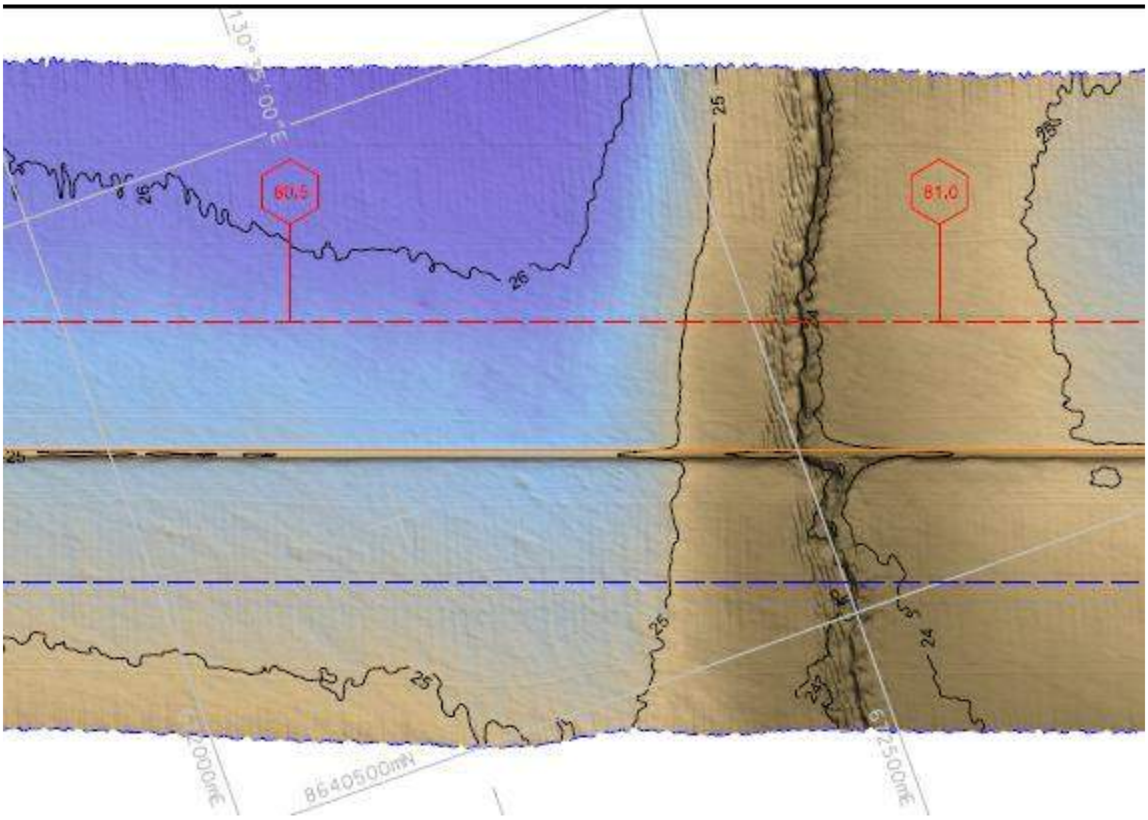

Figure 9-2 Shaded relief of bathymetry between KP80 and KP81 of the pipeline route (red dashed with KP markers) within the Charles Point Wide RFPA

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**).

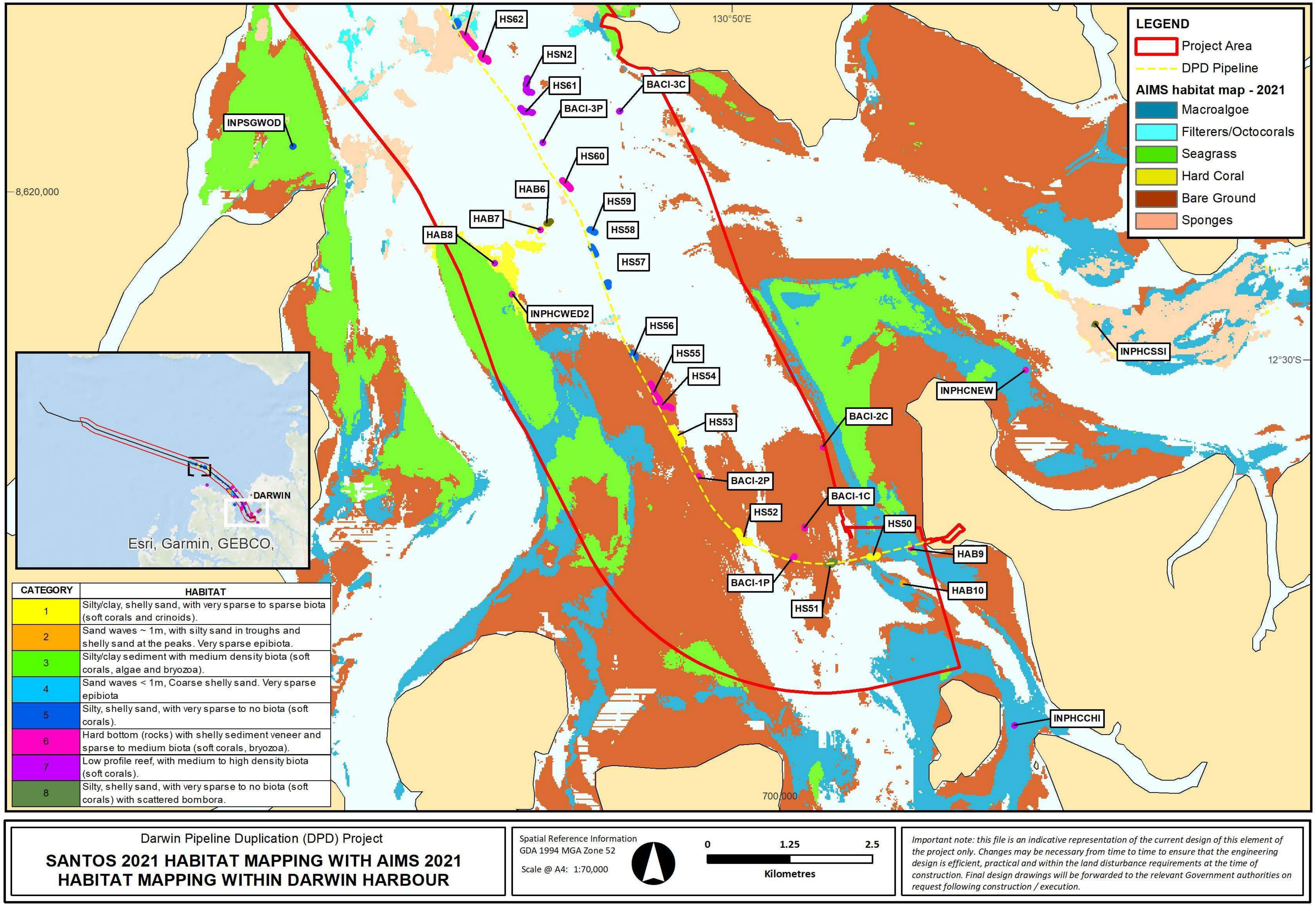

Figure 9-3 RPS surveys habitat mapping against AIMS 2021 habitat mapping within Darwin Harbour (AIMS, 2021)

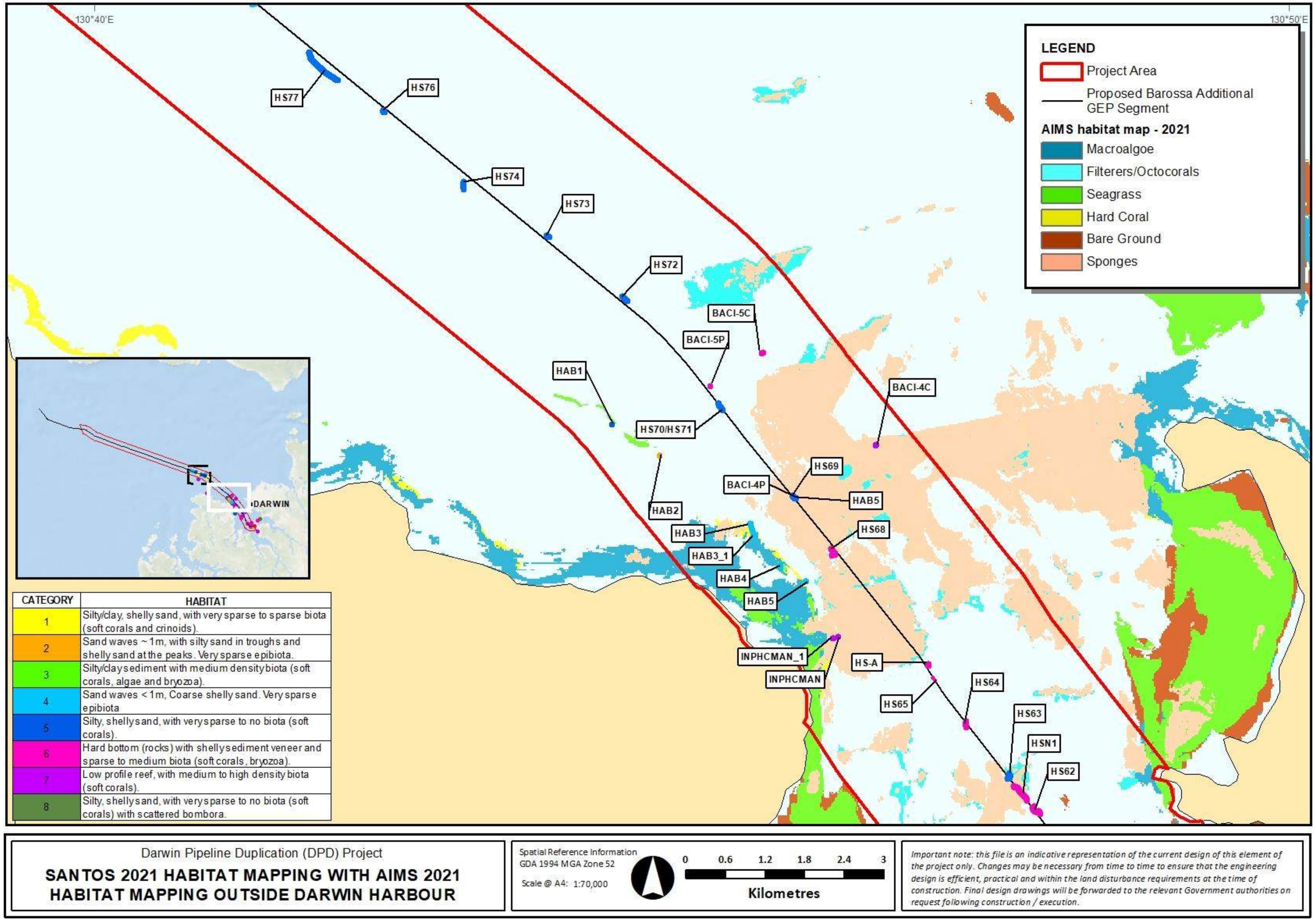

Figure 9-4 RPS surveys habitat mapping against AIMS 2021 habitat mapping outside Darwin Harbour (AIMS, 2021)

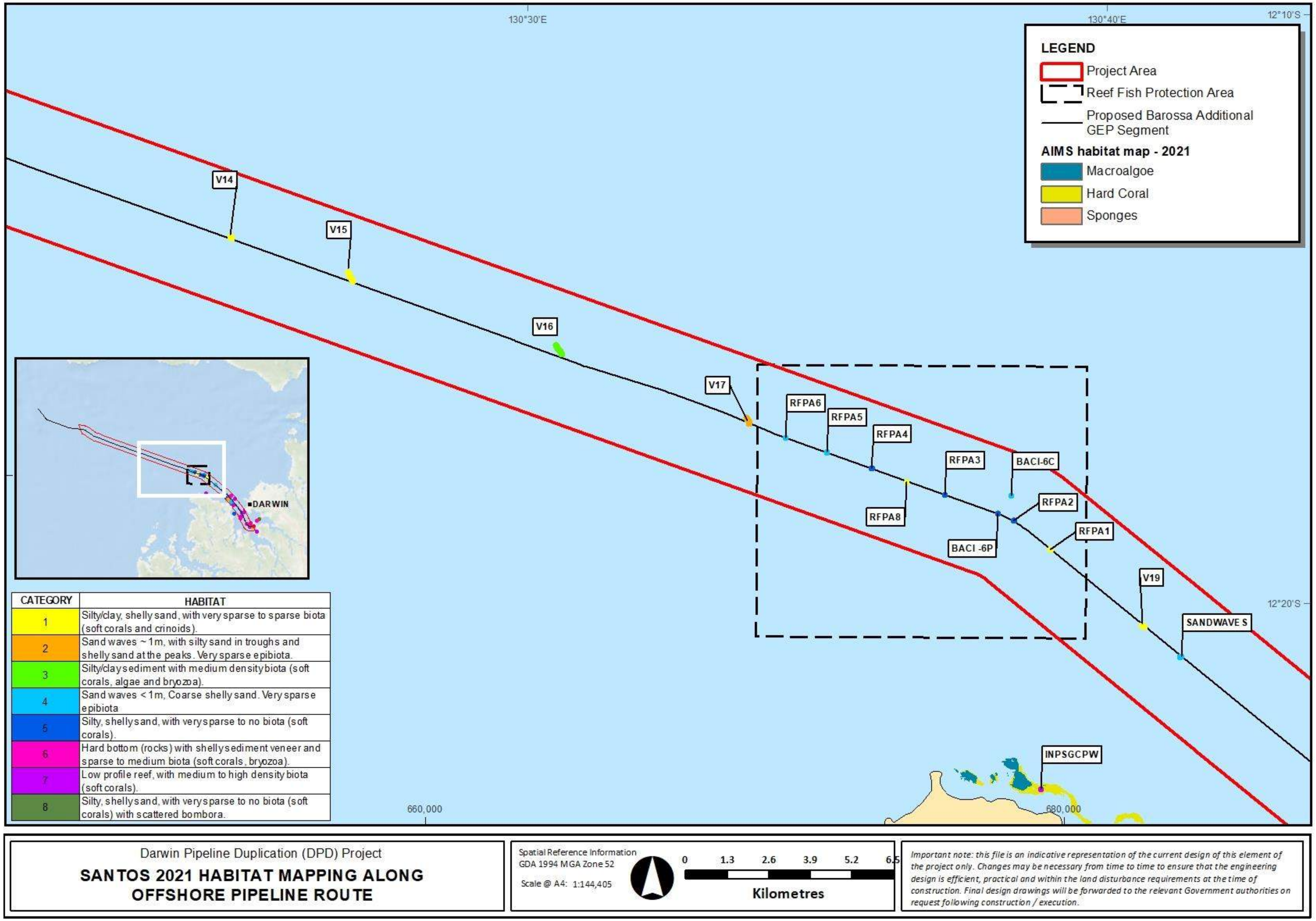

Figure 9-5 RPS surveys habitat mapping along offshore pipeline route

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)'.

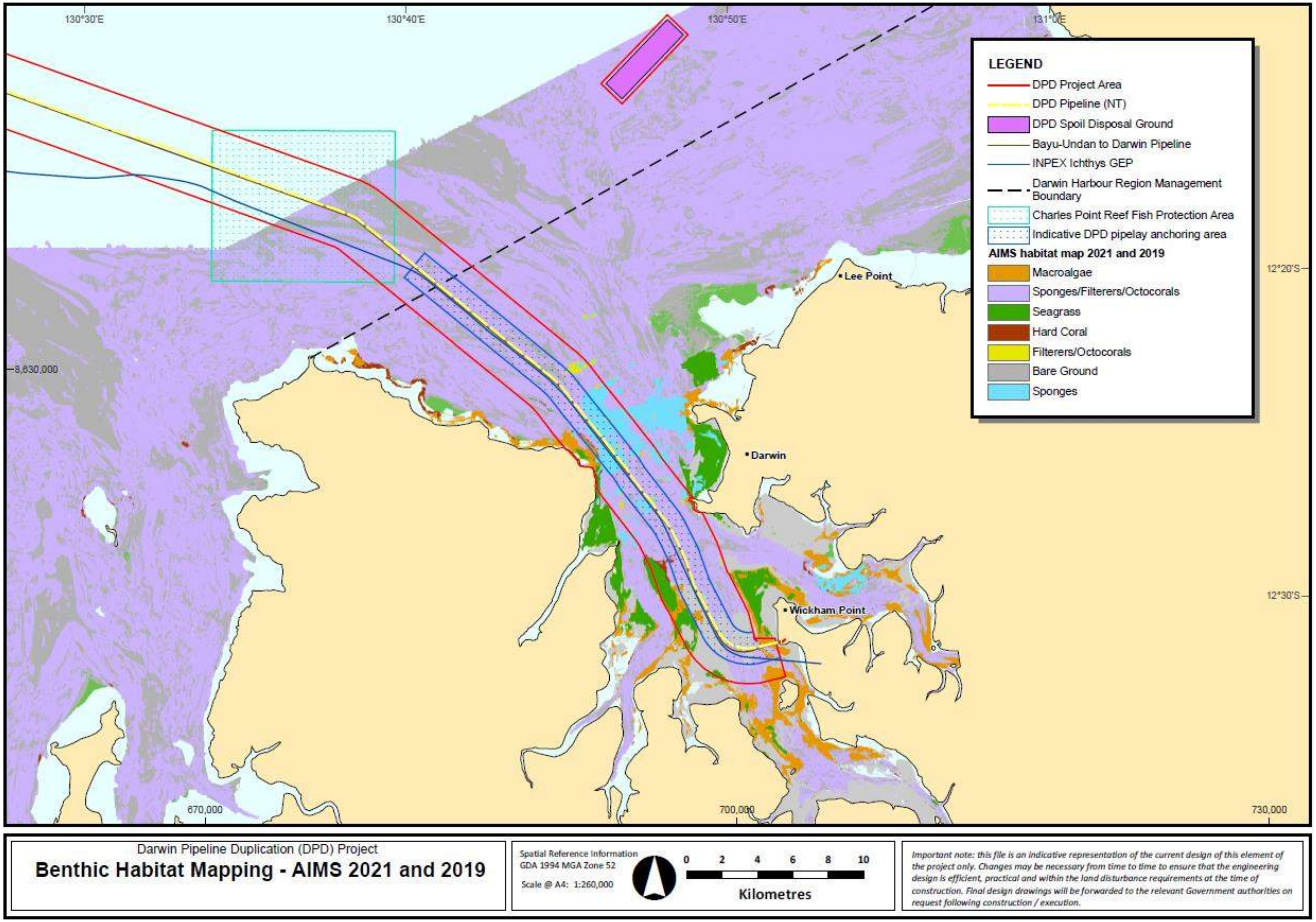

Figure 9-6 Combined AIMS 2021 and 2019 habitat mapping data used to inform the impact assessment sections

Santos

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	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.	breeding sites not currently recognised as BIAs. **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

[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).	key for this 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

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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.	highest from 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 numbers of nests are laid per year in the Northern	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.	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 km². 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**.

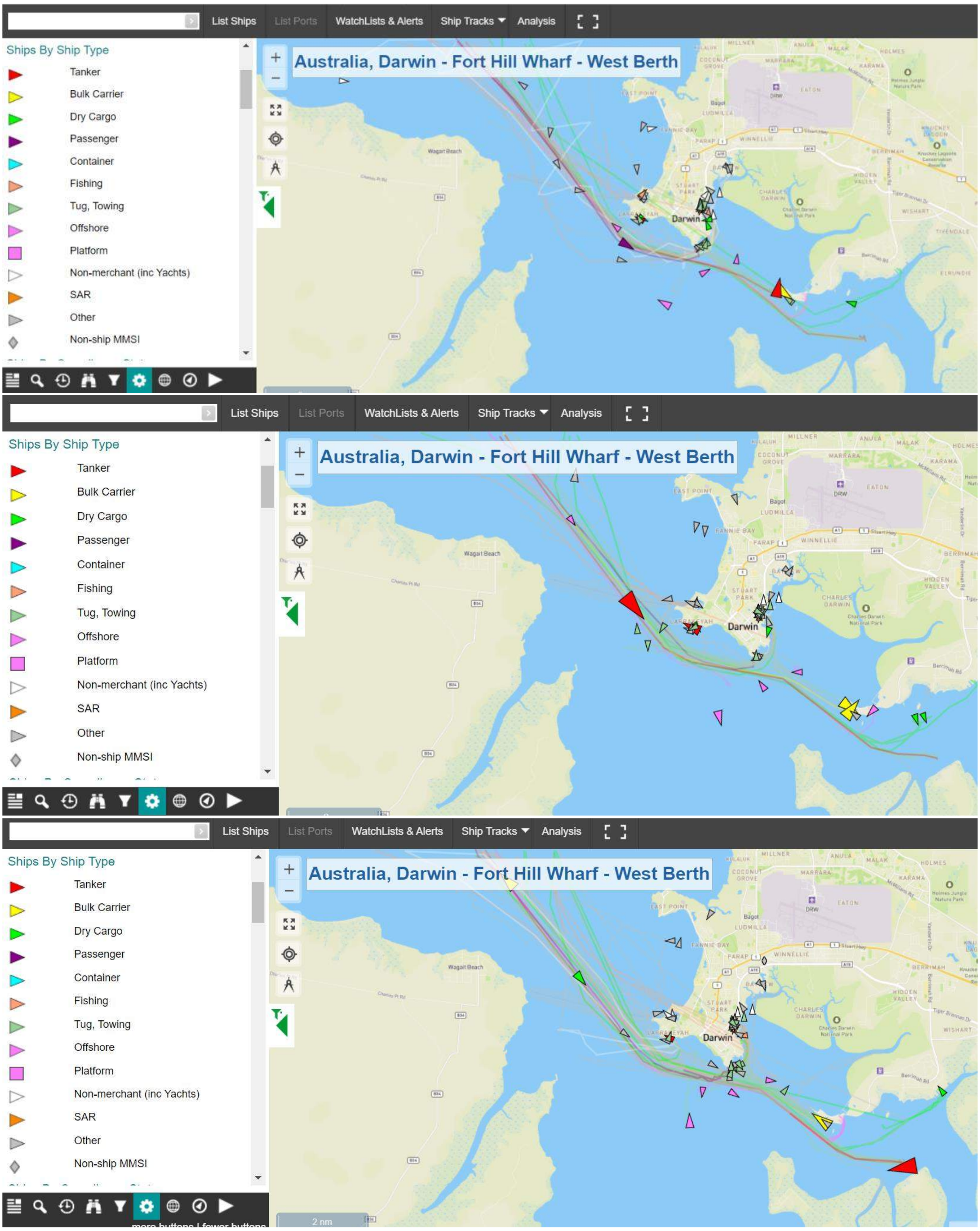

Figure 9-7 Vessel traffic by vessel type in Darwin Harbour on June 6, 7 and 8 2022 from AIS data (AIS Live)

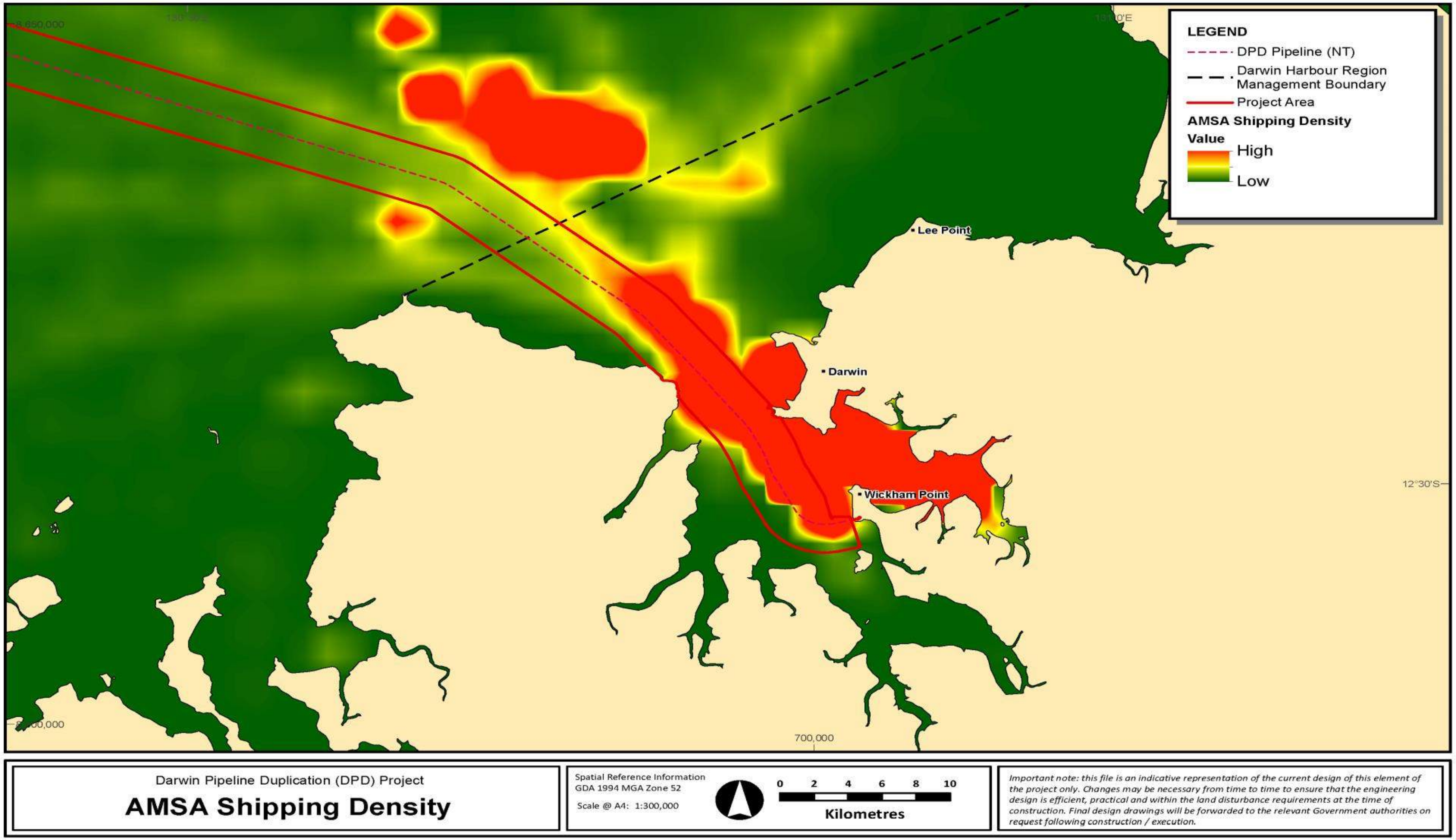

Figure 9-8 AMSA shipping density data for Darwin Harbour from January to May 2022

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.

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.

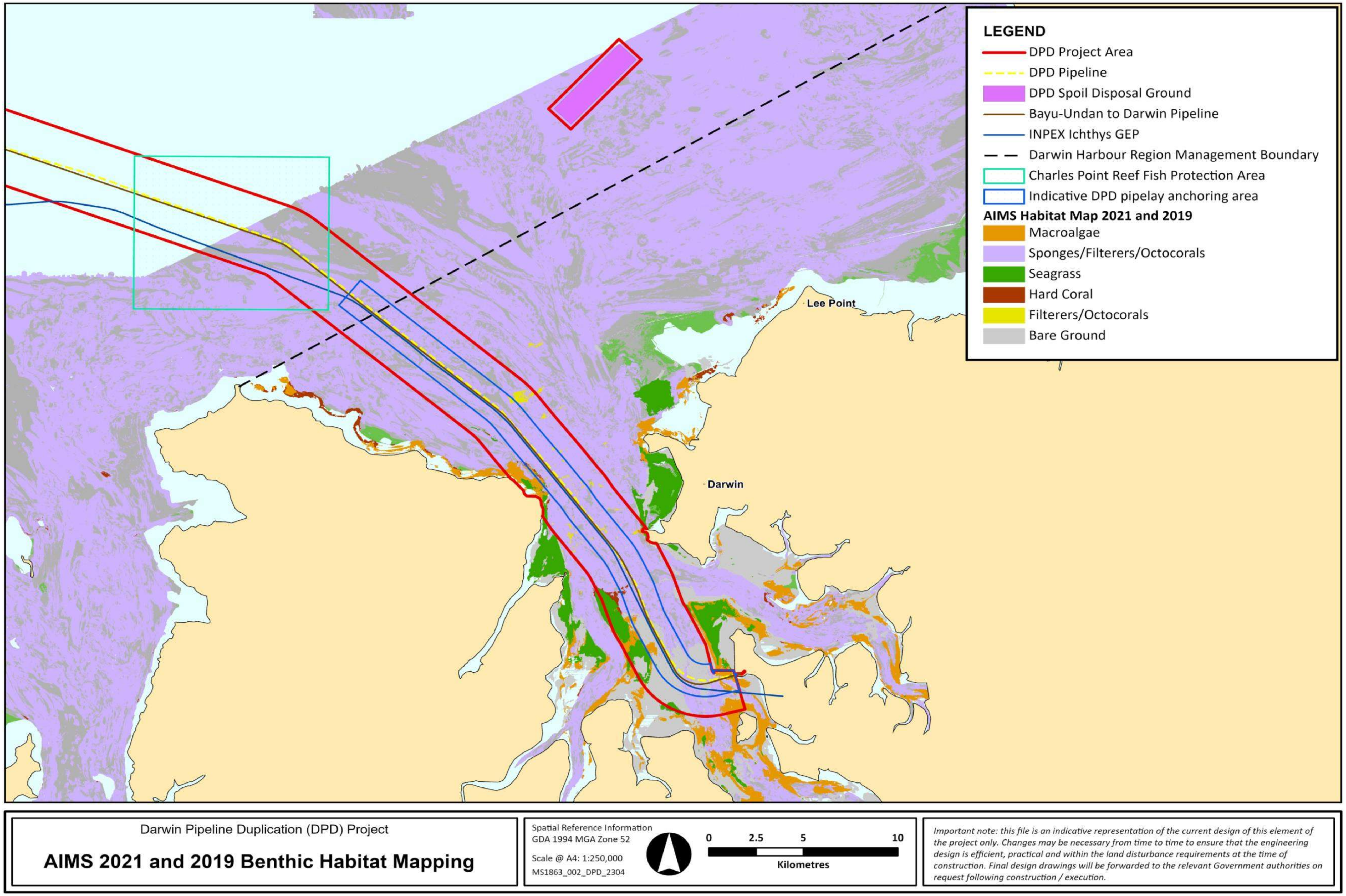

Figure 9-9 Project activities and infrastructure overlaid over mapped benthic habitat

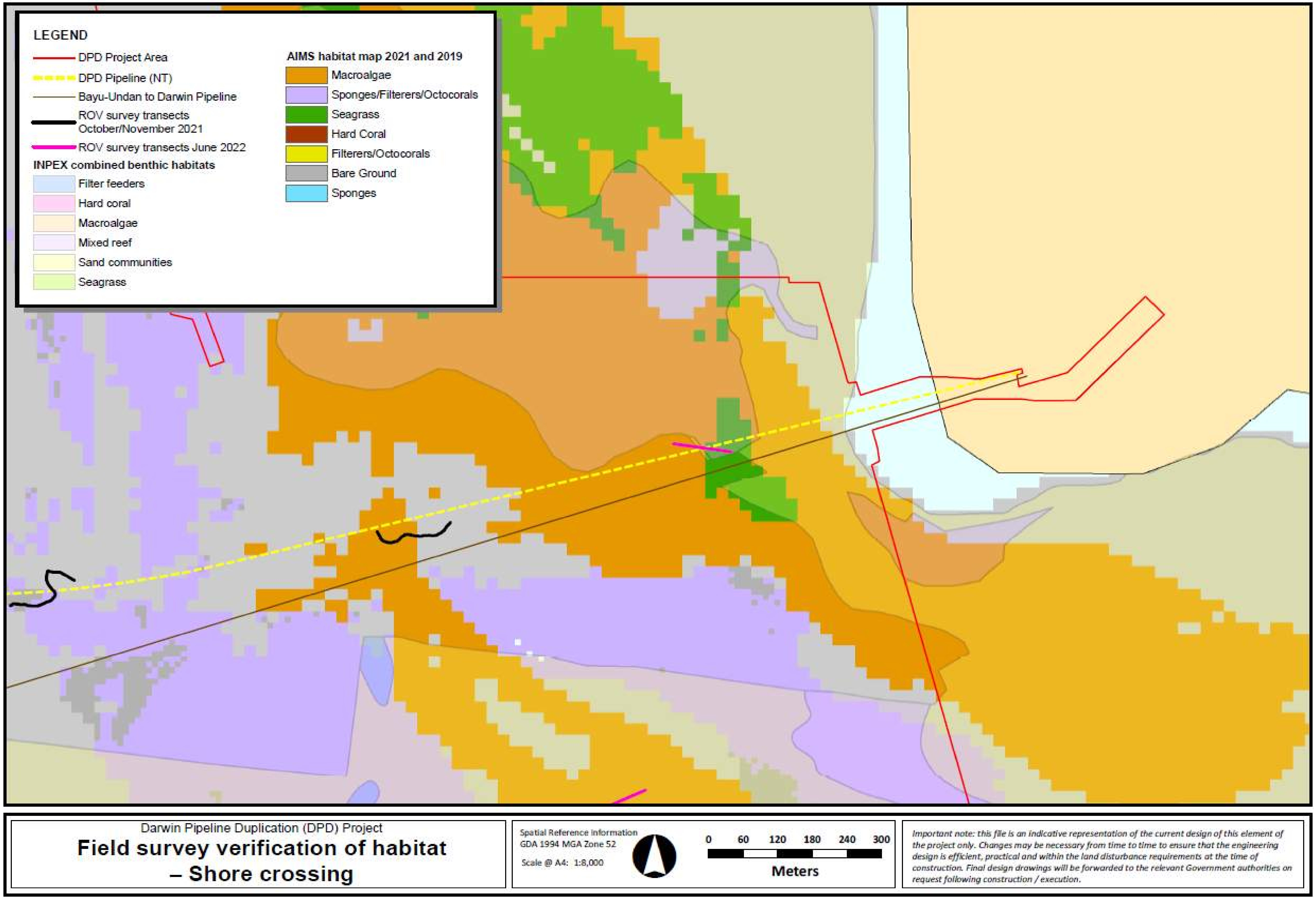

Figure 9-10 Field survey transect verified the nearshore habitat was not AIMS predicted seagrass and macroalgae, but more comparable to INPEX sand community habitat

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.

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.

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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.

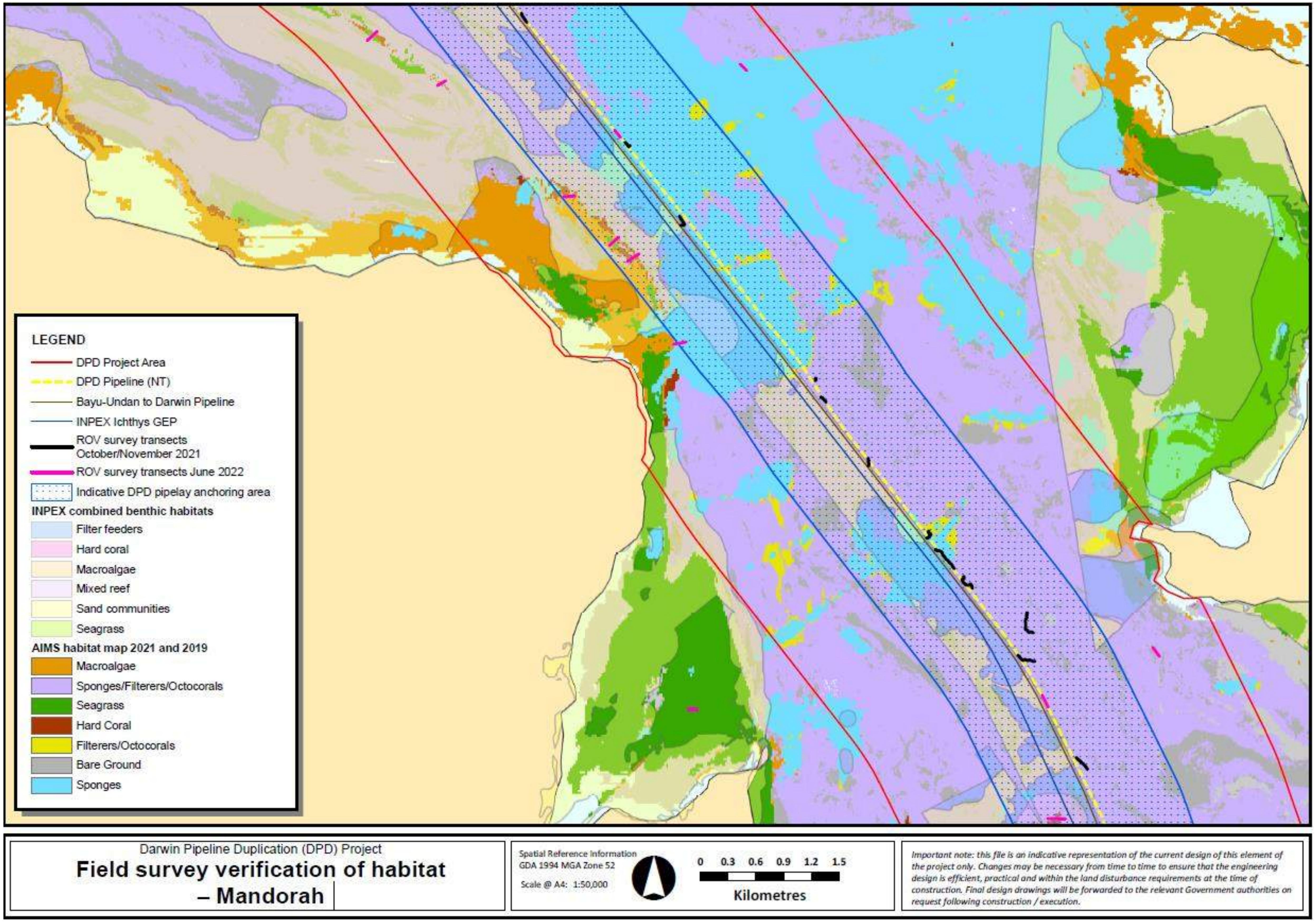

Figure 9-11 Benthic habitat survey locations off Mandorah. Survey data verified assessed the benthic habitat present in the potential anchoring zone

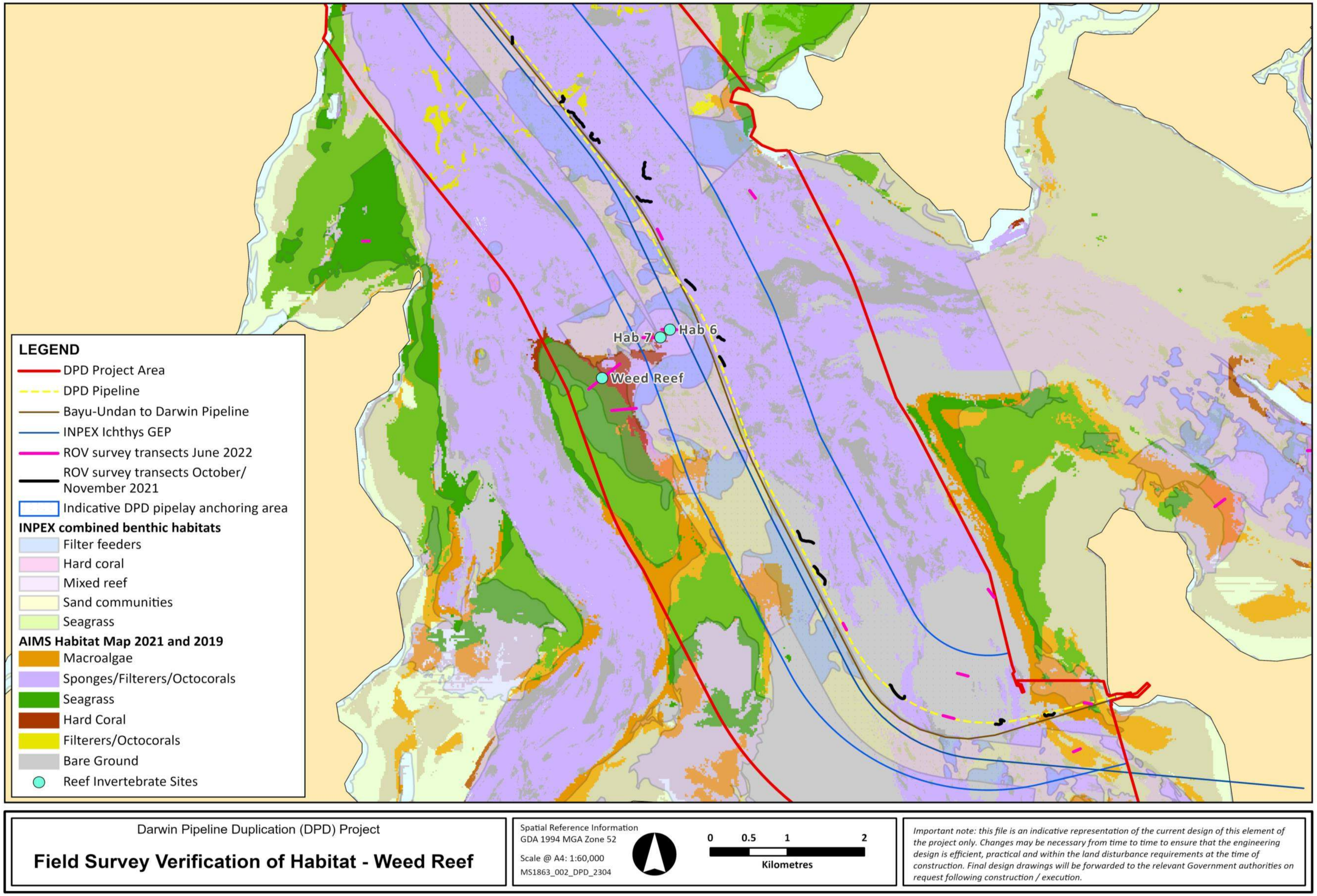

Figure 9-12 Field survey verification of habitat – Weed Reef

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).

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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.

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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).

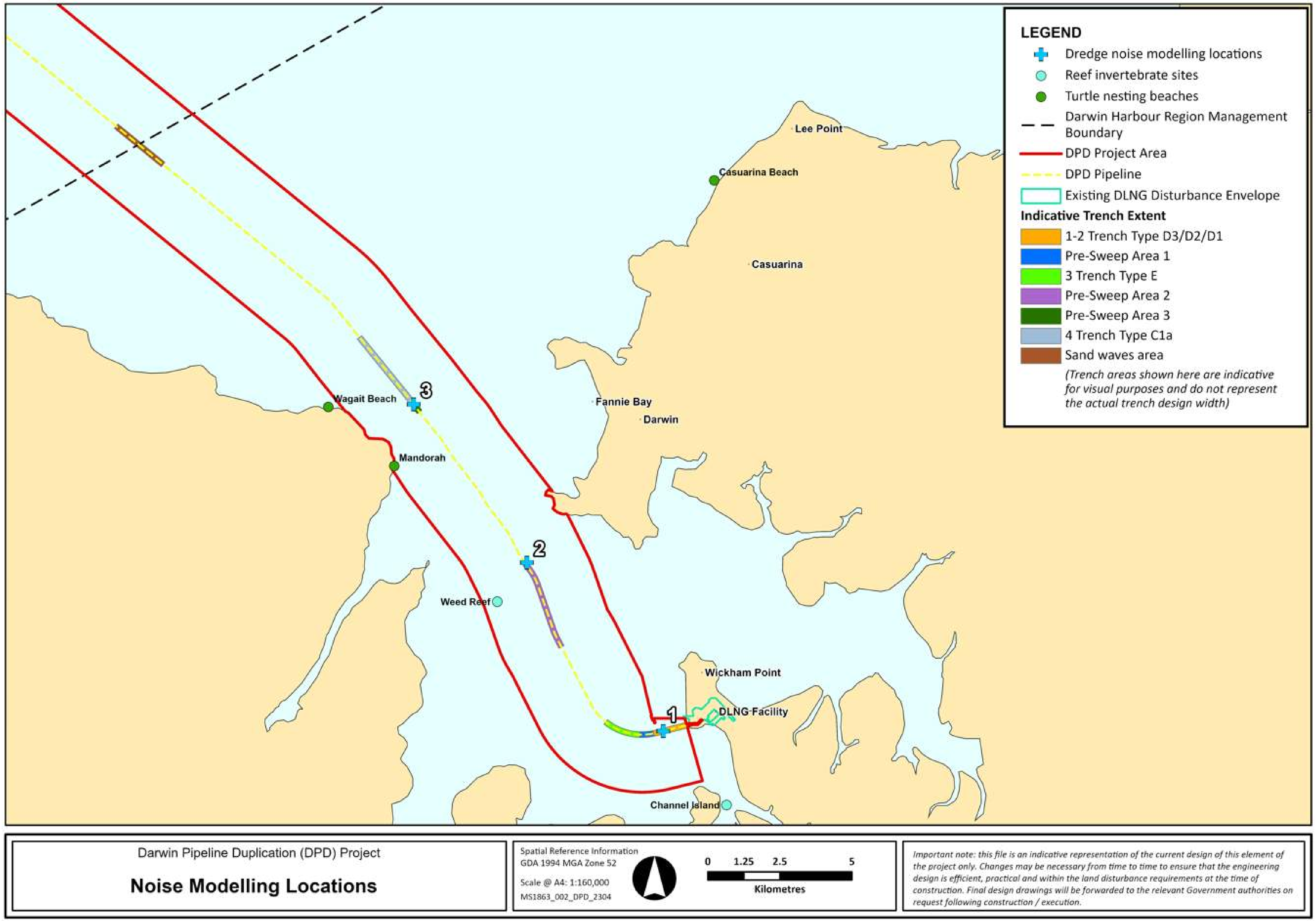


Figure 9-13 Location of modelled noise sources

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

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 draft 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 draft 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.

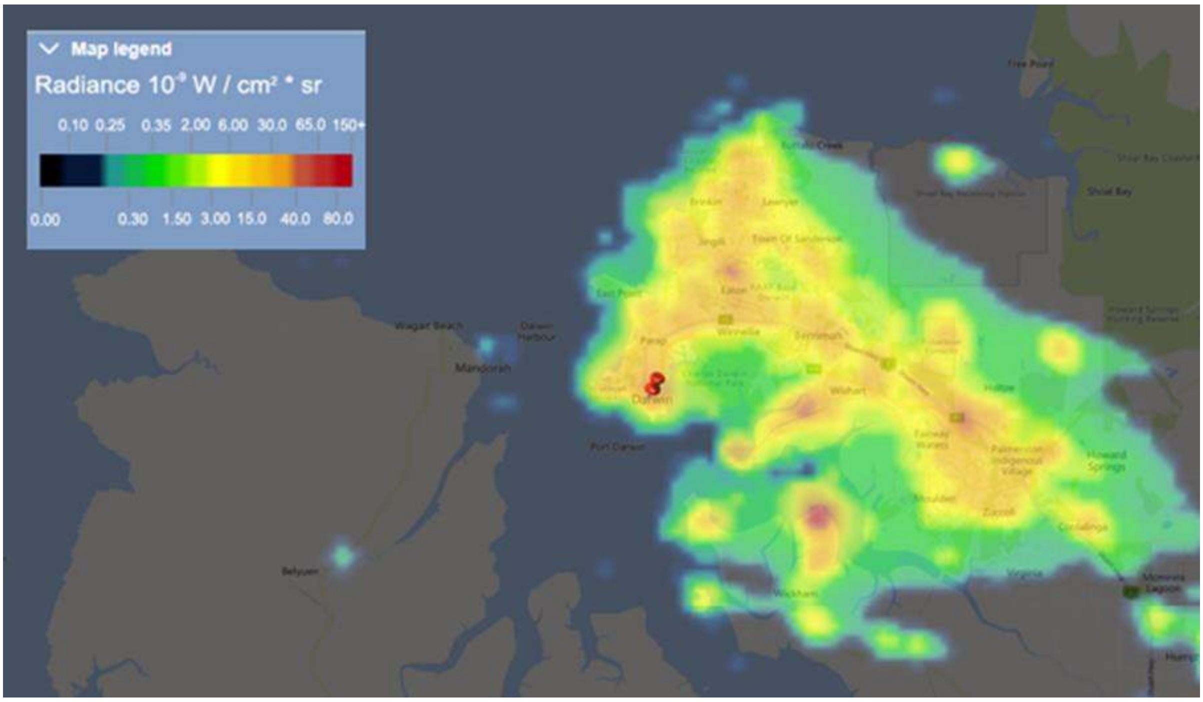
9.5.3.2 Turtle nesting and Project lighting desktop assessment

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

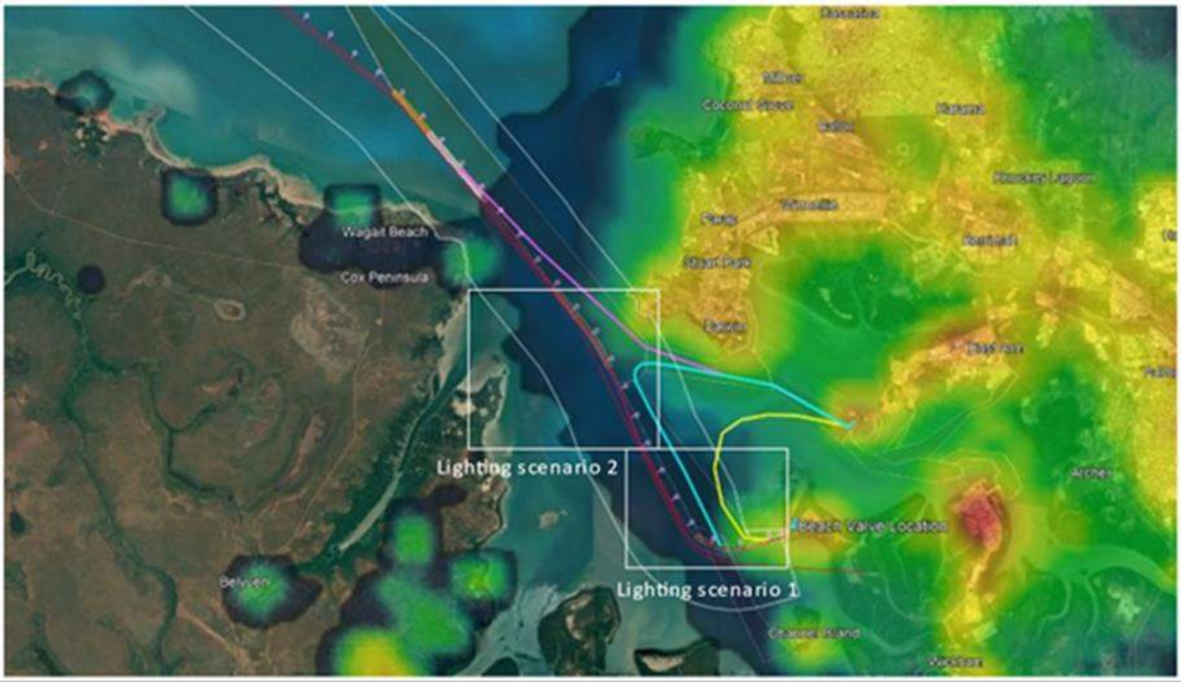


Figure 9-16 Vessel activity zones in Darwin Harbour

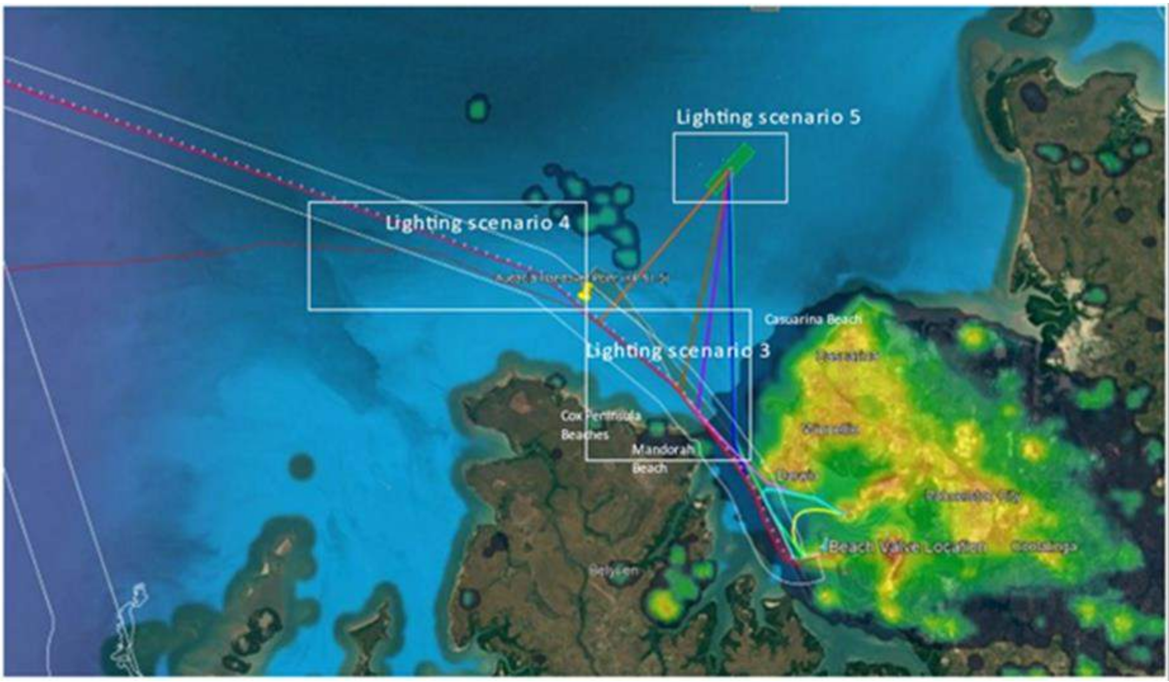


Figure 9-17 Vessel activity zones approaching Darwin Harbour

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.

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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 draft 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.

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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.

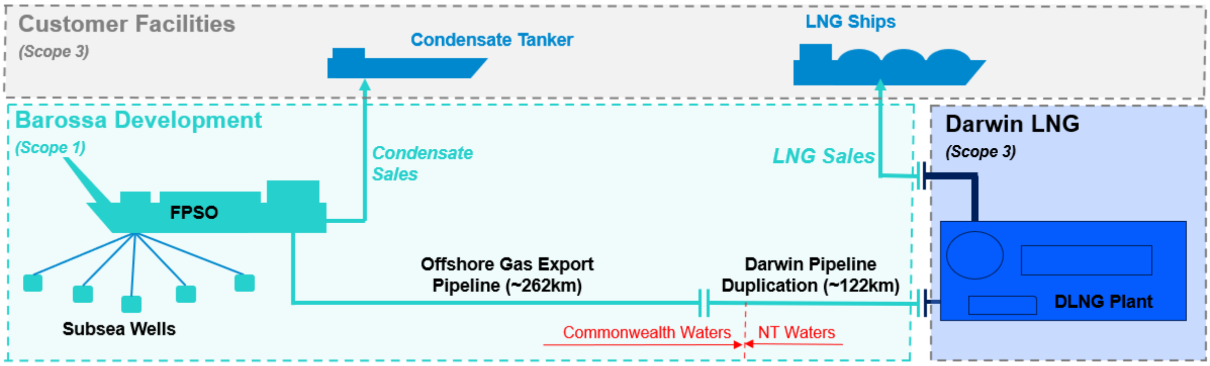

Figure 10-1 Barossa-DLNG schematic

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**.

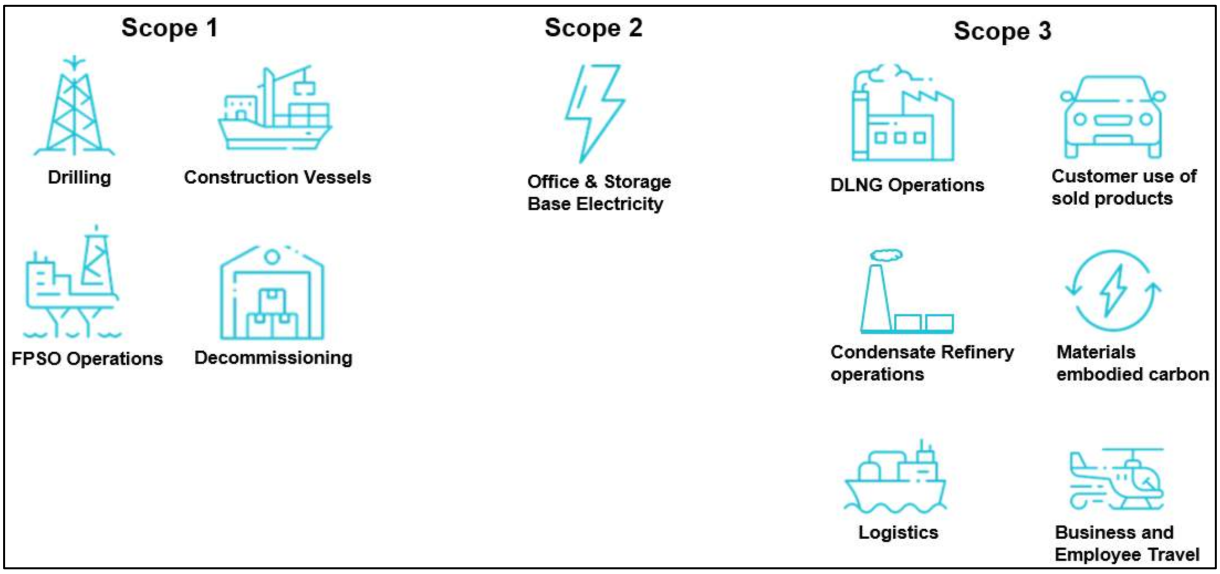

Figure 10-2 GHG inventory assessment boundary

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.

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

		Barossa Contribution (%)				
Stage	Estimated Average[1] Annual CO_2-e Emissions (Mtpa)	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.**

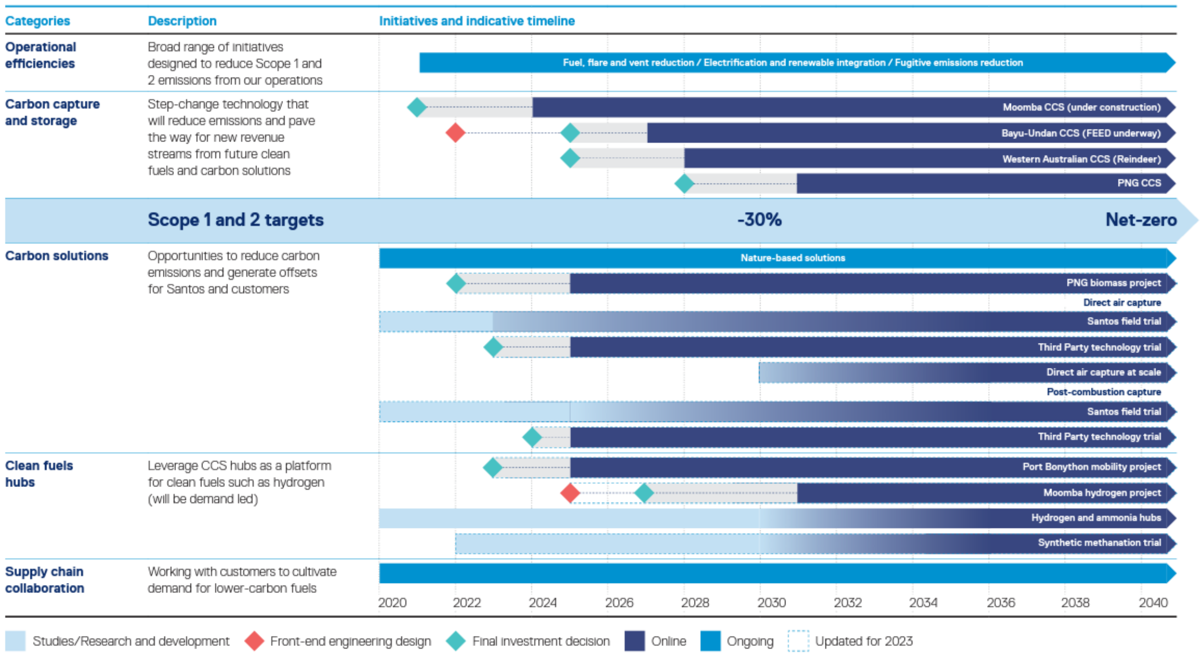

Figure 10-3 Climate transition action plan

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.

Santos

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 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 draft 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 draft 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 draft 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).

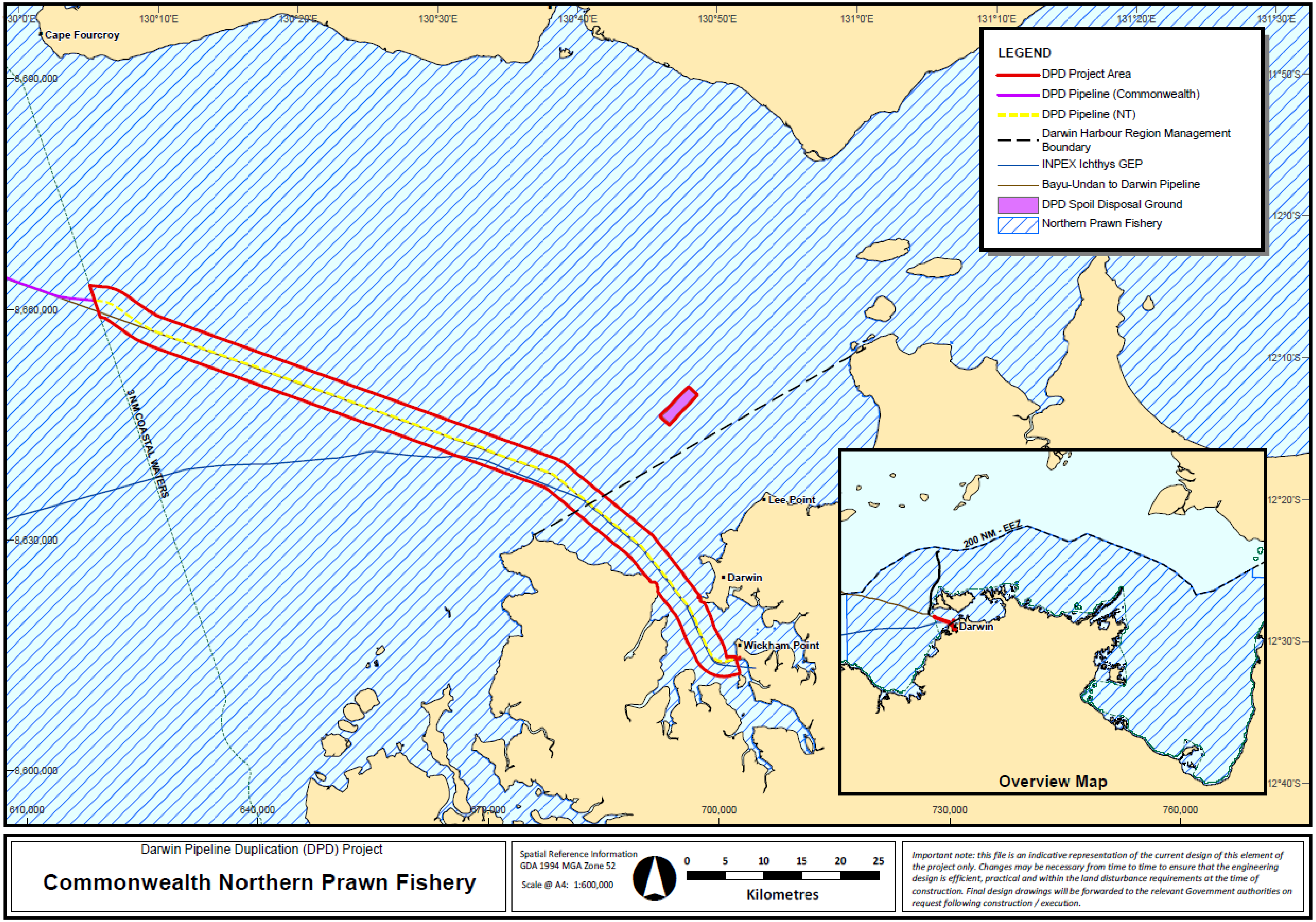

Figure 11-1 Commonwealth northern prawn fishery

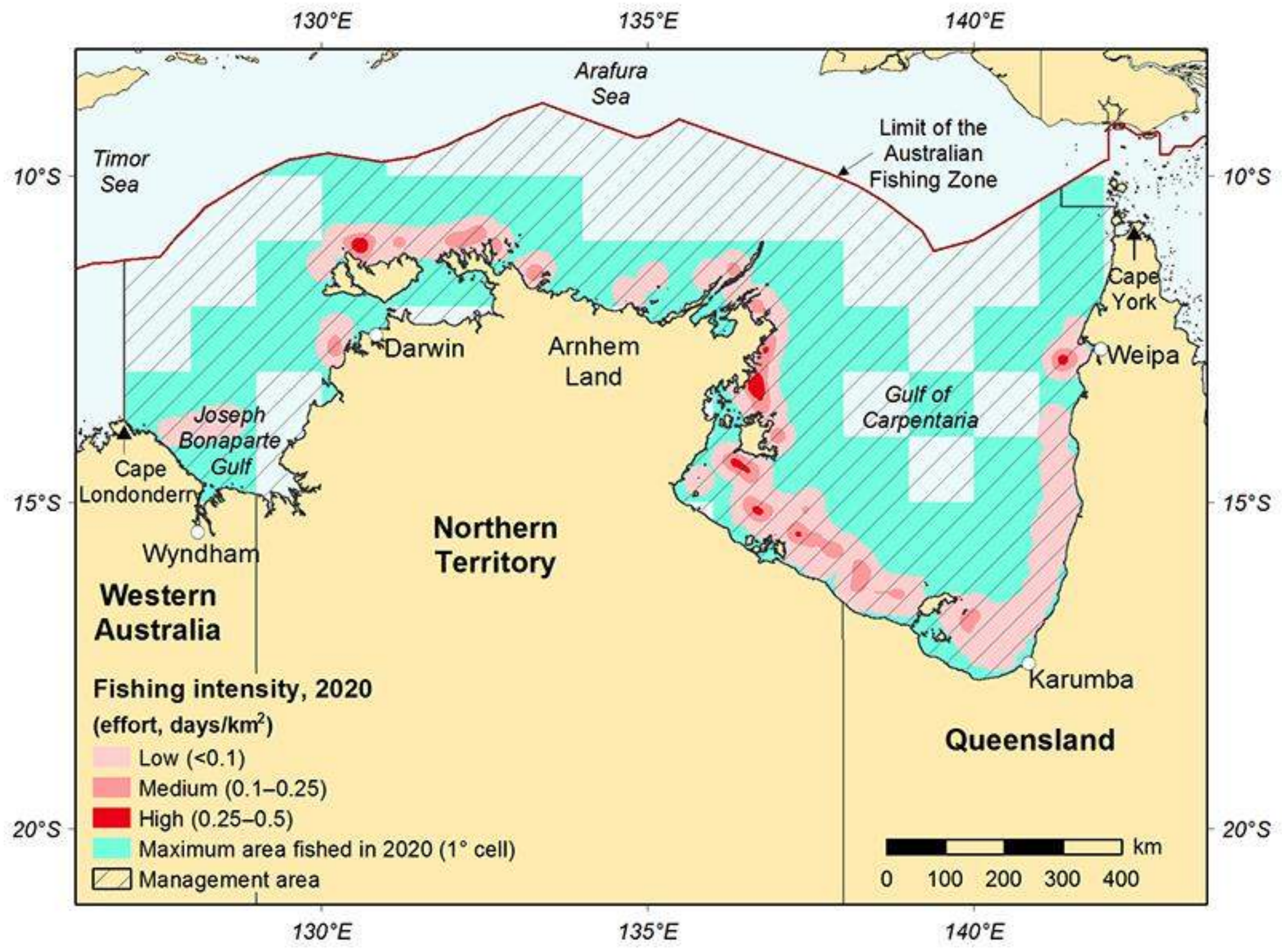

Figure 11-2 Fishing intensity in the northern prawn fishery, 2020 (ABARES, 2022)

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.

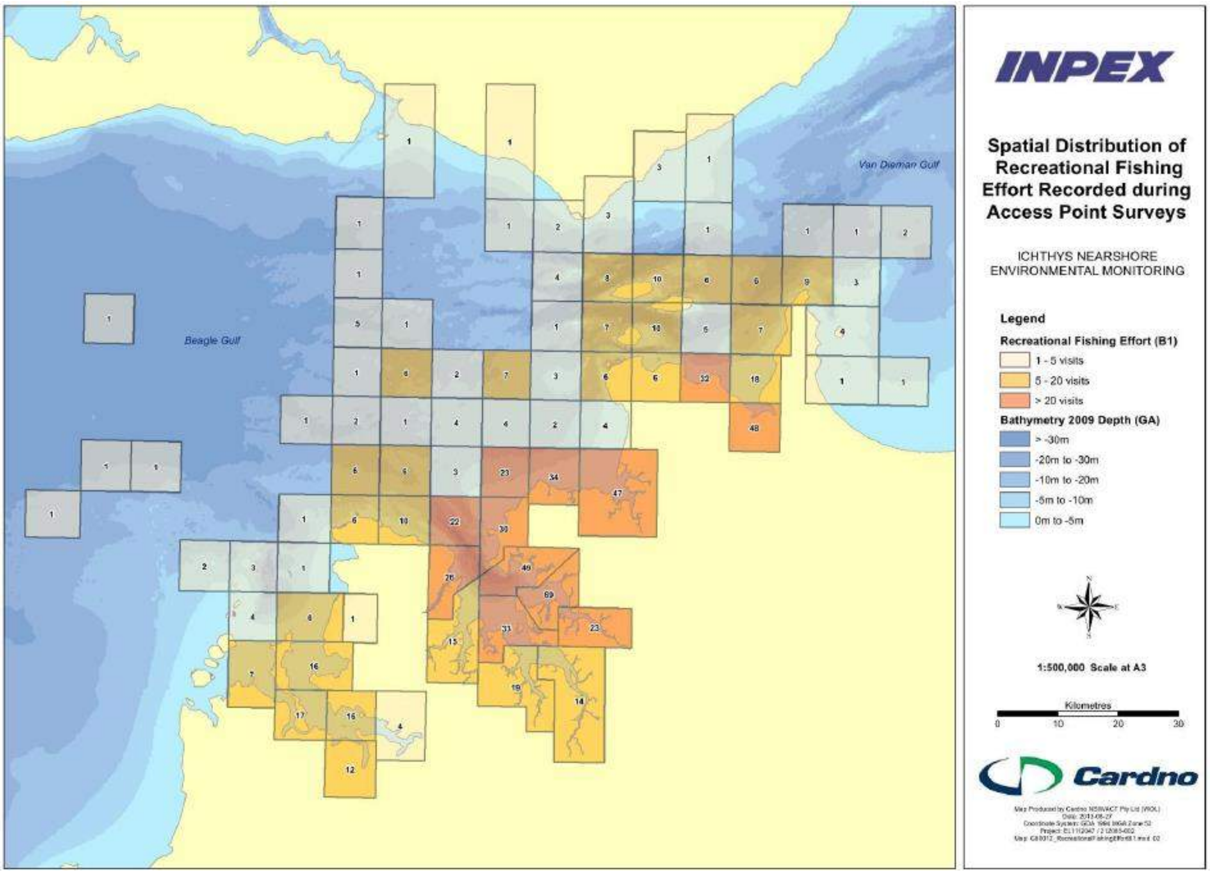

Figure 11-3 Frequency of reported visits by APS interviewees to fish area grids (from Cardno, 2013)

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 draft 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).

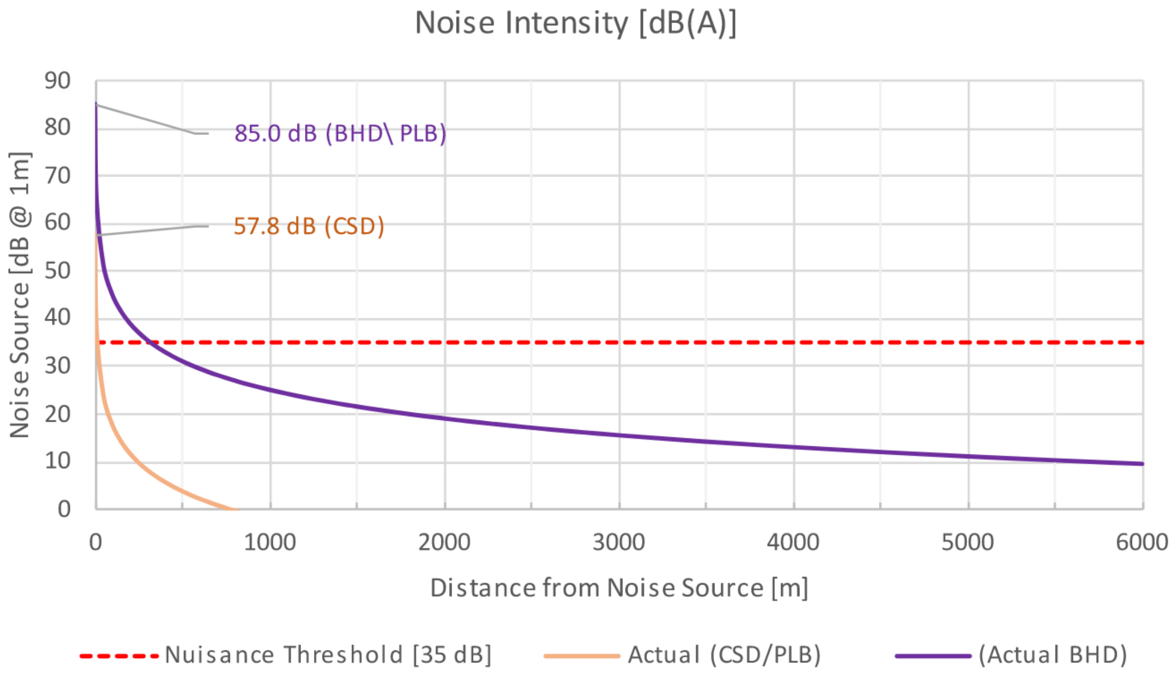

Figure 11-4 Noise attenuation from construction vessels

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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 draft 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.

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	1,700 m	N/A

Name	Type	Year	Wreck event	Location	Approx. distance of DPD pipeline to Exclusion Zone	Statutory heritage protection
				130° 48' 36.576'' E		
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*

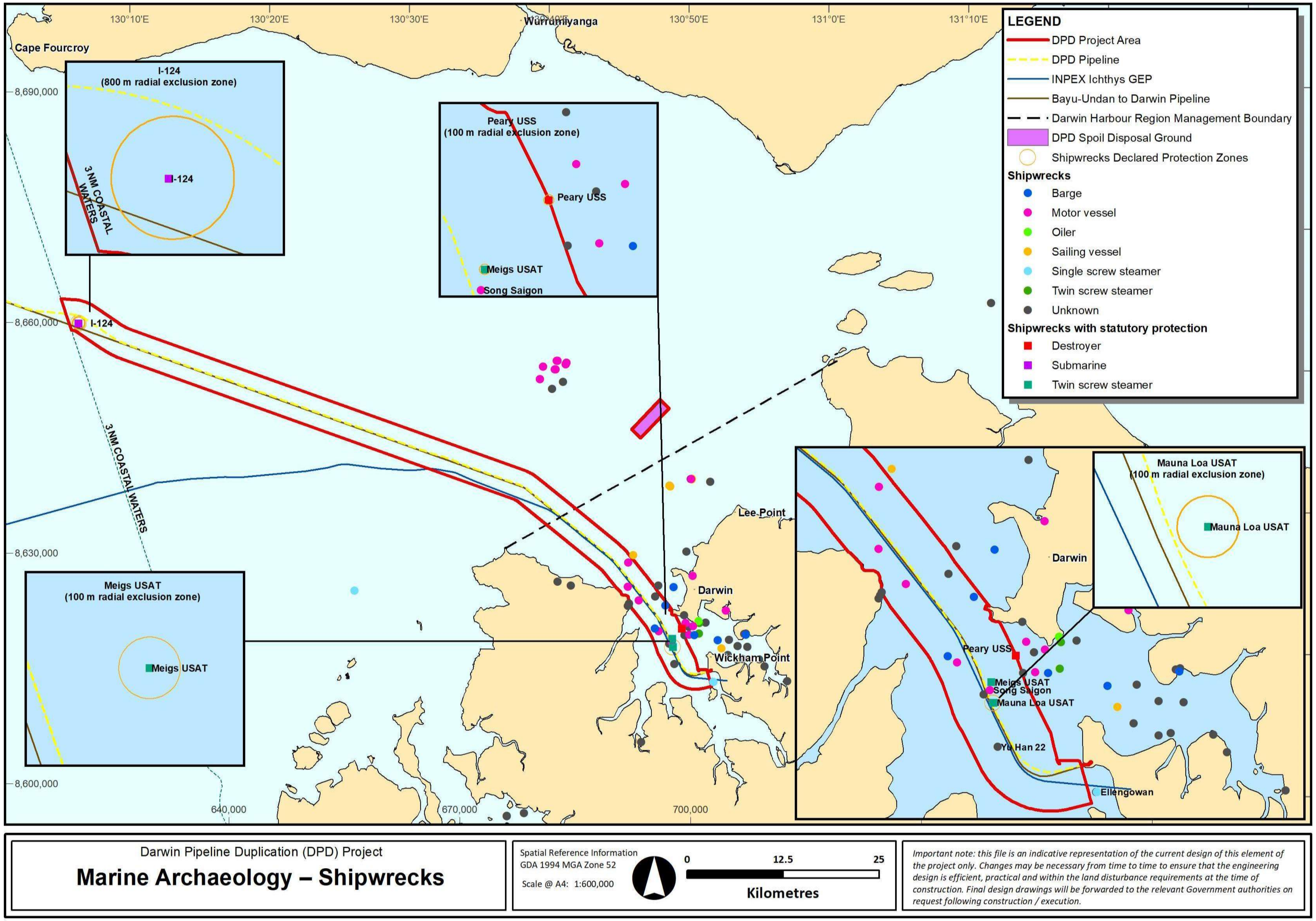

Figure 11-5 Location of known shipwrecks in study area.

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.

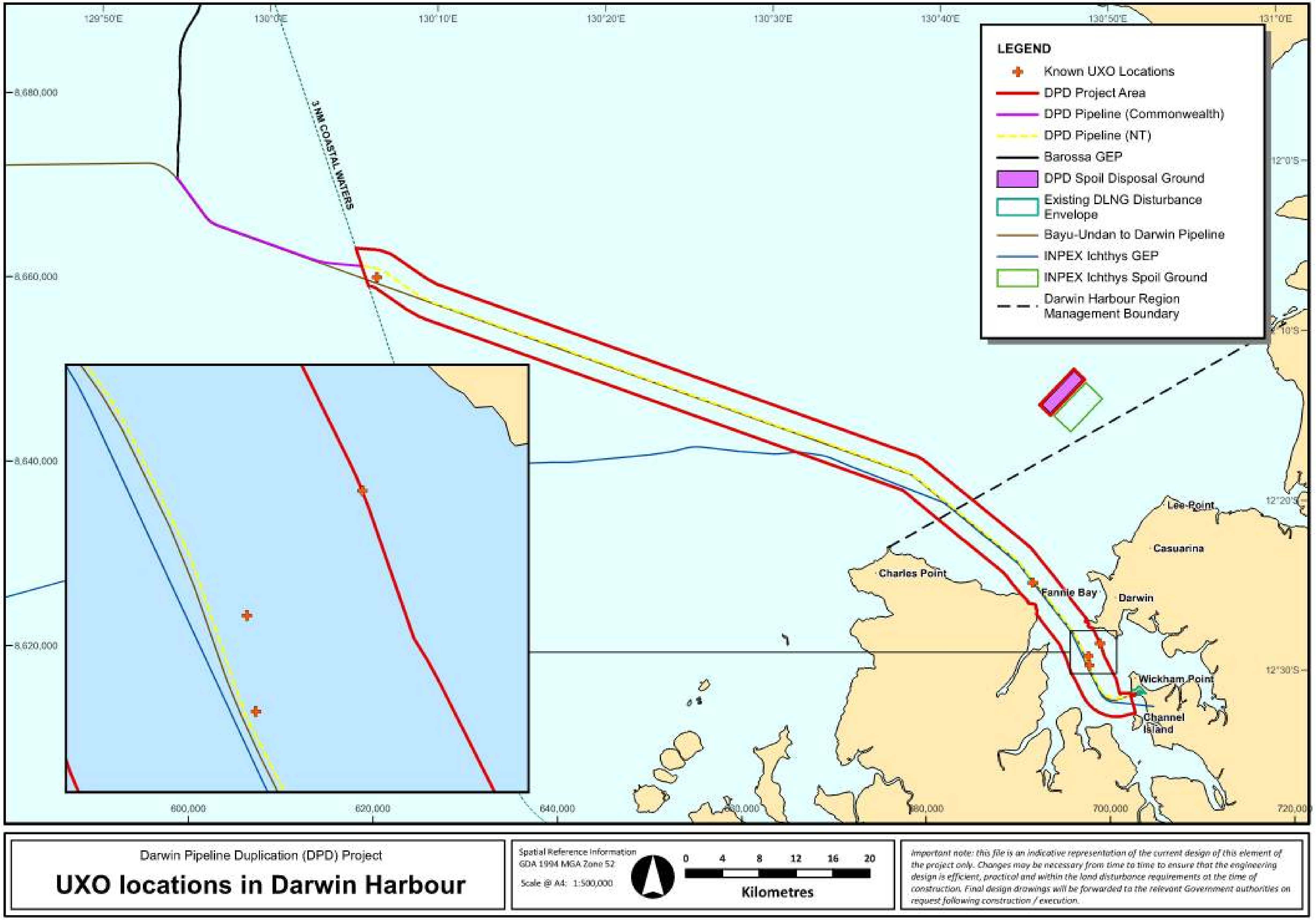

Figure 11-6 UXO locations in Darwin Harbour

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.

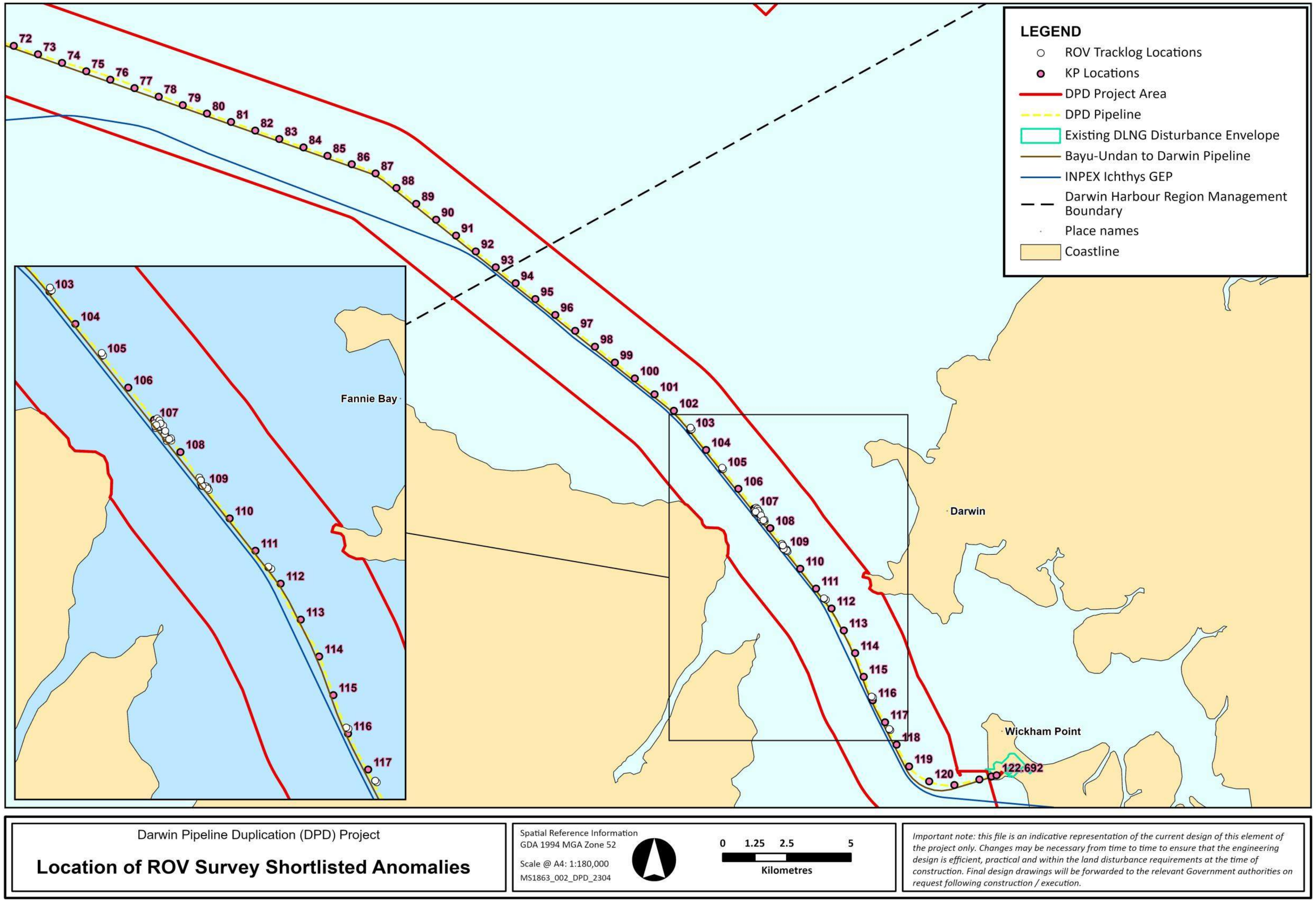

Figure 11-7 Location of ROV survey shortlisted anomalies

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

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 as shown on **Figure 11-10**. The certificate identified that the registered sacred site 5073-105 overlaps the Subject Land area and that a restricted works area (RWA 1) shall apply within which no work or damage can occur (**Figure 11-10**).

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 restricted works area (RWA 1). Santos also intends to involve the Larrakia Sea Rangers in its environmental monitoring program for the DPD Project within Darwin Harbour.

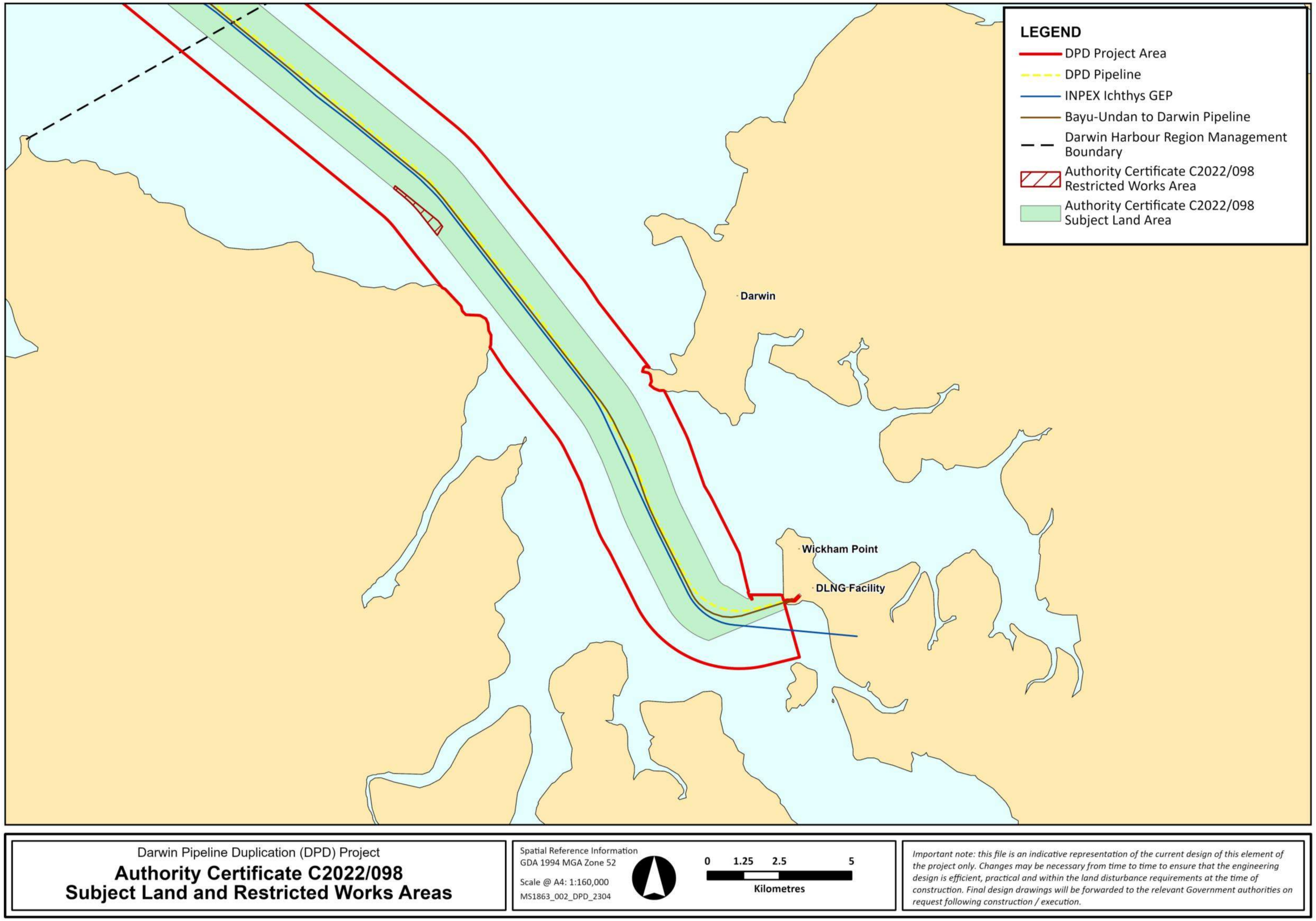

Figure 11-10 Restricted works under AAPA Authority certificate C2022/098

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 (**Figure 11-10**). Therefore, this site has the potential to be impacted by nearshore pipelay barge anchoring if the restricted works area requirements was 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 draft 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 draft 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	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-

Project	Project Impact Type	Description	Assumed Key Impacts Based on Current Knowledge and Related to the Project	Construction / Operation Timeframes	Additional Information
		an 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.

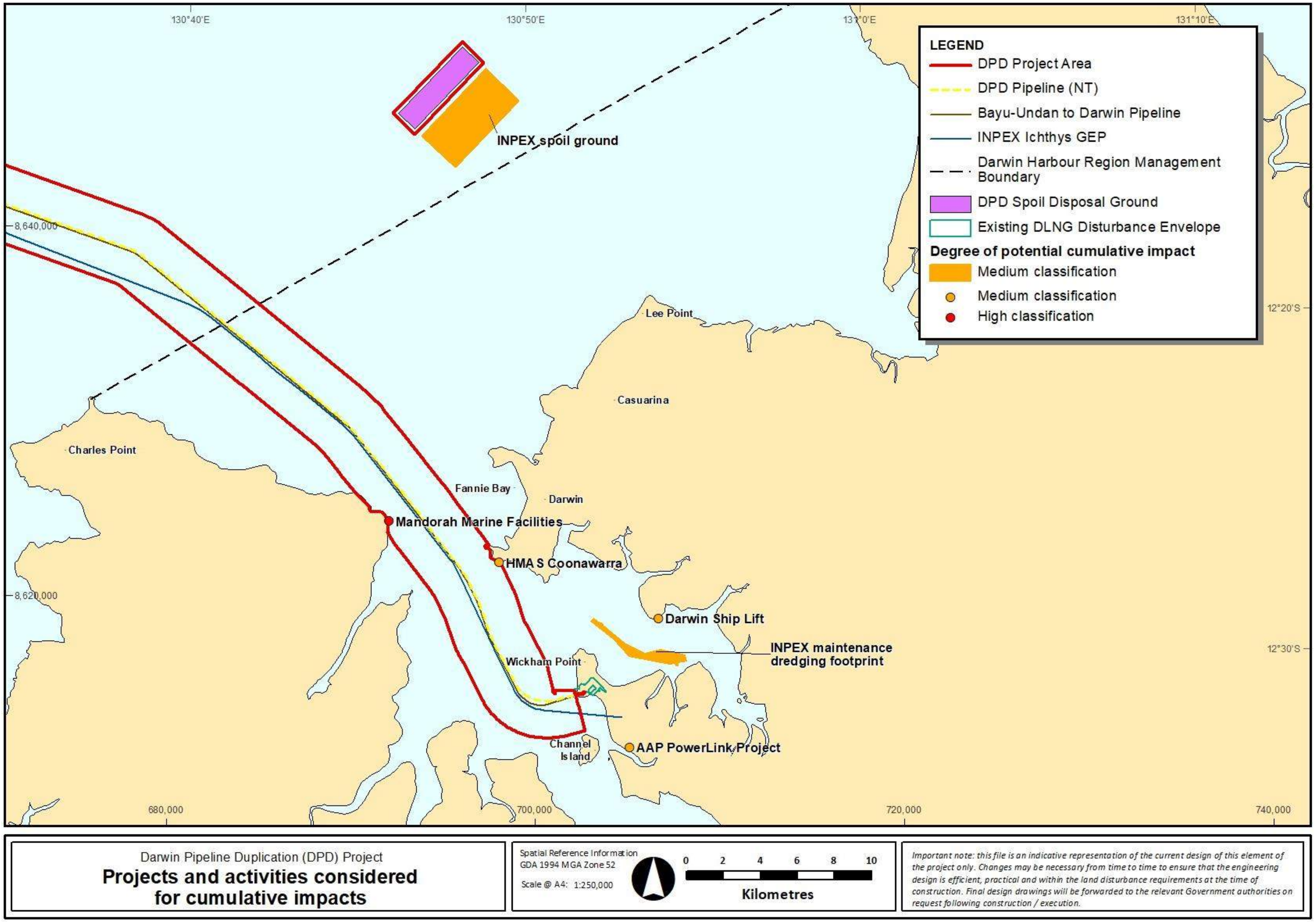

Figure 13-1 Projects and activities considered for cumulative impacts

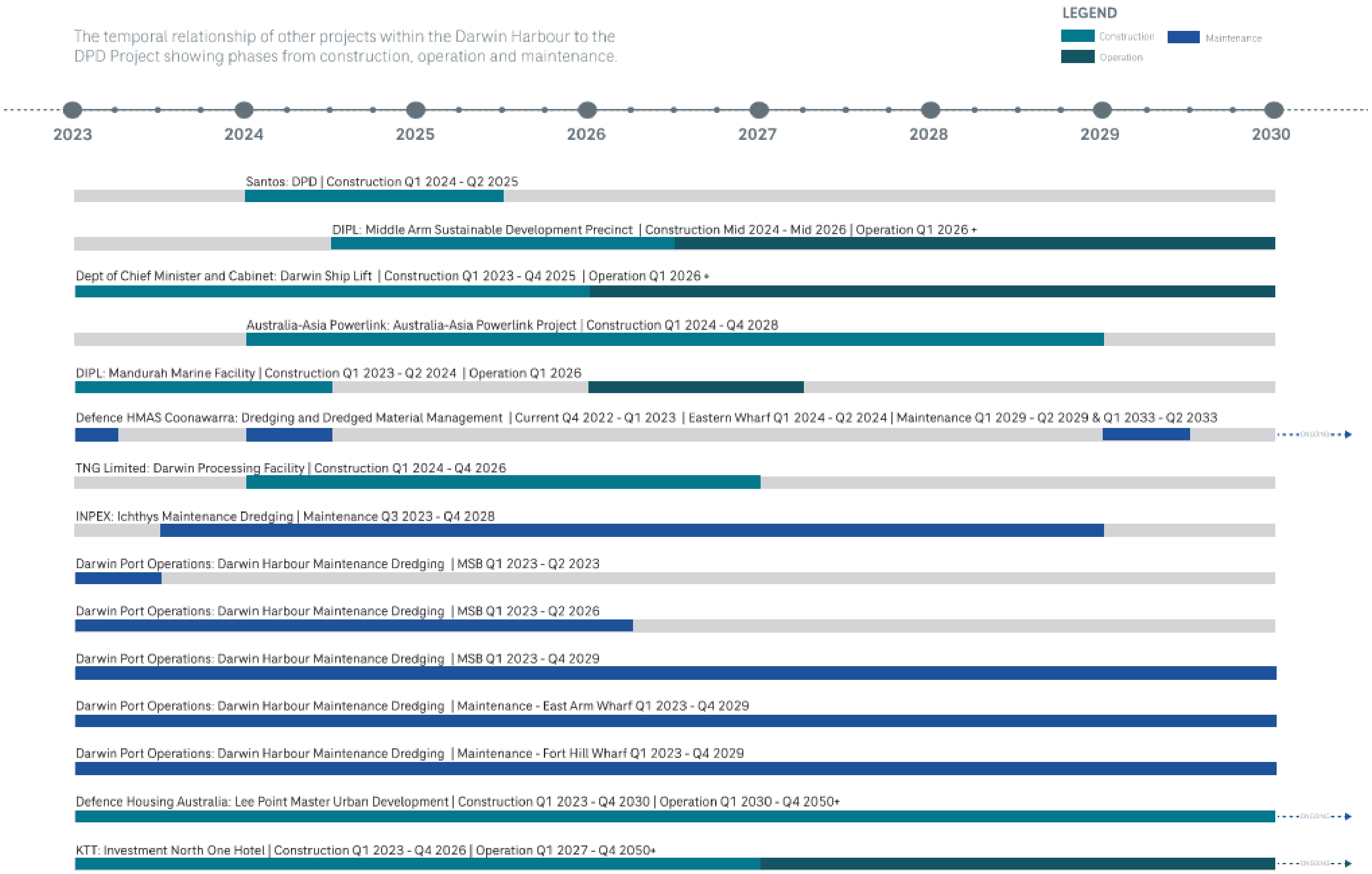

Figure 13-2 Indicative timeline of DPD project and other projects that may create cumulative impacts

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.

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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 draft 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 draft 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.

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 draft 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 draft 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 draft 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

Duty	How Addressed
	indigenous 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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Appendix 1: Additional information requirements for the Supplementary Environmental Report

Appendix 2: Register of all submissions received on the DPD Project referral

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)

Appendix 9: Underwater Noise Modelling Report – Rock Breaking (JASCO)

Appendix 10: Traffic Impact Assessment

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

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Appendix 12: Draft Acid Sulfate Soil and Dewatering Management Plan

Appendix 13: Stakeholder Engagement Plan (SEP)

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Appendix 14: Darwin Harbour Lighting Impact Assessment

Appendix 15: Hydrocarbon Spill Modelling Report

Appendix 16: Maritime Archaeology Heritage Assessment Report and Route Realignment Technical Memo

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