

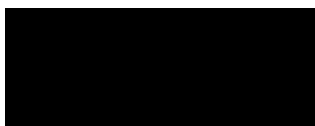
COAL SEAM GAS WASTE MANAGEMENT PLAN GLNG GAS FIELD DEVELOPMENT PROJECT EPBC (2012/6615)

Date	Version	Author	Approver	Reason For Issue
31/03/2021	0	TRE/CH	LD	Submission to Department of Agriculture, Water and the Environment
17/10/2025	1	BW	DG	Review to be consistent with revised CWMMP including plan structure, triggers and thresholds and applicability to above ground storage tanks. AW: 554165

Declaration of accuracy

In making this declaration, I am aware that section 491 of the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) makes it an offence in certain circumstances to knowingly provide false or misleading information or documents to specified persons who are known to be performing a duty or carrying out a function under the EPBC Act or the Environment Protection and Biodiversity Conservation Regulations 2000 (Cth). The offence is punishable on conviction by imprisonment or a fine, or both. I am authorised to bind the approval holder to this declaration and that I have no knowledge of that authorisation being revoked at the time of making this declaration.

Signed



Full name (please print) David Gornall

Organisation (please print) Santos Ltd

Date 24/11/25

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Glossary

Acronym	Definition
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand guidelines for fresh and marine water quality
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AWAF	Associated Water Amendment Facility
BTEX	Benzene, toluene, ethylbenzene, xylene
CRAF	Chemical Risk Assessment Framework
CSG	Coal Seam Gas
CSGWMP	Coal Seam Gas Waste Management Plan
DAWE	Department of Agriculture, Water and the Environment
DETSI	Queensland Department of Environment, Tourism, Science and Innovation
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DSA	Design Storage Allowance
EA	Environmental Authority
EC	Electrical conductivity
ECse	Soil salinity
EOW	End of waste
EP Act	<i>Environmental Protection Act 1994</i>
EPBC Act	<i>Environment Protection and Biodiversity Act 1999</i>
EV	Environmental Value
GAB	Great Artesian Basin
GDE	Groundwater Dependent Ecosystem
GFD	Gas Field Development
GLNG	Gladstone Liquefied Natural Gas
HCS	Hub Compressor Station
HDPE	High-Density Polyethylene
JIF	Joint Industry Framework
LAI	Land amendment irrigation
MNES	Matters of National Environmental Significance
MOV	Maximum Operating Volume
MRL	Mandatory Reporting Level
RMMP	Resource Monitoring and Management Plan
ROC	RO concentrate
RO	Reverse osmosis
ROP	Reverse Osmosis Plant

Acronym	Definition
RPEQ	Registered Professional Engineer Queensland
SAR	Sodium adsorption ratio
SEVT	Semi-evergreen vine thickets
TEC	Threatened Ecological Communities
WRR Act	<i>Waste Reduction and Recycling Act 2011</i>

1. Background

1.1. Introduction

The Santos Gas Field Development (GFD) Project extends the Santos GLNG development area from 6,887 km² to 10,676 km². It will see the development of up to 6,100 production wells (and associated infrastructure) beyond 2,650 production wells authorised by the original GLNG development approvals. The GFD project comprises 35 petroleum tenures, which includes the existing GLNG project area and some surrounding tenures in Arcadia, Fairview, Roma and Scotia. These areas combined are called the Santos GLNG Upstream Project Area.

1.2. Purpose and Scope

This Coal Seam Gas Waste Management Plan – Gas Field Development Project (CSGWMP) has been prepared to satisfy the conditions of approval 2012/6615 issued under the *Environment Protection and Biodiversity Act 1999* (EPBC Act). This plan specifically satisfies requirements of Condition 25, 25B and 28f. These conditions relate to developing and outlining the proposed disposal, management and monitoring of coal seam gas produced water (produced water) and other waste products to avoid, mitigate and manage impacts to Matters of National Environmental Significance (MNES) for the life of the GFD Project. This includes managing potential impacts to surface and groundwater resources, EPBC threatened species and communities and EPBC migratory species.

Table 1: Conditions 25, 25B and 28f of EPBC (2012/6615) Approval

EPBC 2012/6615 Condition		Section
25	The approval holder must submit a CSG Waste Management Plan (CSGWMP) for the project area to the Minister for approval.	N/A
25B	A CSGWMP must include, for the relevant area:	5
	a) Measures that will be implemented to avoid, mitigate and manage impacts to surface water and groundwater resources, EPBC threatened species, EPBC migratory species and EPBC communities as a result of storage and disposal of CSG produced water and waste products during the life of the action;	8
	b) Monitoring to measure the amount of CSG produced water and waste products produced during the life of the action;	3
	c) Details of how the CSG produced water and waste products will be stored, managed and disposed of including, but not limited to: <ul style="list-style-type: none"> i. Beneficial reuse; ii. Re-injection into groundwater aquifers; and iii. Transfer to a licenced waste management facility. 	6
	d) Early warning indicators, trigger thresholds and limits for detecting impacts on surface water and groundwater quality as a result of the storage and disposal of CSG produced water and waste products; and	7
e) Details of a risk-based exceedance response for the activities the approval holder will undertake, and the timeframes in which these activities will be undertaken, if early warning indicators, trigger threshold values or limits are exceeded, including reporting of the location and severity of exceedances to the Minister.	6	
28f	Framework (CRAF) that details how the risk of adverse impacts on protected matters posed by chemicals will be assessed and managed for the duration of this approval. The CRAF must include, but is not limited to: <ul style="list-style-type: none"> f) A commitment to link any relevant mitigation and management measures required for the storage and disposal of waste products arising from coal seam gas operations in the CSGWMP. 	6

1.3. Related management frameworks

GFD Project activities which may pose a risk of a significant adverse impact to MNES, and the relevant management and monitoring measures for these project activities, are addressed in:

- *Chemical Risk Assessment Framework (CRAF), Santos Gas Field Development Project, EPBC 2012/6615* – a framework to assess the risks and lifecycle management of anthropogenic chemicals used for CSG well construction (e.g. drilling fluids), well stimulation activities and in the treatment of CSG water, as well as geogenic constituents (total effluent toxicity).
- *Coal Seam Gas - Joint Industry Framework (managing impacts to groundwater resources in the Surat Cumulative Management Area under EPBC Act approvals), endorsed by DAWE (now Department of Climate Change, Energy, the Environment and Water (DCCEEW) on 17 March 2021* – this is an outcomes and risk-based management framework to achieve stated environmental outcomes for relevant MNES resulting from the potential impacts of coal seam gas extraction.

The Chemical Risk Assessment Framework (CRAF) is designed to provide a process for categorising risk of chemical use to MNES from the full life cycle of drilling operations, specifically the treatment, recycling, re-use and disposal of drilling waste, and outlines risk assessment requirements based on chemical categorisation and use. Some management controls contained in this plan form part of the risk mitigation of chemical use to reduce risk to low levels and to ensure the process is not duplicated in other documents.

Furthermore, the planning of CSG development activity locations, and the types of actions permitted at any location are bound to the Environmental Protocol for Constraints Planning and Field Development – GFD (Santos, 2016) (the Constraints Planning Protocol). The Constraints Planning Protocol was prepared to satisfy Condition 7 of the EPBC (2012/6615) approval. This overlaps considerably with the requirements of this GFD CSGWMP because by carefully selecting the location of project activities, risks to MNES are avoided and minimised. This is discussed further within this plan.

All Santos management plans, protocols and frameworks required by EPBC approval 2012/6615 are available on the Santos website (www.santos.com).

1.4. Project scope

This plan assesses risks to MNES from the storage and disposal of produced water and residual drilling material (drilling cuttings and fluids) and provides management controls for activities appropriate to manage the risk identified. The plan relates to the whole GFD Project area and across the lifetime of project development.

This plan may be updated over the life of the GFD Project. The process for updating this plan is outlined in Section 9 and aligns to the requirements of Condition 28f and 36 of EPBC Approval 2012/6615. Further updates to the plan will be made where an outcome of a chemical risk assessment for a high-risk chemical, as per the CRAF, identifies additional mitigation or management controls are necessary for the storage or disposal of a waste product. These controls will only be added after the chemical and mitigation and management controls have been reviewed and approved.

1.5. Roles and responsibilities

All Santos personnel and contractors are responsible for facilitating compliance with this document, relevant conditions of approval. Specific roles and responsibilities associated with this document are detailed below.

Table 2: Roles and responsibilities

Role	Responsibilities
All personnel and contractors	<ul style="list-style-type: none"> + Implement the document. + Report all water-related incidents and non-compliances in accordance with the plan and SMS requirements.
Operations team	<ul style="list-style-type: none"> + Ensure water containment areas are operated and maintained as designed. + Delegate or conduct detailed reviews on water related incidents.

Role	Responsibilities
	<ul style="list-style-type: none"> + Ensure compliance with mitigation measures + Report non-compliances in accordance with the plan and SMS requirements
Emergency Response Team	<ul style="list-style-type: none"> + Provide first response to emergency water incidents.
Land Access Team	<ul style="list-style-type: none"> + Coordinate notifications to any affected landholders/stakeholders alongside Environmental Advisor.
Environmental Advisor	<ul style="list-style-type: none"> + Contribute to site inductions regarding water-related incidents and emergencies. + Support the implementation of the CWMMP. + Monitor and report on incidents, preventative and corrective actions from the plan. + Review the CWMMP to ensure it remains current and compliant with regulations.
Irrigation Team	<ul style="list-style-type: none"> + Implement and manage irrigation systems according to the CWMMP and RMMPs. + Monitor water usage and efficiency to ensure optimal irrigation practices. + Conduct regular maintenance and inspections of irrigation equipment. + Report any malfunctions or inefficiencies in the irrigation system. + Report non-compliances in accordance with the plan and SMS requirements.
Dust suppression appliers	<ul style="list-style-type: none"> + Apply water directly to manage runoff impacts + Ensure compliance with mitigation measures + Report non-compliances in accordance with the plan and SMS requirements
Drilling and completions team	<ul style="list-style-type: none"> + Select, design and control appropriate RDM application areas. + Monitor and manage RDM activities. + Ensure compliance with mitigation measures + Report non-compliances in accordance with the plan and SMS requirements

1.6. Training

The project has a comprehensive onboarding environmental training package, ensuring all Santos employees and contractors understand their responsibilities under the various environmental requirements, including this plan. The training includes identification of key environmental values, role-specific understanding of the plan requirements and procedures for responding to environmental incidents.

1.7. Emergency contacts and procedures

Santos manages emergencies in line with existing state Environmental Contingency and Emergency Response Plans for the project. Emergency contacts and the procedures are detailed in this document.

2. Regulatory Context

Several Acts and Regulations govern the management of produced water (and its derivatives) and residual drilling material in Queensland. This includes:

- Produced water and residual drilling material management - existing conditions for produced water and residual drilling material management granted in Environmental Authorities issued by the Queensland Department of Environment, Tourism, Science and Innovation (DETSI) under the *Environmental Protection Act 1994*, and
- Waste management – End of waste (EOW) framework, including various EOW codes, under the *Waste Reduction and Recycling Act 2011* (WRR Act). Other legislation may apply, and further details are provided in the sections below.

2.1. Produced water and residual drilling material management

Santos manages produced water and residual drilling material in accordance with the relevant regulatory frameworks and policy, including those approvals listed above. The management strategy adopted is sufficiently flexible to accommodate changes in technology, energy sources and climatic conditions. The strategy is based on a rigorous evaluation and decision-making framework which aims to avoid, minimise and mitigate the risk of adverse impacts to environmental receptors.

The *Petroleum Act 1923* and *Petroleum and Gas (Production and Safety) Act 2004* provide that a petroleum tenure cannot be granted unless an environmental authority (EA) has been issued under the Queensland *Environmental Protection Act 1994* (EP Act). An EA can apply to multiple petroleum tenures.

In relation to produced water, the EA primarily deals with the management of produced water, the storage of chemicals and waste and their potential for impact to the land and surface and groundwater quality. EA conditions specify the way in which particular produced water management activities can only be undertaken or specify the environmental outcomes that must be achieved. For example, EAs may limit the size, location and type of water management activity, as well as stipulating minimum operational requirements, monitoring requirements or reporting and notification requirements.

EA conditions for water management activities can only be granted once a proponent has presented information that describes the proposed activity, an assessment of environmental risk and a resulting management and monitoring plan commensurate to the risk identified.

In relation to residual drilling materials, the EA conditions require off-site disposal at a suitably licensed facility, or on-site disposal provided it is of a suitable quality and is by a disposal method that will not result in environmental harm. The quality and disposal method is either stipulated in the EA or is as per a methodology certified by a suitably qualified third party.

Most notably, the Environmental Authorities granted for the Scotia, Roma, Fairview and Arcadia developments prohibit impacts to water resources (and therefore implicitly MNES) associated with produced water and waste management and disposal activities through specific imposed conditions.

Further, all Santos management processes for produced water and waste management and disposal are informed by the outcomes of chemical risk assessments undertaken in accordance with the CRAF and the GFD Project EPBC Approval. Chemical risk assessment(s) evaluate the potential risks and effects of chemicals used during coal seam gas operations (defined as drilling and completions, hydraulic fracturing and water treatment) to MNES, and demonstrate the risks have been eliminated or reduced as much as reasonably practicable. The CSGWMP then outlines what mitigation or management controls must be implemented to ensure the risks from the activities associated with produced water and waste management and disposal remain as assessed.

2.2. Waste management

The Department of Environment, Tourism, Science and Innovation (DETSI) regulates the management and disposal of wastes in Queensland under the provisions of the EP Act, the WRR Act, the *Environmental Protection Regulation (2008)* and the *Waste Reduction and Recycling Regulation 2011* (WRR Regulation).

Both Acts and Regulations contain provisions for the assessment, classification and management of waste, including storage, transport, processing, recovery and disposal of waste. The Santos waste management hierarchy has been developed in accordance with the management approaches detailed within the legislation and associated policies and guidelines.

To ensure the appropriate management and disposal of waste products, Santos has adopted a sustainable approach to waste management. This approach revolves around a hierarchy, which provides a guideline to target waste production and disposal. The successful implementation of the waste hierarchy principles assists Santos to:

- Minimise waste volumes and the risk of adverse impact to the environment (including MNES); and
- Improve operational efficiency and environmental performance.

The waste management hierarchy, from most preferable to least preferable, is illustrated in Figure 1.

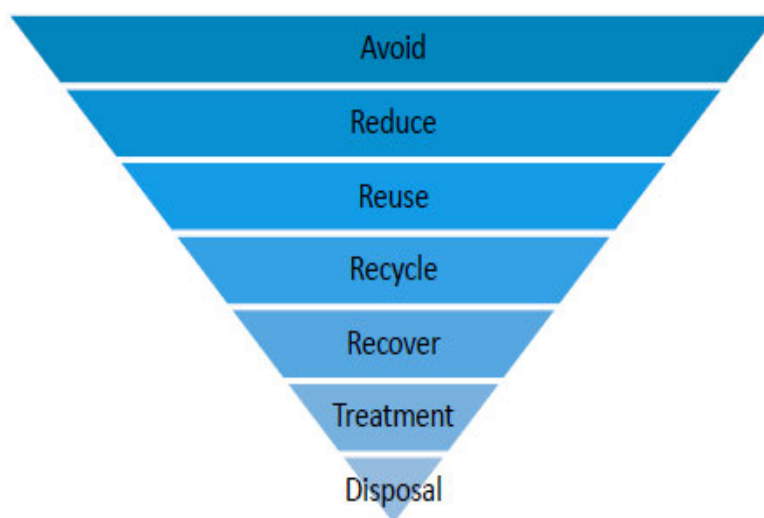


Figure 1: Waste management hierarchy

3. CSG Water Management Activities

This section meets the Condition 25B (c) of EPBC Approval 2012/6615, which requires that this plan must include:

- Details of how the CSG produced water and waste products will be stored, managed and disposed. Details must cover beneficial reuse, re-injection into groundwater aquifers and transfer to a licenced waste management facility.

The following sections describe how produced water and residual drilling material from the GFD Project are managed. A description of the proposed storage, treatment, end use and disposal of produced water and residual drilling material is provided. The descriptions here are a precursor to descriptions of the specific locations and attributes of those activities that could pose a potential risk of adverse impact to MNES, presented in Section 4. Santos aims to utilise fit-for-purpose beneficial re-use of produced water where feasible whilst avoiding the unnecessary generation of other waste (such as brine) and energy consumption while minimising the potential risk of adverse impacts to MNES.

3.1. Water gathering

Water gathering lines are typically constructed from high-density polyethylene (HDPE) pipe of between 100 millimetres (mm) and 1,000 mm in diameter. HDPE is used to limit the potential for line failure due to corrosion. Gathering line right-of-ways are routinely inspected, and may be periodically tested, particularly prior to commissioning. This is not the main control for the detection of leaks, since most of the transfer pipes are buried. The principal control for leaks is material selection and pressure testing (integrity verification testing) at commissioning. Water gathering lines are low pressure pipelines which are designed and operated to comply with the relevant Petroleum Industry Codes of Practice (for example the *Code of Practice for Upstream Polyethylene Gathering Networks in the Coal Seam Gas Industry* published by the Australian Pipelines and Gas Association.)

3.1.1. Scotia

Produced water from Scotia wells is transferred to a network of interconnected production tanks. An overview of the quality of produced water that is gathered is provided in Appendix A1.

Roma

Produced water from Roma is transferred to various produced water storages, or else transferred directly to water management facilities at the Roma Hub Compressor Station (HCS)-02.

An overview of the quality of produced water that is gathered is provided in Appendix A1.

3.1.2. Fairview

Produced water from Fairview South wells is transferred to Associated Water Amendment Facility 1 (AWAF1) feed buffer dam, or else transferred to the water management facilities at the Fairview Hub 4. Produced water from Fairview North wells is transferred to the AWAF2 pond.

An overview of the quality of produced water that is gathered is provided in Appendix A1.

3.1.3. Arcadia

Produced water from Arcadia wells is transferred to the Mount Kingsley Dam produced water storage pond, or else transferred to the Arcadia water management facility / reverse osmosis plant (ROP).

An overview of the quality of produced water that is gathered is provided in Appendix A1.

3.2. Water Management facilities

There are four water management facilities used within the GFD Project. Produced water from Arcadia, Fairview, Roma and Scotia are gathered and directed to a centralised water management facility.

Three desalination units (in Arcadia, Roma and Fairview) comprises fines and sludge removal and a reverse osmosis plant (ROP). ROPs are used where necessary to achieve the requisite water quality for beneficial re-use of water. ROPs work by partitioning select constituents entrained within produced water into a waste stream (brine) leaving a permeate stream of significantly better-quality water.

Produced water may be directly blended with permeate or with other water sources to achieve the required water quality objectives for the intended beneficial use of the water.

Where sodicity and alkalinity is to be managed, the produced water will be treated by chemical amendment. There is an Associated Water Amendment Facility 1 (AWAF 1) in Fairview which chemically amends produced water by dosing with concentrated sulphuric acid to neutralise the alkalinity of the water prior to in-line dosing with micronized gypsum to ameliorate the sodicity of the water. Alternatively, this can be achieved in-situ via the addition of agricultural amendments to soils.

3.3. Storage ponds

3.3.1. Scotia

Produced water is stored in a water storage dam. Key attributes of the water storage facility are summarised in Table 3. The water storage is designed and operated as a 'regulated structure' in accordance with the requirements of the Queensland EP Act.

Table 3: Water storage ponds in Scotia area

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
Bridge Creek Dam	Produced water storage	In ground and above ground	Clay and HDPE	Seepage bores	217

3.3.2. Roma

Produced water is stored in water storage ponds and dams. Key attributes of the various water storage facilities are summarised in Table 4. Most of the water storages described in Table 4 are designed and operated as 'regulated structures' in accordance with the requirements of the Queensland EP Act.

The maximum volume of produced water products (i.e. produced water, permeate etc.) that can be stored in each pond is shown in Table 4.

Table 4: Water storage ponds in Roma area

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
ROMA ROP2 CSG Water Management Pond	Produced water storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	100
ROMA ROP2 Desalinated Water Pond	Permeate water storage	In ground and above ground	Clay and HDPE	Seepage bores	135
Angry Jungle Dam	Produced water storage	In ground and above ground	Clay and HDPE	Seepage bores	180
Pleasant Hills Dam	Irrigation water storage	In ground and above Ground	Clay and HDPE	Seepage bores	170
Raslie Dam	Irrigation water storage	Above ground	Clay and HDPE	Seepage bores	185
Grafton Range Dam	Irrigation water storage	In ground and above ground	Clay and HDPE	ELIMS testing and seepage bores	200

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
Hermitage Dam*	Construction water storage	Above ground	HDPE	Seepage bores	180
Ben Bow Dam	Produced water storage	Turkeys Nest	Clay and HDPE	Seepage bores	180
Treville Downs Dam*	Concentrate storage	In ground and above ground	Clay and HDPE	Seepage bores	175
Mount Hope Dam*	Construction water storage	In ground and above ground	Clay and HDPE	Seepage bores	120
Old Coxon Creek Dam*	RO Permeate	In ground and above ground	Nil	Nil	20
New Coxon Creek Dam*	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Seepage bores	170
Pickanjinnie Dam	Produced water storage	Turkeys Nest	Clay and HDPE	Seepage bores	180
Reuben Downs Dam	Produced water storage	Turkeys Nest	Clay and HDPE	Leak detection layer and seepage bores	80ML
Washpool Creek Dam	Produced water storage	Turkeys Nest	Clay and HDPE	Seepage bores	184

*These dams were not in use at the time of writing this plan however may be used again in future.

3.3.3. Fairview

Produced water is stored in water storage ponds and dams. Key attributes of the various water storage facilities are summarised in Table 5. Most of the water storages described in Table 5 are designed and operated as 'regulated structures' in accordance with the requirements of the Queensland EP Act.

Table 5: Water storage ponds in Fairview area

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
Fairview 77 Feed buffer dam*	Produced water storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	30
Fairview AWA1 Feed buffer dam	Produced water storage	Turkeys Nest	Clay and HDPE	Under drainage and seepage bores	110

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
Fairview 82 Feed buffer dam*	Produced water storage	Turkeys Nest	Clay and HDPE	Under drainage and seepage bores	5
Fairview RM94 10ML dam (AWAF2)	Produced water storage	In ground	Clay and HDPE	Under drainage and seepage bores	12
Fairview RM94 15ML dam	Produced water storage	In ground	Clay and HDPE	Under drainage and seepage bores	16
F-HCS-04 Associated water dam	Produced water storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	205
F-HCS-04 Permeate dam	RO permeate	In ground	Clay and HDPE	Under drainage and seepage bores	340
F-HCS-05 Amended water dam	Produced water storage	In ground and above ground	Clay and HDPE	Seepage bores	35
F-HCS-05 Associated water dam	Produced water storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	40
IR4 Dam	Irrigation water storage	In ground and above ground	Clay and HDPE	Under drainage	68
Spring Rock Dam*	Produced water storage	Turkeys Nest	Clay and HDPE	Seepage bores	200

*These dams were not in use at the time of writing this plan however may be used again in future.

3.3.4. Arcadia

Produced water is stored in Mount Kingsley Dam. Key attributes of the various water storage facilities are summarised in Table 6. Some of the water storages described in Table 6 are designed and operated as 'regulated structures' in accordance with the requirements of the Queensland EP Act.

Table 6: Water storage ponds in Arcadia area

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
Mount Kingsley dam	Produced water storage	In ground and above ground	HDPE	Seepage bores	225
Permeate Dam	RO permeate storage	In ground and above ground	Clay	Nil	20

3.4. Beneficial re-use – operational purposes

Operational re-use of produced water reduces the need to source water from elsewhere. Operational re-uses may include use in construction, ground compaction, drilling and completions, or dust suppression. It occurs only on disturbed areas and/or engineered surfaces.

Water for operational re-use may be taken directly from transfer pipeline, or from interconnected production tanks described in Table 3, or from any of the water storage facilities described in Table 4, Table 5, or Table 6 where it meets the required water quality objectives for the intended use.

3.5. Beneficial re-use – irrigation

Land amendment irrigation (LAI) describes the application of stoichiometric amounts of agricultural amendments (sulphur and gypsum) to treat the soil prior to the application of irrigation water. This is undertaken to manage risks to soil structure and crop health due to the quality of the irrigation water. Fertilised Rhodes grass and leucaena is irrigated with irrigation management activities maintaining soil salinity (EC_{se}) within the tolerances stated within the ANZECC 2000 guidelines.

In Fairview, in addition to LAI, chemically amended associated water irrigation is also undertaken. The associated water is chemically amended by dosing with concentrated sulphuric acid to neutralise the alkalinity of the water prior to in-line dosing with micronized gypsum to ameliorate the sodicity of the water. A combination of Rhodes Grass, leucaena and Chinchilla White Gum are irrigated with amended water in Fairview.

The completed risk assessments of chemicals in accordance with the CRAF, as well as the Resource Monitoring and Management Plans (RMMPs) required by the *End of Waste Code for Irrigation of Associated Water (including coal seam gas water)* (DETSI, 2025) for the various irrigation Projects (see Section 10) demonstrate how irrigated soils can be treated with agricultural amendments to manage the potential risks to soil structure and plant health.

The chemical risk assessments, completed in accordance with the CRAF have assessed irrigation practices where applicable to any assessed chemical and determined that existing practices are adequate to manage risk to soils and plant health.

The irrigated Rhodes grass is grazed in-situ by beef cattle. Irrigation application rates (and, conversely, the required area of irrigation required) are determined using key soil parameters (e.g. initial soil salinity, soil depth, soil water holding capacity and hydraulic conductivity), climatic conditions and crop demand.

Irrigation forms the largest volumetric means of produced water re-use by Santos within the Scotia, Roma, Fairview, and Arcadia development areas. Irrigation has been selected by Santos as it aligns with the waste management hierarchy (Figure 1), complies with regulatory approval conditions and provides an economic benefit through grazing, the main land use in the broader region.

Beneficial re-use via irrigation avoids the generation of additional waste and consumption of energy that would otherwise be required for alternate re-use options which can be both energy intensive and generate waste that must be managed.

3.5.1. Scotia

Scotia produced water is utilised at the Avalon LAI area with a maximum application rate of 10 ML/ha/yr for pivot irrigation area.

Scotia irrigation area is operated by Santos in accordance with the Queensland Government's End of Waste Code and site specific RMMP. Scotia LAI water quality limits are detailed in Table 7.

Table 7: Scotia LAI Water Quality Limits

Quality Characteristic	Release Limit
Electrical conductivity (EC)	5,000 µs/cm
pH	6.0 – 10.0
Sodium adsorption ratio (SAR) for heavy soils	180
Aluminium	20 mg/L
Arsenic	2.0 mg/L
Boron	6.0 mg/L
Cadmium	0.05 mg/L
Chromium	1 mg/L
Cobalt	0.1 mg/L
Copper	5 mg/L
Fluoride	6 mg/L
Iron	10 mg/L
Lithium	2.5 mg/L
Lead	5 mg/L
Manganese	10 mg/L
Mercury	0.002 mg/L
Molybdenum	0.05 mg/L
Nickel	2 mg/L
Zinc	5 mg/L

3.5.2. Roma

Roma produced water can be distributed to the following LAI areas with a maximum application rate of 10 ML/ha/yr for pivot irrigation areas:

- Belbri East Irrigation Area
- Pleasant Hills Irrigation Area
- Roleen Irrigation Area
- Tantatton Irrigation Area;
- The Bend South Irrigation Area.

These areas are all operated in accordance with the Queensland Government's End of Waste Code and site specific RMMP's. Roma LAI water quality limits are detailed in Table 8.

Table 8: Roma LAI Water Quality Limits

Quality Characteristic	Release Limit
Electrical conductivity (EC)	5,000 $\mu\text{s}/\text{cm}$
pH	6.0 – 10.0
Sodium adsorption ratio (SAR) for heavy soils	180
Aluminium	20 mg/L
Arsenic	2.0 mg/L
Boron	6.0 mg/L
Cadmium	0.05 mg/L
Chromium	1 mg/L
Cobalt	0.1 mg/L
Copper	5 mg/L
Fluoride	6 mg/L
Iron	10 mg/L
Lithium	2.5 mg/L
Lead	5 mg/L
Manganese	10 mg/L
Mercury	0.002 mg/L
Molybdenum	0.05 mg/L
Nickel	2 mg/L
Zinc	5 mg/L

3.5.3. Fairview

Fairview produced water can either be irrigated via LAI or amended and irrigated via drip irrigation.

Fairview produced water can be distributed to the following LAI areas with a maximum application rate of 10 ML/ha/yr for pivot irrigation:

- IR3 pivot irrigation area;
- IR4 pivot irrigation area; and
- IR8 pivot irrigation area.

Amended produced water can be distributed to the following irrigation areas with a maximum application rate of 2.5 ML/ha/yr for drip irrigation areas and 10 ML/ha/yr for pivot irrigation areas:

- IR5 (1) drip irrigation area;
- IR5 (2) pivot irrigation area;
- IR6 (1) drip and pivot irrigation area;
- IR6 (2) drip and pivot irrigation areas;
- IR6 (3) pivot irrigation area; and
- IR7 drip irrigation area.

These areas are all operated by Santos in accordance with the Queensland Government's End of Waste Code and site specific RMMPs. Irrigation water quality limits for LAI and Amended irrigation areas are detailed in Table 9.

Table 9: Fairview LAI and Amended Irrigation Water Quality Limits

Quality Characteristic	LAI Irrigation Water	Amended Irrigation Water
Electrical conductivity (EC)	5,000 µs/cm	4,500 µs/cm
pH	6.0 – 10.0	4.5 – 8.5
Sodium adsorption ratio (SAR) for heavy soils	180	30
Aluminium	20 mg/L	20 mg/L
Arsenic	2.0 mg/L	2.0 mg/L
Boron	6.0 mg/L	6.0 mg/L
Cadmium	0.05 mg/L	0.05 mg/L
Chromium	1 mg/L	1 mg/L
Cobalt	0.1 mg/L	0.1 mg/L
Copper	5 mg/L	5 mg/L
Fluoride	6 mg/L	6 mg/L
Iron	10 mg/L	10 mg/L
Lithium	2.5 mg/L	2.5 mg/L
Lead	5 mg/L	5 mg/L
Manganese	10 mg/L	10 mg/L
Mercury	0.002 mg/L	0.002 mg/L
Molybdenum	0.05 mg/L	0.05 mg/L
Nickel	2 mg/L	2 mg/L
Zinc	5 mg/L	5 mg/L

3.5.4. Arcadia

Arcadia produced water is utilised at the Bottle Tree LAI area with a maximum application rate of 8 ML/ha/yr for pivot irrigation area.

Bottle Tree irrigation area is operated by Santos in accordance with the Queensland Government's End of Waste Code and site specific RMMP. Arcadia LAI water quality limits are detailed in Table 10.

Table 10: Arcadia LAI Irrigation Water Quality Limits

Quality Characteristic	Release Limit
Electrical conductivity (EC)	5,000 µs/cm
pH	6.0 – 10.0
Sodium adsorption ratio (SAR) for heavy soils	180
Aluminium	20 mg/L

Quality Characteristic	Release Limit
Arsenic	2.0 mg/L
Boron	6.0 mg/L
Cadmium	0.05 mg/L
Chromium	1 mg/L
Cobalt	0.1 mg/L
Copper	5 mg/L
Fluoride	6 mg/L
Iron	10 mg/L
Lithium	2.5 mg/L
Lead	5 mg/L
Manganese	10 mg/L
Mercury	0.002 mg/L
Molybdenum	0.05 mg/L
Nickel	2 mg/L
Zinc	5 mg/L

3.6. Release to Watercourses

In the Fairview field, up to 18 ML/day of desalinated produced water (permeate) (up to a maximum of 6,570 ML per year) can be released to the Dawson River in accordance with approval conditions (EPBC 2021/8914). The desalinated produced water is pumped from the ROP2 Desalinated Water Dam via a 5.3 km pipeline to a release point located at the upper limit of an ephemeral drainage feature. From there:

- The desalinated produced water is released to a fenced, rock-lined outlet at the head of an ephemeral drainage feature via a diffuser. The ephemeral drainage feature has been partially rock-armoured in selected areas of identified higher potential erosion for protection from scouring.
- The released desalinated produced water flows for 2.9 km down an ephemeral drainage feature before discharging into a waterhole (an oxbow lake).
- The waterhole is a semi-permanent water body estimated to have a volume of approximately 500 ML. The waterhole naturally discharges via a 2.2 km watercourse which discharges into the Dawson River midway between “Dawson’s Bend” and “Yebna Crossing”.

3.7. Aquifer re-injection

There is no reinjection of CSG produced water from the GFD project.

3.8. Brine / RO concentrate storage

Brine / RO concentrate (ROC) is produced as a by-product of the ROPs at Roma, Fairview and Arcadia. This waste stream is generated where desalination (e.g. reverse osmosis) is required to facilitate beneficial reuse of water.

All of the brine/RO concentrate storage dams described in Table 11 are designed and operated as ‘regulated structures’ in accordance with the requirements of the Queensland EP Act (1994).

Table 11: Brine Storage Dams

Asset	Purpose	Dam construction	Liner composition	Leak detection type	Maximum allowable storage volume (ML)
R-HCS-02 Brine Containment Dam A	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	324
R-HCS-02 Brine Containment Dam B	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer and seepage bores	321
F-HCS-04 350ML Remote Brine Dam A	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	351
F-HCS-04 350ML Remote Brine Dam B	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	359
F-HCS-04 350ML Remote Brine Dam C	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	359
F-HCS-04 350ML Remote Brine Dam D	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	358
F-HCS-04 350ML Remote Brine Dam E	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	360
Bottle Tree Brine Dam A	Brine / concentrate storage	In ground	Clay and HDPE	Under drainage and seepage bores	230
Bottle Tree Brine Dam B	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	308
Pine Ridge Dam	Brine / concentrate storage	In ground and above ground	Clay and HDPE	Under drainage and seepage bores	150

3.9. Brine and salt disposal

Ultimate management and subsequent disposal of brine will be carried out in accordance with regulatory requirements. It should be noted that the waste fluid is not classified as brine until it is concentrated up to a total

dissolved solids (TDS) exceeding 40,000 mg/L as defined by Environmental Authorities issued under the Queensland EP Act.

The waste management hierarchy (refer Figure 1) for prioritising management of brine (saline waste) includes:

- Priority 1 – brine or salt residues are treated to create useable products wherever feasible.
- Priority 2 – after assessing the feasibility of treating the brine or solid salt residues to create useable and saleable products, disposing of the brine and salt residues in accordance with strict standards that protect the environment.

The management options available can be divided into two categories: commercial salt recovery or disposal.

Commercial recovery of saleable salt product requires an assessment of a number of critical factors such as technical considerations, environmental impacts, market proximity and economic factors. Currently this option is not considered feasible due to the significant energy intensity, cost and low commercial volumes of salt.

Commercial salt beneficial use options may become more economic where economies of scale can be employed.

Currently the base-case management strategy for concentrated brine or salt comprises disposal. However, the transfer of brine or solid salt to a licenced waste management facility will only occur after other options have been assessed and considered unfeasible.

Brine concentration options can be used to reduce the volume of brine or to sufficiently concentrate brine to allow crystallisation of solid salt. Various technologies are available to enhance the rate of concentration. These technologies have differing energy intensity, environmental footprint, technical complexity, operability and economics.

This plan does not address the management of brine or salt, other than for storage as described in Section 3.8.

3.10. Residual drilling materials storage and disposal

Residual drilling material fluid comprises drill cuttings and drilling muds. Drill cuttings comprise rock and solid material and account for approximately 30 percent of the drilling fluids recovered from a well. The remaining 70 percent is comprised of drilling mud. Drilling mud is essentially water with additives designed increase the viscosity of the water which helps to entrain and return drill cuttings to the surface.

Drilling fluid is continuously processed during drilling to maximise the volume of drilling mud that can be recirculated and reused. Drill cuttings are preferentially removed during the drilling process to maintain the performance of the drilling mud, i.e. its ability remove drill cuttings from the bore.

Residual drilling materials comprise the drill cuttings and any drilling mud that is not reused or recycled. Residual drilling materials are ultimately managed as a waste stream. Management options for residual drilling material include the following:

- Land application – residual drilling materials are mechanically applied to land and subsequent incorporation into soils within the operational area of the well lease or other defined area in accordance with EA conditions.
- Dust suppression – water and residual drilling materials (fluids) are blended and applied to roads and access tracks or other disturbed areas to bind moisture and particulates of the upper road surface to limit airborne particulate as a result of truck traffic in accordance with EA conditions.
- Disposal to a licensed waste management facility.

Residual drilling materials may also be stored temporarily in brine dams prior to their eventual disposal at a licenced waste facility.

The exposure assessment pathways for residual drilling materials are addressed as part of the CRAF. The CRAF outlines the process to evaluate exposure pathways for low and high-risk chemicals as part of risk assessment requirements. If an exposure pathway is deemed to be not complete for a specific chemical, this must be discussed in the risk assessment specific to the use of that chemical. Based on the outputs of the risk assessments, there should be no significant risks of adverse impacts to MNES as a result of residual drilling materials management. The risk assessments included implementation of the Constraints Planning Protocol, any identified management controls and monitoring and the ongoing review of the effectiveness of controls.

4. MNES Exposure Pathway

For there to be a risk of adverse impact to MNES there needs to be:

- A source of produced water / waste (the hazard)
- An MNES receptor(s)
- A valid pathway – for the source water to reach the MNES receptor(s)

If any one of the above is missing, then there is no risk to MNES. For example, if there is either no source, no MNES present or no pathway present, then there can be no risk of adverse impact to MNES.

Potential sources, MNES receptors and pathways are described in the sections below.

MNES exposure pathways and MNES receptors relevant to the disposal of residual drilling material assessed in accordance with the CRAF. Please refer to this document and completed assessments for detailed exposure pathway analysis. Completed assessments are available on the Santos website (www.santos.com).

4.1. Produced water / waste sources - Hazards

Produced water from each development area in the GFD Project is gathered and transferred to water management facilities. Based on the activities described in Section 3, the following sources have been identified:

- Water stored in storage ponds listed in Tables 3-5.
- Water applied to irrigation areas described in Section 3.5.
- Water applied to engineered surfaces during construction and dust suppression.

NOTE: The risk of significant residual impacts to MNES associated with drilling and completion activities (including hydraulic fracturing) are addressed in the CRAF (see Section 10).

4.1.1. Conceptual Exposure Model

The following section describes potential migration pathways or mechanisms for produced water or waste they may facilitate an exposure to a receptor (if present). These migration mechanisms are carried into the exposure assessment below.

4.1.1.1. Irrigation

Irrigation aims to apply water in balance with crop demand in consideration of infiltration capacity, climatic conditions and soil quality objectives. Mechanisms by which irrigation water may migrate from the irrigated soils includes:

- Subsurface vertical migration
- Subsurface horizontal migration along a zone of lower permeability
- Surface flow or run-off down topographic gradient

For the purpose of this assessment all above migration pathways are considered.

4.1.1.2. Dust suppression

Dust suppression aims to minimise dust generation during construction activities at a given location and / or during vehicle movements between locations. Water is applied to the surface using spray equipment. In accordance with Environmental Authority conditions no pooling or run-off is permitted. Mechanisms by which dust suppression water may migrate may include:

- Subsurface vertical migration
- Subsurface horizontal migration along a zone of lower permeability
- Surface flow or run-off down topographic gradient

However, given the short duration of the activity and that no pooling of water is authorised, subsurface vertical or horizontal migrations are not considered valid migration pathways and will not be considered further.

Although surface run-off is also not authorised, it is retained as a potentially complete migration pathway for the purpose of the assessment due to the potential proximity of MNES to dust suppression activities.

4.1.1.3. Water Storages

Water storages are engineered structures designed to contain produced water in accordance with Environmental Authority requirements. Mechanisms by which water may migrate include:

- Subsurface vertical migration beneath the dam
- Subsurface horizontal migration along a zone of lower permeability beneath the dam
- Surface flow or run-off down topographic gradient from a failure to contain (walls of the storage or over topping).

For the purpose of this assessment all above migration pathways are considered.

4.1.1.4. Water Pipelines

Water pipelines are pressurised transport conduits to convey water from one location to another. They are buried (except at surface facilities). Given that pipelines are buried and under pressure, should releases occur, the water moves from an area of high pressure to low pressure via the path of least resistance. This results in the water migrating to the surface whereby it can undertake surface flow. Should the release volume / rate be limited then the expression of water may be visible as a wetted area.

Based on this the following potential migration pathway is considered:

- Surface flow or run-off down topographic gradient.

4.1.1.5. Residual Drilling Material

Potential migration pathway assessment is undertaken in accordance with the CRAF and outlined in completed chemical risk assessments. No further discussion is provided in this document.

4.2. MNES receptors

A description of potential MNES receptors within the GFD Project area and adjacent to the various irrigation areas (the main release points for produced water) is provided below. Potential MNES receptors identified via the DCEEWW Protected Matters Search Tool (PMST) are based on generic databases held by the Commonwealth and States and are not always validated by ground surveys. Confirmation of a PMST listed species is indicated in each of the following sub-sections.

4.2.1. Habitat for a MNES listed species

4.2.1.1. Scotia

The only PMST threatened flora species with the potential to occur within Scotia is detailed in Table 13. Field surveys within Scotia have failed to identify this species including surveys of the irrigation and adjacent areas and is therefore not considered to be present.

Six MNES threatened fauna species are predicted or known to be present within the Scotia area (see Table 14). A patch of vegetation mapped as Regional Ecosystem 11.3.2: Poplar box woodlands on alluvial plains is located 800m to the north-west of the irrigation area. This vegetation community potentially provides habitat values these EPBC Act listed threatened fauna species.

4.2.1.2. Roma

The PMST identifies one threatened flora species with a potential to occur within Roma project area as indicated in Table 13.

Field surveys within the vicinity of the project disturbances and the immediate surrounds have failed to identify the presence of *H. belsoni*.

The irrigation activities occur in areas of historic clearing that are dominated by exotic pasture grasses. This species is therefore not considered to be present within the irrigation and adjacent areas.

A number of different non-MNES vegetation communities are present within the project area including Blyth Creek and its tributaries that provide suitable habitat values for eight MNES threatened fauna species. These eight species and their corresponding distribution and known habitat uses are provided in Table 15.

4.2.1.3. Fairview

The PMST identifies nine threatened flora species with a potential to occur within Fairview project area as listed in Table 13. Three of the listed PMST flora species are confirmed to occur within the Fairview project area as indicated in Table 16.

A number of different vegetation communities and unique fauna habitats are present within the project area including the Dawson River and Hutton Creek. These vegetation communities provide suitable habitat values for 13 species of MNES threatened fauna species (see Table 16).

4.2.1.4. Arcadia

The PMST identifies 10 threatened flora species with potential to occur within the Arcadia project area as indicated in Table 13. Two of the listed PMST flora species are known to occur within the Arcadia project area as indicated in Table 17.

A number of different vegetation communities and unique fauna habitats are present within the project area including sandstone escarpments and caves, large areas of Brigalow and the Dawson River. These vegetation communities provide suitable habitat values for 13 species of MNES threatened fauna species (see Table 13).

Table 12: Likely occurrence of threatened MNES flora in GFD Project Area

Species	Common Name	EPBC Act Status ¹	Distribution and Known Habitat Use	Likely occurrence in GFD Project Areas			
				Scotia	Roma	FV ²	AV ³
<i>Homopholis belsonii</i>	Belson's panic	V	Field surveys within the vicinity of the project disturbances and the immediate surrounds have failed to identify the presence of <i>H. belsoni</i> .	L ⁴	L ⁴	X	X
<i>Acacia grandifolia</i>	-	V		X	X	L	L
<i>Aristida annua</i>	-	V		X	X	X	L
<i>Arthraxon hispidus</i>	Hairy-joint grass	V		X	X	L	X
<i>Bertya opposens</i>	-	V	<i>Bertya opposens</i> - recorded during surveys as growing in mixed shrublands on the sandstone hills and escarpments within the Fairview project area.	X	X	L&C ⁵	L
<i>Cadellia pentastylis</i>	Ooline	V	<i>Cadellia pentastylis</i> - occurs within the valley and in a variety of areas including open paddocks within the Arcadia project area	X	X	L	L&C
<i>Daviesia discolor</i>	-	V		X	X	L	L
<i>Dichanthium queenslandicum</i>	King Blue-grass	E		X	X	X	L
<i>Dichanthium setosum</i>	Bluegrass	V		X	X	X	L
<i>Eucalyptus beaniana</i>	Beans Ironbark	V		X	X	L	L
<i>Phaius australis</i>	Lesser Swamp Orchid	E		X	X	L	X

Species	Common Name	EPBC Act Status ¹	Distribution and Known Habitat Use	Likely occurrence in GFD Project Areas			
				Scotia	Roma	FV ²	AV ³
<i>Thesium australe</i>	Austral Toadflax, Toadflax	V		X	X	X	L
<i>Xerothamnella herbacea</i>	-	E	<i>Xerothamnella herbacea</i> - recorded during surveys to occur in the far northern areas of the Fairview project area, and is recorded in riparian areas in the southern half of the Arcadia project area	X	X	L&C	L&C
<i>Eriocaulon carsonii</i>	Salt Pipewort, Button Grass	E	<i>Eriocaulon carsonii</i> - is known to occur in a spring complex in the west of the project area.	X	X	L&C	X

- Table notes:
1. V = vulnerable; E = endangered
 2. FV is Fairview
 3. AV is Arcadia.
 4. L = Listed in the PMST
 5. C = Confirmed during a project

Table 13: Likely occurrence of threatened MNES fauna in GFD Project Area

Species	Common Name	EPBC Act Status ¹	Distribution and Known Habitat Use	Likely occurrence in GFD Project Areas			
				Scotia	Roma	FV ²	AV ³
<i>Botaurus poiciloptilus</i>	Australasian bittern	E	Heron-like waterbird inhabiting shallow vegetated wetlands with dense reeds, sedges or similar vegetation where it forages and nests (Pizzey and Knight 2010). It is found in coastal and subcoastal SE Australia including Tasmania, with the mid- to lower Murray-Darling drainage being an important population centre (Pizzey and Knight 2010, ALA 2019). It is infrequently recorded in inland southern Queensland, with no records in close proximity to the Site (ALA 2019).	X	L	L	L
<i>Erythrorichis radiatus</i>	Red goshawk	V	A sparsely distributed species occurring in north-eastern and northern Australia. It is a highly mobile species with a large home range; breeding habitat is in intact tall forest associated with major drainage lines, especially near permanent water bodies and where there is high avian prey diversity, but the species could potentially forage much further away from these areas (Marchant and Higgins 1993). Based on known occurrence (ALA 2019) the forested uplands of the Fitzroy and Dawson River catchments may potentially support this species.	X	X	✓	✓
<i>Geophaps scripta</i>	Squatter pigeon	V	Occurs in southern and central eastern Australia, being almost entirely confined to Queensland. It inhabits grassy woodlands with open areas for foraging habitat usually near a water source (Higgins and Davies 1996). There are numerous records from the adjacent Fairview gas-field (ALA 2019, Santos unpubl.).	X	X	L&C	✓
<i>Rostratula australis</i>	Australian painted snipe	E/M	Recorded over much of Australia other than the driest interior, but most frequently recorded within the Murray-Darling Basin (ALA 2019). Forages at shallow edges and adjacent vegetated margins of freshwater wetlands (DoEE 2019b) and is able to use both artificial and natural	✓	✓	✓	✓

Species	Common Name	EPBC Act Status ¹	Distribution and Known Habitat Use	Likely occurrence in GFD Project Areas			
				Scotia	Roma	FV ²	AV ³
			ephemeral and permanent wetlands (Marchant and Higgins 1993).				
<i>Turnix melanogaster</i>	Black-breasted button-quail	V	This bird lives in drier rainforest types (including SEVT), Brigalow shrubby open forest and littoral shrublands from about Byfield, central Qld south to the Northern Rivers area of NSW, where it forages in deep leaf litter (Smith and Mathieson 2012). The species is recorded at Palmgrove NP, ca. 80km northeast of the site and within a large tract of intact vegetation extending north and east from the Expedition Range (ALA 2019).	×	×	✓	✓
<i>Furina dunmalli</i>	Dunmall's snake	V	This snake is almost endemic to southern-central Queensland, having been also reported in the far north of NSW. Occupies woodlands and open forests; may be reliant on presence of abundant fallen woody debris (Hobson 2012). The species has been recorded from the nearby Arcadia Valley (BOOBOOK unpubl. data).	✓	✓	✓	✓
<i>Denisonia maculata</i>	Ornamental snake	V	This snake is endemic to Queensland. It occurs in lowlands associated with the Dawson and Fitzroy catchments (DoEE 2019b). Known southern distribution limit is approximately Lake Nuga Nuga, ca. 80 km northwest (ALA 2019). Lives in woodland and grassland with cracking clay soils, usually in close proximity to wet or seasonally wet areas e.g. billabongs, gilgais, floodplains, riparian corridors (DoEE 2019b).	×	×	×	✓
<i>Delma torquata</i>	Collared delma	V	This lizard is endemic to sub-coastal and inland southern Queensland. Occupies a range of eucalypt woodlands and open forests; lives under surface rock and large woody debris (Wilson 2015). The Site is within the species' potential range with several records from locations north-west of Roma (ALA 2019).	✓	✓	✓	✓
<i>Egernia rugosa</i>	Yakka skink	V	This lizard is endemic to inland southern Queensland, where it lives in a range of woodland and open forests	✓	✓	✓	✓

Species	Common Name	EPBC Act Status ¹	Distribution and Known Habitat Use	Likely occurrence in GFD Project Areas			
				Scotia	Roma	FV ²	AV ³
			dominated by Eucalyptus, Acacia and Callitris spp.; also, grassland with regrowth trees (DoEE 2019b). Requires suitable soils for burrows or shelters in sinkholes, abandoned rabbit warrens or large fallen/piled woody material (Eddie 2012). There are historical records of the species from the Arcadia Valley, ca. 30km northwest (ALA 2019).				
<i>Chalinolobus dwyeri</i>	Large-eared pied bat	V	This species occurs in inland to coastal areas of New South Wales and Queensland (ALA 2019). All known occurrences of this species are within or near forested landscapes with relatively high relief (DoEE 2019b). The species may be present in uplands with appropriate geology (usually sandstone) providing essential habitat (caves, crevices, holes) and associated foraging habitat. The species is known from Expedition Range NP and Belington Hut SF (ALA 2019).	×	×	✓	✓
<i>Nyctophilus corbeni</i>	South-eastern long-eared bat	V	The distribution and habitat preferences of this species are very poorly known, but it has been reported from a wide variety of dry woodland and open forest types in south central Queensland (Reardon 2012). The species has been recorded in the Expedition Range, with a record within 40km of the Site (ALA 2019).	✓	✓	✓	✓
<i>Dasyurus hallucatus</i>	Northern quoll	E	Formerly widespread in south-central Queensland this species has declined markedly and is now confined to rugged and remote areas throughout its distribution (Burnett 2012). Forested uplands with high relief and/or containing abundant rock outcrops may support the species. The nearest recent records are from the Carnarvon Range (ALA 2019).	×	×	✓	✓
<i>Phascolarctos cinereus</i>	Koala	V	Occurs in coastal and inland areas from South Australia to northern Queensland. This species requires eucalypt woodland and forest habitat with suitable food trees (primarily Eucalyptus spp.) (DoEE 2017b). Woodlands	✓	✓	✓	✓

Species	Common Name	EPBC Act Status ¹	Distribution and Known Habitat Use	Likely occurrence in GFD Project Areas			
				Scotia	Roma	FV ²	AV ³
			containing food trees in riparian/alluvial areas are particularly favoured (Melzer et al. 2014). The Site is within the known range of the species (ALA 2019). Potential food trees occurring within the Site include <i>Eucalyptus tereticornis</i> , <i>E. camaldulensis</i> , <i>E. populnea</i> , <i>E. melanophloia</i> , <i>E. major</i> and <i>E. crebra</i> .				
<i>Maccullochella peelii</i>	Murray cod	V	In Queensland naturally occurring populations of this species are confined to permanent water in riverine environments in the Condamine, Maranoa-Balonne, Weir, Moonie and Macintyre River catchments (Lintermans 2007).	×	✓	×	×
<i>Rheodytes leukops</i>	Fitzroy river turtle	V	The species is confined to the Fitzroy and Dawson River catchments of Queensland where it requires permanent water in riverine environments, preferentially foraging in shallow, well-oxygenated riffles (Limpus et al. 2011).	×	×	L&C	×
<i>Elsaya albagula</i>	Southern Snapping Turtle, White-throated snapping turtle	CE	The species is predominantly found in permanent waters of the Burnett, Mary and Fitzroy Rivers and their associated tributaries, and in nearby coastal waterways (e.g. Kolan and Burrum Rivers). However, there are also some records of the species from isolated waterholes in non-permanent reaches of the Burnett River and in some tributaries of the Fitzroy River. Confirmed sightings in the Dawson River within the Fairview project area.	×	×	L&C	✓

- Tables notes:
1. V = vulnerable; E = endangered; M = marine, CE = Critically Endangered
 2. FV is Fairview
 3. AV is Arcadia
 4. L = Listed in the PMST
 5. C = Confirmed during a project

4.2.2. Threatened ecological communities

4.2.2.1. Scotia

One EPBC Act Threatened Ecological Community (TEC): Brigalow (*Acacia harpophylla* dominant and codominant) occurs within the project area. A known patch of Brigalow TEC is located approximately 650m to the east of the Scotia irrigation area.

4.2.2.2. Roma

Three EPBC Act TECs occur within the project area. Brigalow (*Acacia harpophylla* dominant and co-dominant) occurs in many areas within the project area. This TEC is known to be present in proximity to Belbri and Bend South irrigation areas. There are two other TECs present within Roma. These TECs are Weeping Myall Woodlands with the Weeping Mayall (*Acacia pendula*) as the dominant (but not sole) overstorey species with and understorey of open layer of shrubs above an open ground layer of grasses and herbs and Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions Woodlands. Whilst these TECs are present with the Roma project area, they only occur in small, isolated patches and are not known to occur in the vicinity of the irrigation areas.

4.2.2.3. Fairview

Six TECs are potentially present in the Fairview project area as follows:

- Coolibah – Black Box Woodlands of the Darling Riverine Plains and the Brigalow belt South Bioregions
- Poplar Box Grassy Woodland on Alluvial Plains
- Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions
- Weeping Myall Woodlands
- Brigalow (*Acacia harpophylla* dominant and co-dominant) and,
- The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin.

Four TECs are confirmed to occur via survey in the Fairview project area as follows:

- RE 11.3.1 and/or 11.9.5 - Brigalow (*Acacia harpophylla* dominant and co-dominant) occurs on the undulating plains and lowlands within the Fairview project area.
- RE 11.9.4 - Semi-evergreen vine thickets (SEVT) of the Brigalow Belt (North and South) and Nandewar Bioregions TEC are predominately present on the moister south facing slopes associated with the sandstone escarpments. Both Brigalow and SEVT communities are common in Fairview and are located in close proximity to irrigation areas and water storages.
- RE 11.3.2 - Poplar Box Grassy Woodland on Alluvial Plains has been confirmed as being present and one (the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin)
- The Yebna2 spring complex, vent 534 is considered analogous with the EPBC TEC (GAB Springs) within the Fairview project area.

4.2.2.4. Arcadia

Field surveys conducted across the gas field have confirmed the presence of two TECs within Arcadia. Brigalow (*Acacia harpophylla* dominant and co-dominant) and the TEC 'Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar' are present. Both these communities are relatively common in Arcadia, and both occur in close proximity to irrigation infrastructure.

4.2.3. Migratory Species

All listed EPBC Act migratory species with potential to occur within the project area can best be described as passage, or seasonal migrant, or widely distributed and common species. All listed migratory species are unlikely to be significantly impacted by the proposed wastewater management activities as these will not substantially modify, degrade, destroy, or isolate an area of important habitat for any migratory bird species and will not seriously disrupt the lifecycle of an ecologically significant proportion of a population. In addition, the water management activities are not expected to result in unacceptable impact to migratory bird species.

4.2.4. Riparian vegetation and referable wetland

4.2.4.1. Scotia

A series of referable wetlands are associated with Bungaban Creek, located approximately 10km to the north of the irrigation area. Approximately 800m to the north-west of the irrigation area is the closest patch of riparian vegetation (associated with a tributary of Bullock Creek), mapped as Regional Ecosystem 11.3.2: Poplar box woodlands on alluvial plains.

4.2.4.2. Roma

Riparian vegetation is generally associated with Blyth Creek and its tributaries. It is mapped as Regional Ecosystem 11.3.25: River Red Gum (*Eucalyptus camaldulensis*) open forest to woodland, and is located approximately:

- 2.5km south-east of Pleasant Hills irrigation areas
- 2.2km east of Belbri/Somerset irrigation areas
- 300m north of Roleen irrigation area
- 100m north-west of Bend South Irrigation area

A series of Referrable Wetlands associated with Blyth Creek and its tributaries, is located approximately:

- 1.5km north-east of Bend South irrigation area
- 1km east of Pleasant Hills irrigation areas
- 800m east of Belbri/Somerset irrigation areas
- 300m north of Roleen irrigation areas.

4.2.4.3. Fairview

Riparian vegetation is generally associated with Hutton Creek and the Dawson River and their associated tributaries. The vegetation associated with both Hutton Creek and the Dawson River generally consists of:

- Regional Ecosystem 11.3.25: *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines. A riparian community growing below the high banks of the Dawson River, represented by woodland to open forest of Queensland Blue Gum (*Eucalyptus tereticornis*), River Oak (*Casuarina cunninghamiana*), Rough-barked Apple (*Angophora floribunda*) and Weeping Bottlebrush (*Melaleuca viminalis*), the latter dominating on lower banks. This RE is classified as Least Concern under the Queensland Nature Conservation Act (1992) and does not contain species listed in the EPBC Protected Matters report for the Fairview area.
- Regional Ecosystem 11.3.19: *Callitris glaucophylla*, *Corymbia* spp. and/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains, typically present on sandy levees above the high banks of the Dawson River that are considered to at least periodically access groundwater from shallow alluvial aquifers. The RE is listed as No Concern at present under the Nature Conservation Act (1992) and does not contain species listed in the EPBC Protected Matters report for the Fairview area

Hutton Creek is defined by DCCEEW as a permanent connected river with variable gaining and losing reaches in the areas immediately south of IR8 and IR1, west of IR6(1) and IR6(2), and north of IR5(1), IR5(2) and IR4. The aquatic Groundwater Dependent Ecosystem (GDE) rule generally states that the river is supported by channel alluvia connected to the Precipice Sandstone with a fresh, permanent groundwater connectivity regime.

There are four lacustrine wetlands situated along Hutton Creek and Dawson River within 5km of irrigated areas. All four wetlands are bound within the creek/riverbanks and have all been designated as derived terrestrial GDEs.

4.2.4.4. Arcadia

Riparian vegetation is generally associated with the Dawson River in the south of the project area and a number of small creeks that flow north. The vegetation associated with both systems is generally Regional Ecosystem 11.3.25: River Red Gum (*Eucalyptus camaldulensis*) open forest to woodland.

There are a number of smaller ephemeral wetlands in Arcadia Valley and these are generally associated with Regional Ecosystem 11.3.27.

4.2.5. Groundwater resource

4.2.5.1. Scotia

There are several water supply bores registered within the State of Queensland that are adjacent to Santos' produced water management activities in the Roma area.

The Hutton Sandstone is a major regionally extensive aquifer in the Surat Basin, with bore yields in the range of 0-12 L/s and water quality that is generally fresh to brackish (Golder, 2011). In the broader region, groundwater from this aquifer is used for town water supply, stock watering and domestic use. The groundwater level in the Hutton Sandstone aquifer at the proposed Scotia irrigation site is approximately RL 250 mAHD. Depth to the Hutton Sandstone aquifer is approximately 60-70m below ground level in proximity to the irrigation area. Groundwater flow direction at the Scotia irrigation area is towards the northwest (i.e. towards the Dawson River). Groundwater levels across a broader area were considered in Golder 2011, which indicated groundwater flow towards the north towards the Dawson River in the Hutton Sandstone across the Scotia Field. At a larger scale flow in the Hutton Sandstone is generally towards the southwest (i.e. down dip, and towards the areas of lower elevation within the Surat Basin). The nearest water supply bore constructed in the Hutton Sandstone is RN38337 is located about 800m north-west of Pivot 6.

A complex of discharge springs is located near Cockatoo Creek (Golder, 2011), at a distance of approximately 35 km from the irrigation area. The spring source aquifer for Cockatoo Creek spring is understood to be the Precipice Sandstone (OGIA 2019).

Watercourse springs (also referred to as aquatic GDEs in the JIF) were noted along Bungaban Creek in Golder (2011), at a distance of approximately 10 km from the irrigation area. The spring source aquifer for Bungaban Creek is understood to be the Hutton Sandstone or the Injune Creek Group depending on where it intersects the geology.

4.2.5.2. Roma

There are several water supply bores registered within the State of Queensland that are in proximity to Santos' produced water management activities in the Roma area.

The hydrogeological units underlying the various water management areas varies, with formations generally dipping from north-east to south-west, with the older formations outcropping in the north-east. The Roleen area is underlain by outcropping units of the Mooga Sandstone. The Bend South, Belbri/Somerset and Pleasant Hills areas are all underlain by the Bungil Formation.

The Mooga Sandstone is the shallowest aquifer unit beneath the irrigation areas. In the broader region, groundwater from this aquifer is used for town water supply, stock watering and domestic use and bore yields range widely up to 35 L/s. However locally the unit is close to outcrop and the water resource is not consistently present, particularly in more northern areas. Groundwater level in the Mooga Sandstone aquifer is shallowest at the location of the Bend South irrigation area where the groundwater level is 20m below the pivots and locally intersects ground surface and supports watercourse springs in Blyth Creek. The intersection of groundwater only supports permanent pools of water, not permanent flowing water, which suggests the intersection does not result in significant aquifer discharge.

The Orallo Sandstone is a minor aquifer though where groundwater is present is can support small scale stock and domestic uses.

Water supply bores in the local area are typically stock and domestic bores that access the Gubberamunda Sandstone which provides higher yielding fresh to brackish water supplies suitable for stock watering.

Groundwater flow directions in all formations is generally expected to be towards the south and south-west, i.e. down dip and towards the areas of lower elevation within the Surat Basin.

The nearest water supply bore constructed in the Mooga Sandstone is RN38337 is located about 800m north-west of Pivot 6.

The closest spring comprises the Barton spring complex. This complex comprises two discharge vent springs located approximately 30km north-east of the Roleen irrigation area. The spring source aquifer for Barton Spring complex is understood to be the Gubberamunda Sandstone (OGIA, 2016).

As described above, watercourse springs (aquatic GDEs) are noted along Blyth Creek (OGIA, 2016), at a distance of approximately 100m from the Bend South irrigation area. The spring source aquifer for Blyth Creek is understood to be the Mooga Sandstone.

4.2.5.3. Fairview

At Fairview all of the Surat Basin geological units dip to the south towards the deeper parts of the Surat Basin (such as the Mimosa Syncline). The Westgrove Sandstone generally underlies the irrigation areas on the central flat-lying parts of the elevated plateaus. This formation acts as a regional aquitard.

The Boxvale Sandstone proudly outcrops along the peripheries of the irrigated plateaus and formed the resistive layer against erosion of the escarpment. There are large swathes of Boxvale Sandstone outcrop across the escarpment, with permeable quartzose beds and regular fracturing and jointing patterns allowing for effective recharge along the escarpment ridges and gullies. This preferential recharge mechanism was recognised by Kellett et al. (2003) as one of the key components of GAB recharge, and far more effective than diffuse recharge to the water table. The Boxvale Sandstone dips to the south and groundwater in this formation flows away from the Hutton River valley downstream receptors.

The lower Evergreen aquitard lies beneath the Boxvale Sandstone and allowed for significant erosion during the formation of the incised valleys. This aquitard provides resistance to vertical flow between the Boxvale Sandstone and the deeper Precipice Sandstone aquifer.

The Precipice Sandstone lies at the base of the valley and is the source aquifer for several discharge springs along the Hutton Creek floodplain (down-gradient of the irrigation areas). The Precipice Sandstone also provides base flow to Hutton Creek. Generally, groundwater within this regional aquifer flows from northwest to southeast with a strong convergence of flow along the Dawson River near a number of Precipice Sandstone spring vents.

There are 55 existing, registered, sub-artesian (i.e. non-artesian) water supply bores in the immediate extents of the irrigation areas and up to 5km down-gradient of the irrigation areas. Seventeen bores are directly tapping the Boxvale Sandstone where it crops out along the plateaus. A majority of the remaining bores are situated along the precipice Sandstone/Evergreen Formation geological contact and are likely to either be Precipice Sandstone bores or deeper bores that intersect the Bandanna Formation.

There are sixteen spring vents along the floodplains of Hutton Creek and Dawson River within 5km of all Fairview irrigation areas. Fifteen of the springs have a permanent connection with the Precipice Sandstone (via surficial alluvia in places), and all sixteen are known aquatic GDEs (highest confidence based on local expert knowledge supported by field studies).

4.2.5.4. Arcadia

The Bowen Basin is a north-south oriented sedimentary basin of Permo-Triassic age predominately consisting of layered siltstones, sandstones, mudstones and shales. Basement rocks consist of Devonian to Carboniferous age strata including the Timbury Hills Formation and volcanic rocks (e.g. Roma Granite) (URS, 2011).

In the Arcadia Valley, the Rewan Group (a regional tight aquitard) outcrops and the GAB formations of the upper Bowen Basin (Moolayember Formation and Clematis Sandstone) are the prominent formations forming the steep cliffs of the Expedition Range. The lowest three formations of the Surat Basin sequence, the Precipice Sandstone, the Evergreen Formation and Hutton Sandstone are not present.

The Clematis Sandstone is the primary aquifer in the region and is hydraulically disconnected from the Arcadia Valley where the Bottle Tree Irrigation Area occurs. Quaternary Colluvium comprises the surface geology of the Bottle Tree Irrigation Area. The Quaternary Colluvium consists of clay, silt, sand and gravel and is a flood-plain alluvium system with shallow groundwater present.

4.3. Potential complete exposure pathways

Source, migration pathway and Receptor assessments have identified the specific potential pathways in each development area that have the potential to transmit produced water and / or waste sources to MNES receptors. The sub-sections below describe those potentially complete exposure pathways for each relevant project activity.

Where a source, receptor and a potentially complete or complete exposure pathway is identified, then further assessment is undertaken to determine whether there is a risk of significant adverse impact to a MNES receptor. Mitigation measures are then identified to manage such risk.

Monitoring actions are then assigned to assess the effectiveness of mitigation controls and assign triggers for further actions as required.

Both monitoring and management actions are described in the following sections.

4.3.1. Irrigation activities

4.3.1.1. Scotia

At Scotia, the potentially complete pathways associated with irrigation activities include:

- Riparian vegetation, mapped as Regional Ecosystem (RE) 11.3.2: Poplar box woodlands on alluvial plains, located approximately 800m to the north-west and down-gradient of the irrigation area. Given the presence of drainage features in proximity to the irrigation area, this pathway is considered as potentially complete.
- The Hutton Sandstone aquifer, located approximately 60-70 m below the irrigation area and its associated registered water supply bore RN38337. Given the duration of irrigation activities, regardless of the considerable depth to groundwater, this pathway is considered as potentially complete for the purpose of this assessment.

4.3.1.2. Roma

At Roma, the potentially complete pathways associated with irrigation activities include:

- Brigalow TEC – Some minor areas of Brigalow TEC occur down topographic gradient of the Bend South Pivot and west of the Roleen Pivots. In accordance with regulatory approvals, irrigation application rates must be managed to ensure irrigation water infiltrates the ground and the risk of run-off is minimised. However, for this purpose of this assessment the exposure pathway is considered as potentially complete.
- Blyth Creek and associated wetlands, located ~100 m from the Bend South Irrigation area. Given the presence of drainage features in proximity to the irrigation area, this pathway is considered as potentially complete.
- The Mooga Sandstone aquifer, located approximately 20 m below the Bend South irrigation area. Given the duration of irrigation activities and the vertical distance to the water table, this pathway is considered as potentially complete.

4.3.1.3. Fairview

At Fairview, the potentially complete pathways associated with irrigation activities include:

- Vegetation mapped as RE 11.9.4 Semi-evergreen vine thicket or *Acacia harpophylla* with a semi-evergreen vine thicket understorey on fine-grained sedimentary rocks within close proximity and downgradient of the IR8 and IR4 irrigation pivots (note that at the time of writing this plan, IR4 pivots were inactive). In accordance with regulatory approvals, irrigation application rates must be managed to ensure irrigation water infiltrates the ground and the risk of run-off is minimised. However, for this purpose of this assessment the exposure pathway is considered as potentially complete.
- Springs (aquatic GDEs) associated with Hutton Creek – the source aquifer (Precipice Sandstone) is hydraulically isolated from the irrigation areas through the presence of the Evergreen aquitard. This exposure pathway is incomplete.
- Hutton Creek and associated wetlands – irrigated water runoff is considered a potentially complete exposure pathways to Hutton Creek in the areas down-gradient of the irrigated plateaus.
- Boxvale Sandstone aquifer, located on the peripheries of the irrigated areas along the escarpment ridgelines. The strong fracture networks observed in outcrop indicates that this pathway is potentially complete.
- Precipice Sandstone aquifer, present along the base of the Hutton Creek valley floor. As described above, this aquifer is hydraulically isolated from the irrigation areas through the presence of the Evergreen aquitard. This exposure pathway is incomplete.

4.3.1.4. Arcadia

At Arcadia, the potentially complete pathways associated with the Bottle Tree Irrigation Area include:

- Some minor areas of Brigalow TEC occur 2 km west and down gradient of the Bottle Tree irrigation area. Given the distance to this TEC, the exposure pathway is incomplete.
- The nearest spring occurs approximately 16 km to the west of the irrigation area. This permanent spring (705-Spring Creek) is sourced from the Clematis Sandstone, which is hydraulically isolated from the irrigation area by the Rewan Formation. This exposure pathway is incomplete.
- There are no GAB or Bowen Basin aquifers in hydraulic connection with the Bottle Tree Irrigation Area. This exposure pathway is incomplete.
- There is one existing water supply bore within 5 km of the site (RN158164) which taps the Rewan Formation aquitard. There are four Santos dam seepage monitoring bores that tap the Rewan Formation aquitard to the northeast of the irrigation area. Given that the Rewan Formation is a tight regional aquitard (OGIA, 2019), this exposure pathway is incomplete.
- There are no surface spring ecosystems, watercourse springs, or subterranean GDE areas within 5km of the irrigation area. This exposure pathway is incomplete.

4.3.2. Dust suppression and construction activities

4.3.2.1. Scotia

At Scotia, the potentially complete pathways associated with dust suppression and construction activities include:

- Brigalow TEC – A potentially complete exposure pathway may exist should engineered surfaces, construction or dust suppression activities occur in proximity to a TEC. Location selection would be in accordance with the Constraints Planning Protocol.
- Bungaban Creek and associated wetlands - Given the presence of drainage features, this pathway is considered as potentially complete.
- Riparian vegetation, mapped as Regional Ecosystem 11.3.2: Poplar box woodlands on alluvial plains. Given the presence of drainage features this pathway is considered as potentially complete.
- The Hutton Sandstone aquifer – given significant depth to groundwater and limited duration and volume of application, this pathway is not considered complete.

4.3.2.2. Roma

At Roma, the potentially complete pathways associated with dust suppression and construction activities include:

- Brigalow TEC – A potentially complete exposure pathway may exist should engineered surfaces, construction or dust suppression activities occur in proximity to a TEC. Location selection would be in accordance with the Constraints Planning Protocol.
- Blyth Creek - Given the presence of drainage features, this pathway is considered as potentially complete.
- The Mooga Sandstone aquifer – given depth to groundwater, limited duration and typical volume of application, this pathway is not considered complete.

4.3.2.3. Fairview

At Fairview, the potentially complete pathways associated with dust suppression and construction activities include:

- Springs associated with Hutton Creek – the source aquifer (Precipice Sandstone) is hydraulically isolated from roads and construction areas situated on the elevated plateaus through the presence of the Evergreen aquitard. This exposure pathway is incomplete.
- Hutton Creek and associated wetlands – given the presence of drainage features this is considered as a potentially complete exposure pathway to Hutton Creek.

- Precipice Sandstone aquifer, present along the base of the Hutton Creek valley floor. As described above, this aquifer is hydraulically isolated from the elevated development areas through the presence of the Evergreen aquitard. This exposure pathway is incomplete.

4.3.2.4. Arcadia

At Arcadia, the potentially complete pathways associated with dust suppression and construction activities include:

- There are terrestrial GDEs situated within select locations of the Arcadia Valley. These are Quaternary alluvial aquifers with a fresh, intermittent groundwater connectivity regime. Given the presence of drainage features this is considered a potentially complete exposure pathway to these terrestrial GDEs.
- There are two threatened flora species known to occur within the project area and on Bottle Tree property. Ooline (*Cadellia pentastylis*) and Xerothamnella (*Xerothamnella herbacea*) occurs within select locations the valley including riparian areas. Given the presence of drainage features this is considered a potentially complete exposure pathway.
- Brigalow and the TEC 'Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar' are present within select locations of Arcadia. Given the presence of drainage features this is considered a potentially complete exposure pathway.

5. Measures to Avoid, Mitigate and Manage Adverse Impact

This section meets Condition 25B (a) of EPBC Approval 2012/6615, which requires that this plan must include:

- Detail measures that will be implemented to avoid, mitigate and manage impacts to surface and groundwater resources, EPBC threatened species, EPBC migratory species and EPBC communities as a result of the storage and disposal of CSG produced water and waste products during the life of the action.

Section 5.1 outlines Santos GLNG's constraints planning process. This describes how the planning process which locates project activities, including those related to the production, storage and disposal of CSG produced water and waste products during the life of the project, avoids adverse impact to ecologically sensitive areas. Ecologically sensitive areas include habitats that may support EPBC threatened species, EPBC migratory species and EPBC communities.

Section 5.2 provides information specific to the production, storage and disposal of CSG produced water and waste products during the life of the project at Scotia, Roma, Arcadia and Fairview. In summary, that section:

- describes the various mechanisms and processes by which an adverse impact to a water resource may occur without adequate management controls in place as a result of various actions.
- references the existing documentation that provides further information on.
- how the risk of adverse impact has been assessed.
- provides a justification for the measures that are implemented to avoid, mitigate and manage impacts to surface and groundwater resources.

5.1. Constraints to development

All project activities listed in Section 3 are considered hazards to groundwater resources, EPBC threatened species, EPBC migratory species and EPBC communities. For these hazards to pose a risk to MNES, both a MNES receptor and an exposure pathway must be present.

The Santos GLNG constraints planning process follows the approved Environmental Protocol for Constraints Planning and Field Development (available on the Santos website). Constraints planning provides a mechanism for avoidance and then minimisation of potential risks MNES through location selection, without the need for further mitigation or management.

The need for additional mitigation and management of activities in the following location section is determined after the application of the avoidance measures based on the evaluation of exposure pathways to an MNES receptor.

5.2. Determination of measures

The section provides information specific to the storage and disposal of CSG produced water and waste products during the life of the GFD project at Scotia, Roma, Fairview and Arcadia areas. These focus on avoiding uncontrolled releases of water or residual drilling material.

Based on the outcomes of the exposure / pathway assessment, Table 15, Table 16, Table 17 and Table 18 present a summary of the potential CSG waste management actions which without management controls in place, may pose a significant risk of adverse impact to MNES including water resources. It describes the various mechanisms and processes by which water or waste may be released.

Tables 15, 16, 17 and 18 then reference supporting documentation that can provide further information on how the risk of significant adverse impact has been assessed. The supporting documents justify the proposed measures that are implemented to avoid, mitigate and manage impacts to MNES receptors.

5.2.1. Water storage ponds

Most storage ponds described in Table 3, Table 4 and Table 5 include (where they are defined as regulated structures):

- Mandatory hydraulic performance engineering standards as defined by the Queensland Government to manage containment
- Leak detection systems and / or seepage monitoring bores to demonstrate containment and to the risk of seepage to both groundwater and the surface environment
- Annual engineering inspections by a Registered Engineer Practicing in Queensland (RE PQ) to demonstrate that the pond is performing as designed
- Maximum operating limits and mandatory reporting limits to manage the risk over topping

Early warning, trigger thresholds and limits for detecting impact on surface water and groundwater resources due to the operation of produced water storage ponds are provided in Section 6. A risk-based exceedance response plan is presented in Section 7.

5.2.2. Irrigation

In Queensland, criteria for irrigation water quality are defined in *End of Waste Code – Irrigation of Associated Water (including coal seam gas water)* (DETSI, 2025). This provides general approval conditions for resource producers and users issued in accordance with the *Queensland Waste Reduction and Recycling Act (2011)* (WRR Act). These criteria determine minimum standards that must be achieved by water management activities to avoid environmental impact and reflect the same standards that are applied to primary industries that may use any groundwater (i.e. from water bearing strata, including coal seams) for the same purpose. These criteria are adopted or derived in accordance with ANZECC (2000).

Where a generic standard for a particular water quality parameter cannot be met, an End of Waste Code RMMP is required. An RMMP:

- is provided to the administering authority and must be certified by an independent and suitably qualified person
- states the extent to which the water quality does not meet the generic required standard
- states the varied water quality parameters (for the parameters that do not meet the required standards) that ensures:
 - soil structure, stability and productive capacity can be maintained or improved
 - toxic effects to crops do not result; and
 - yields and produce quality are maintained or improved

RMMPs have been produced for each of the Irrigation areas described in Section 3.5. Monitoring of irrigation water quality, soil structure and chemistry, crop health and soil infiltration rates is specified in that RMMP.

Deep drainage refers to the infiltration of irrigation water beneath the shallow soil layer effectively utilised by the irrigated crop. Hydrogeological risk assessments (refer to Section 10) assess the risk of subsurface migration of irrigation water where deep drainage occurs. They assess that subsurface migration pathways to water resource receptors may be present such as land uses, terrestrial GDEs, aquatic GDEs, aquifers, registered water supply bores, springs (including GAB springs) and terrestrial receptors. The hydrogeological risk assessment reports for Scotia, Roma and Fairview have concluded that the risk of vertical and horizontal migration is very low and can be managed through irrigation management and monitoring. A hydrogeological risk assessment is not required for Arcadia because the presence of the Rewan Formation aquitard throughout the Arcadia Valley nullifies the risk of subsurface irrigation water migration in this area, i.e. there is no complete pathway to assess.

For irrigated areas in the Roma development, under a conservative modelled irrigation scenario, irrigation water is expected to largely remain within the vadose zone and not migrate laterally more than 50m laterally. This can be readily demonstrated through shallow groundwater monitoring throughout the life of the project. Should irrigation water reach the water table, the water quality approximates that of the receiving environment due to the large travel time and the dilution that occurs due to rainfall infiltration over the period it takes to reach groundwater. In most irrigation areas this period is more than 1000 years. For the northern-most pivots in the Bend South Irrigation area (Pivots 4 and 5), the period it takes to reach the water table is more than 100 years.

For irrigated areas in the Scotia development, salinity modelling through the vadose zone concludes that the risk of vertical and horizontal migration is very low and can be managed through irrigation design and monitoring. Under a conservative modelled irrigation scenario, irrigation water is predicted to migrate laterally less than 200 m from the pivot areas over a period of greater than 30 years and can be readily demonstrated through monitoring.

Irrigation water is expected to remain within the vadose zone and can be readily demonstrated through monitoring.

For irrigated areas in the Fairview development, salinity modelling through the vadose zone concludes that the risk of irrigation-induced deep drainage contributing salinity to the Boxvale Sandstone aquifer is very low. The migration of dissolved salts to groundwater may take decades to hundreds of years (based on solute transport modelling), and the salt flux will be small compared to the existing salt content in the aquifer.

Although no environmental receptors are predicted to be, or at risk of being impacted, monitoring is proposed to verify the report findings, demonstrate environmental outcomes and to inform adaptive management, if required.

5.2.3. Operational re-use of coal seam water

Assessment of complete pathways for operational water beneficial re-use is presented in Section 4.3. The State EA specifies that dust suppression water is not permitted to be applied at a rate that pools.

To manage this risk, Santos will not undertake dust suppression activities within or adjacent to watercourses. Further, the Constraints Planning Protocol avoids project activities, including dust suppression within or adjacent to areas of wetlands, including all springs.

Early warning, trigger thresholds and limits for detecting impact on surface water (and shallow groundwater at these locations) due to the suppression of dust on roads using coal seam water are provided in Section 6. A risk-based exceedance response plan is presented in Section 7.

5.2.4. Disposal of residual drilling material by land application

Without adequate management controls in place, the disposal of residual drilling material via land application has the potential to pose a risk surface water receptor. This is because application to land could take place within or adjacent to the surface water receptor, where project activities intersect or are proximal to them.

The *Eastern Queensland Residual Drill Material Management Plan (0007-650-PLA-0015)* (Santos 2024) and *Residual Drill Material: Land Application Procedure (0007-220-PRO-0026)* (Santos 2022) specify the methods used to manage risks to environmental receptors from residual drilling materials. This method outlines the application methods, volumes, application areas and monitoring which are required. Risk of exposure to MNES receptors is assessed in completed chemical risk assessments undertaken in accordance with the CRAF.

These documents show that the potential risk to MNES receptors is low because:

- the physical and chemical properties of the residual drilling material is largely benign, that is so not generally exceed screening criteria
- well leases are remote from surface water receptors, and surface water courses are ephemeral

- there is large vertical separation of groundwater receptors from surface activities
- EA conditions adequately regulate land application techniques and a methodology to avoid environmental harm has been developed by a suitable qualified third-party.

Although no environmental receptors are predicted to be or at risk of being impacted, monitoring demonstrates that environmental outcomes have been achieved. Monitoring comprises:

- visual observation of areas post application of the material
- sampling and characterisation of the residual drilling material from 1 in 10 wells; and
- sampling and characterisation of soil samples at 1 in 10 areas where residual drilling material has been applied to land approximately 12 months post application and after one wet season.

Early warning, trigger thresholds and limits for managing the risk of adverse impact to surface water and groundwater resources due to the disposal of residual drilling materials by land application are provided in Section 6. A risk-based exceedance response plan is presented in Section 7.

Should approved chemical risk assessments identify additional management controls or monitoring requirements, then the CSGWMP will be revised as outlined in Section 9.

Table 14: CSG waste assessment methods and controls for potential impacts to MNES in Scotia

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
Irrigation of produced water	Irrigation areas described in Section 3.5	Irrigation water migrates to surface water	Overland flow of irrigation water to surface water resource	Change in surface water quality	- Water balance modelling to quantify irrigation size and inform design to manage risk of run-off	Constraints planning protocol	- Irrigation location selection to ensure potential run-off is buffered by adjacent dryland cropping area - Design and control of irrigation area size and application rates to avoid run-off - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans ¹)
		Irrigation water migrates to a sensitive habitat	Overland flow of irrigation water to flora and / or fauna habitat	Impact to health of flora or fauna		End of Waste Code RMMPs (refer to Section 10).	
		Irrigation water migrates to a groundwater resource	Subsurface migration of irrigation water to groundwater resource	Change in ground water quality	- Water balance modelling and quantify size and inform design to quantify deep drainage rates	End of Waste Code RMMPs (refer to Section 10).	- Irrigation location selection - Design and control of irrigation area size and application rates to manage deep drainage rates - Monitoring of sub-surface migration pathways (specified in Section 6).
		Irrigation water migrates to surface water	Subsurface migration of irrigation water to surface water resource	Change in surface water quality	- Hydrogeological risk assessment	Scotia Irrigation Hydrogeological and Risk Assessment (Golder, 2017)	
		Irrigation water disperses the soil	Direct application	Impact to soil structure	- Threshold electrolyte concentration (TEC) calculation	End of Waste Code RMMPs (refer to Section 10).	- Irrigation location selection (soil type) - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans ¹)
		Irrigation water disperses the soil, rainfall runoff erodes and transports sediment to a water resource	Overland flow of sediment to surface water resource	Change in surface water quality	- Soil chemistry modelling - Calculation of stoichiometric quantities of amendment chemicals		
		Irrigation water affects crop, e.g. foliar damage, osmotic effects or toxicity to plant health	Direct application of irrigation water	Impact to crop health - change in productivity	- Irrigation foliar studies - Soil chemistry modelling (pH, University of Queensland)	End of Waste Code RMMPs (refer to Section 10).	
Dust Suppression	Within all development and operational areas in Scotia.	Dust suppression water migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	- Identify water resource and ecological receptors - Constraints planning protocol and location selection	Santos GLNG Upstream: Using Coal Seam Water and Liquids Management Specification	- Location selection - no direct application plus within 50m buffer of a watercourse - visual observations - no pooling of run-off
		Dust suppression water migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			
Application of Residual Drilling Material to Land	Within all well lease areas, camp locations, construction disturbance areas, operational areas, unsealed roads and tracks	Residual drilling material migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	- Identify water resource and ecological receptors - Constraints planning protocol and location selection	Chemical Risk Assessment Framework and associated chemical risk assessments	- Location selection - Design and control of application area size and application rates to avoid run-off - Visual observation – no run-off
		Residual drilling material migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna		Eastern Queensland Residual Drill Material Management Plan (0007-650-PLA-0015) (Santos	

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
		Residual drilling material disperses the soil	Direct application	Impact to soil structure	- Residual drilling material chemistry - Soil chemistry studies	2024) and Residual Drill Material: Land Application Procedure (0007-220-PRO-0026) (Santos 2022)	- Design and control of application area size and application rates - Monitoring, observation and adaptive management of irrigation application rates and residual drilling material quality
		Residual drilling material affects crop / pasture e.g. toxicity to plant health	Direct application	Impact to plant health - change in productivity	- Residual drilling material chemistry - Soil and foliar characterisation studies		

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Table 15: CSG waste assessment methods and controls for potential impacts to MNES in Roma

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
Irrigation of produced water	The irrigation areas described in Section 3.5.	Irrigation water migrates to surface water	Overland flow of irrigation water to surface water resource	Change in surface water quality	- Water balance modelling to quantify irrigation size and inform design to manage risk of run-off (probabilistic climatic modelling and crop/water modelling, verified by suitably qualified third-party)	Constraints planning protocol End of Waste Code RMMPs (refer to Section 10).	- Irrigation location selection to ensure potential run-off is buffered by adjacent dryland cropping area - Design and control of irrigation area size and application rates to avoid run-off - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans ¹) - Grazing and land management practices that maintain high infiltration rates and maintain healthy plants to maximise plant water uptake
		Irrigation water migrates to a sensitive habitat	Overland flow of irrigation water to flora and / or fauna habitat	Impact to health of flora or fauna			
		Irrigation water migrates to a groundwater resource	Subsurface migration of irrigation water to groundwater resource	Change in ground water quality	- Water balance modelling and quantify size and inform design to quantify deep drainage rates	End of Waste Code RMMPs (refer to Section 10).	- Irrigation location selection - Design and control of irrigation area size and application rates to manage deep drainage rates
		Irrigation water migrates to surface water	Subsurface migration of irrigation water to surface water resource	Change in surface water quality	- Hydrogeological risk assessment	Irrigation Hydrogeological and Risk Assessments (refer to Section 10..	- Monitoring of sub-surface migration pathways (specified in Section 6).
		Irrigation water disperses the soil	Direct application	Impact to soil structure	- Threshold electrolyte concentration (TEC) calculation	End of Waste Code RMMPs (refer to Section 10).	- Irrigation location selection (soil type) - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans ¹)
		Irrigation water disperses the soil, rainfall runoff erodes and transports sediment to a water resource	Overland flow of sediment to surface water resource	Change in surface water quality	- Soil chemistry modelling - Calculation of stoichiometric quantities of amendment chemicals		
		Irrigation water affects crop, e.g. foliar damage, osmotic effects or toxicity to plant health	Direct application of irrigation water	Impact to crop health - change in productivity	- Irrigation foliar studies - Soil chemistry modelling (pH, University of Queensland)	End of Waste Code RMMPs (refer to Section 10).	- Crop selection - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans ¹)
Dust Suppression	Within all development and operational areas in Roma	Dust suppression water migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	- Identify water resource and ecological receptors - Constraints planning protocol and location selection	Santos GLNG Upstream: Using Coal Seam Water and Liquids Management Specification	- Location selection - no direct application plus within 50m buffer of a watercourse - visual observations - no pooling of run-off
		Dust suppression water migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			
Application of Residual Drilling Material to Land	Within all well lease areas, camp locations, construction disturbance areas, operational areas, unsealed roads and tracks	Residual drilling material migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	- Identify water resource and ecological receptors - Constraints planning protocol and location selection	Chemical Risk Assessment Framework and associated chemical risk assessments Eastern Queensland Residual Drill Material	- Location selection - Design and control of application area size and application rates to avoid run-off - Visual observation – no run-off
		Residual drilling material migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
		Residual drilling material disperses the soil	Direct application	Impact to soil structure	- Residual drilling material chemistry - Soil chemistry studies	Management Plan (0007-650-PLA-0015) (Santos 2024) and Residual Drill Material: Land Application Procedure (0007-220-PRO-0026) (Santos 2022)	- Design and control of application area size and application rates - Monitoring, observation and adaptive management of irrigation application rates and residual drilling material quality
		Residual drilling material affects crop / pasture e.g. toxicity to plant health	Direct application	Impact to plant health - change in productivity	- Residual drilling material chemistry - Soil and foliar characterisation studies		

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Table 16: CSG waste assessment methods and controls for potential impacts to MNES in Fairview

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
Storage of produced water in ponds	All water storages described in Table 4 and Section 3.3.	Water over-tops or leaks from pond	Overland flow to surface water resource	Change in surface water resource quality		Constraints planning protocol	<ul style="list-style-type: none"> - Location selection - Design in accordance with Australian Standards and Environmental Authority conditions - Fit with water level sensor - Fit with leakage detection system
			Subsurface migration to groundwater resource	Change in ground water resource quality			
			Overland flow to flora or fauna habitat	Impact to health of flora or fauna			
Irrigation of produced water	The irrigation areas described in Section 3.5.	Irrigation water migrates to surface water	Overland flow of irrigation water to surface water resource	Change in surface water quality	<ul style="list-style-type: none"> - Water balance modelling to quantify irrigation size and inform design to manage risk of run-off (probabilistic climatic modelling and crop/water modelling, verified by suitably qualified third-party) 	Constraints planning protocol	<ul style="list-style-type: none"> - Irrigation location selection to ensure potential run-off is buffered by adjacent dryland cropping area - Design and control of irrigation area size and application rates to avoid run-off - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans¹) - Grazing and land management practices that maintain high infiltration rates and maintain healthy plants to maximise plant water uptake
		Irrigation water migrates to a sensitive habitat	Overland flow of irrigation water to flora and / or fauna habitat	Impact to health of flora or fauna			
		Irrigation water migrates to a groundwater resource	Subsurface migration of irrigation water to groundwater resource	Change in ground water quality	<ul style="list-style-type: none"> - Water balance modelling and quantify size and inform design to quantify deep drainage rates - Hydrogeological risk assessment 	End of Waste Code RMMPs (refer to Section 10).	
		Irrigation water migrates to surface water	Subsurface migration of irrigation water to surface water resource	Change in surface water quality			
		Irrigation water disperses the soil	Direct application	Impact to soil structure	<ul style="list-style-type: none"> - Threshold electrolyte concentration (TEC) calculation - Soil chemistry modelling - Calculation of stoichiometric quantities of amendment chemicals 	End of Waste Code RMMPs (refer to Section 10..)	
		Irrigation water disperses the soil, rainfall runoff erodes and transports sediment to a water resource	Overland flow of sediment to surface water resource	Change in surface water quality			
		Irrigation water affects crop, e.g. foliar damage, osmotic effects or toxicity to plant health	Direct application of irrigation water	Impact to crop health - change in productivity			
Dust Suppression	Within all development and operational areas in the Fairview area	Dust suppression water migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	<ul style="list-style-type: none"> - Identify water resource and ecological receptors - Constraints planning protocol and location selection 	Santos GLNG Upstream: Using Coal Seam Water and Liquids Management Specification	<ul style="list-style-type: none"> - Location selection - no direct application plus within 50m buffer of a watercourse - visual observations - no pooling of run-off
		Dust suppression water migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
Application of Residual Drilling Material to Land	Within all well lease areas, camp locations, construction disturbance areas, operational areas, unsealed roads and tracks	Residual drilling material migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	- Identify water resource and ecological receptors - Constraints planning protocol and location selection	Completed chemical risk assessments in accordance with the CRAF Eastern Queensland Residual Drill Material Management Plan (0007-650-PLA-0015) (Santos 2024) and Residual Drill Material: Land Application Procedure (0007-220-PRO-0026) (Santos 2022)	- Location selection - Design and control of application area size and application rates to avoid run-off - Visual observation – no run-off
		Residual drilling material migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			
		Residual drilling material disperses the soil	Direct application	Impact to soil structure	- Residual drilling material chemistry - Soil chemistry studies		- Design and control of application area size and application rates - Monitoring, observation and adaptive management of irrigation application rates and residual drilling material quality
		Residual drilling material affects crop / pasture e.g. toxicity to plant health	Direct application	Impact to plant health - change in productivity	- Residual drilling material chemistry - Soil and foliar characterisation studies		

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Table 17: CSG waste assessment methods and controls for potential impacts to MNES in Arcadia

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
Storage of produced water in ponds	All water storages described in Table 5 and Section 3.3.	Water over-tops or leaks from pond	Overland flow to surface water resource	Change in surface water resource quality		Constraints planning protocol	<ul style="list-style-type: none"> - Location selection - Design in accordance with Australian Standards and Environmental Authority conditions - Fit with water level sensor - Fit with leakage detection system
			Subsurface migration to groundwater resource	Change in ground water resource quality			
			Overland flow to flora or fauna habitat	Impact to health of flora or fauna			
Irrigation of produced water	The irrigation areas described in Section 3.5.	Irrigation water migrates to surface water	Overland flow of irrigation water to surface water resource	Change in surface water quality	<ul style="list-style-type: none"> - Water balance modelling to quantify irrigation size and inform design to manage risk of run-off (probabilistic climatic modelling and crop/water modelling, verified by suitably qualified third-party) 	Constraints planning protocol	<ul style="list-style-type: none"> - Irrigation location selection to ensure potential run-off is buffered by adjacent dryland cropping area - Design and control of irrigation area size and application rates to avoid run-off - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Resource Monitoring and Management Plans¹) - Grazing and land management practices that maintain high infiltration rates and maintain healthy plants to maximise plant water uptake
		Irrigation water migrates to a sensitive habitat	Overland flow of irrigation water to flora and / or fauna habitat	Impact to health of flora or fauna			
		Irrigation water migrates to a groundwater resource	Subsurface migration of irrigation water to groundwater resource	Change in ground water quality	<ul style="list-style-type: none"> - Water balance modelling and quantify size and inform design to quantify deep drainage rates - Hydrogeological risk assessment 	End of Waste Code RMMPs (refer to Section 10).	
		Irrigation water migrates to surface water	Subsurface migration of irrigation water to surface water resource	Change in surface water quality		Irrigation Hydrogeological and Risk Assessments (refer to Section 10).	
		Irrigation water disperses the soil	Direct application	Impact to soil structure	<ul style="list-style-type: none"> - Threshold electrolyte concentration (TEC) calculation - Soil chemistry modelling - Calculation of stoichiometric quantities of amendment chemicals 	End of Waste Code RMMPs (refer to Section 10).	
		Irrigation water disperses the soil, rainfall runoff erodes and transports sediment to a water resource	Overland flow of sediment to surface water resource	Change in surface water quality			
		Irrigation water affects crop, e.g. foliar damage, osmotic effects or toxicity to plant health	Direct application of irrigation water	Impact to crop health - change in productivity	<ul style="list-style-type: none"> - Irrigation foliar studies - Soil chemistry modelling (pH, University of Queensland) 	End of Waste Code RMMPs (refer to Section 10..)	
Dust Suppression	Within all development and operational areas in the Arcadia area	Dust suppression water migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	<ul style="list-style-type: none"> - Identify water resource and ecological receptors - Constraints planning protocol and location selection 	Santos GLNG Upstream: Using Coal Seam Water and Liquids Management Specification	<ul style="list-style-type: none"> - Location selection - no direct application plus within 50m buffer of a watercourse - visual observations - no pooling of run-off
		Dust suppression water migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			

Proposed Action	Locations	Unwanted event / causal factor	Complete or potentially complete pathway to MNES receptor	Potential adverse impact	Assessment methodology	Supporting documentation	Management controls
Application of Residual Drilling Material to Land	Within all well lease areas, camp locations, construction disturbance areas, operational areas, unsealed roads and tracks.	Residual drilling material migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	- Identify water resource and ecological receptors - Constraints planning protocol and location selection	Completed chemical risk assessments in accordance with the CRAF Eastern Queensland Residual Drill Material Management Plan (0007-650-PLA-0015) (Santos 2024) and Residual Drill Material: Land Application Procedure (0007-220-PRO-0026) (Santos 2022)	- Location selection - Design and control of application area size and application rates to avoid run-off - Visual observation – no run-off
		Residual drilling material migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna			
		Residual drilling material disperses the soil	Direct application	Impact to soil structure	- Residual drilling material chemistry - Soil chemistry studies		- Design and control of application area size and application rates - Monitoring, observation and adaptive management of irrigation application rates and residual drilling material quality
		Residual drilling material affects crop / pasture e.g. toxicity to plant health	Direct application	Impact to plant health - change in productivity	- Residual drilling material chemistry - Soil and foliar characterisation studies		

1 – Resource Monitoring and Management Plans – as required by the QLD 'End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW07546918)' (refer to Section 10)

6. Early Warning Indicators, Trigger Thresholds and Limits for Detecting Impact

This section meets the requirements of Condition 25B of EPBC Approval 2012/6615, which states that this plan must include:

- Early warning indicators, trigger thresholds and limits for detecting impacts on surface water and groundwater quality as a result the storage and disposal of CSG produced water and waste products.

Table 18 describes the early warning indicators, triggers thresholds and limits for detecting impacts MNES within the Scotia, Roma, Fairview and Arcadia development areas.

These monitoring values have been derived conservatively. For example, an exceedance of a 'limit for detecting impact' would not necessarily confer that an impact to surface water or groundwater quality and associated MNES has occurred or is likely to occur in the future. The early warning indicators, trigger thresholds and limits for detecting impact have been derived to demonstrate that the pathways to adverse impact need to be confirmed and may remain only partially or entirely incomplete.

Management responses to exceedances of trigger thresholds, as presented in Section 7, will require investigation of the potential adverse impact, relative completion of the impact pathway, and the need for possible impact mitigation or site remediation. New or modified existing management controls may also be necessary to prevent a recurrence of the trigger threshold exceedance and will be confirmed pending the application of the management response to that exceedance.

The risk-based exceedance responses which are described in Section 7 include the ability to review and revise the derivation of early warnings, trigger thresholds and limits for detecting impacts on surface and groundwater quality. This plan would be revised in accordance with Section 9 if a revision of the values is required or if a new and/or modified management control is identified as necessary.

Table 18: Proposed Early Warning, Threshold Triggers and Limits for detecting risk of impact related to management of CSG produced water and waste products across the Santos GFD

Proposed action	Unwanted event / causal factor	Complete or potentially complete pathway	Potential adverse impact	Attribute to monitor	Method	Early Warning Indicator (EW) monitoring result	EW management response	Trigger Threshold (TT) monitoring result	TT management response	Limit for detecting impact
Storage of produced water in ponds	Produced water over-tops or leaks from pond	Overland flow to surface water resource	Change in surface water resource quality	- Pond integrity - Pond level	- Telemetered pond water level readings (daily) - Inspection of leak detection system (bi-annual) - Engineering inspection of pond condition and integrity (annual)	- Water level reaches maximum operating level (MOL) - Fluid detected in leak detection system	- Reduce volume of water stored in pond - Fluid in leak detection system is sampled and analysed in the lab.	- Water level reaches mandatory reporting level (MRL) - Fluid analysed from leak detection system is confirmed to be produced water	- Reduce volume of water stored in pond to safe levels - Pond liner repair / remedial engineering actions to reinstate integrity of liner	Water level reaches design storage limit (DSA)
		Subsurface migration to groundwater resource	Change in ground water resource quality							
		Overland flow to flora or fauna habitat	Impact to health of flora or fauna							
Land amendment irrigation of coal seam water	Irrigation water migrates to surface water	Overland flow of irrigation water to surface water resource	Change in surface water quality	- Applied irrigation volume - Land run-off	- Visual inspection of soil within the pivot, and land surface immediately adjacent to pivots (Weekly) - Measure of irrigation application volume (daily) - Refer to EMP	- Visual inspection identifies irrigation water run-off to adjacent targeted (buffer) dryland grazing areas	- Implement adaptive management (e.g. adapt irrigation volume, duration, frequency, time of day) - Continue visual monitoring to evaluate effectiveness	Visual inspection identifies: - irrigation water run-off in area outside the adjacent targeted (buffer) dryland grazing areas - changes in grazing vegetation type i.e. species adapted to wetter conditions in adjacent target (buffer) dryland areas	- Implement adaptive management (e.g. adapt irrigation volume, duration, frequency, time of day) - Increased frequency of visual monitoring to evaluate effectiveness of management - Increase extent of monitoring to include down-gradient drainage feature	Visual inspection identifies irrigation water run-off within drainage feature
	Irrigation water migrates to a sensitive habitat	Overland flow of irrigation water to flora and / or fauna habitat	Impact to health of flora or fauna							
	Irrigation water migrates to a groundwater resource	Subsurface migration of irrigation water to groundwater resource	Change in ground water quality	Groundwater along vertical migration pathway via seepage monitoring bore	Seepage detection (vertical migration pathways) via a monitoring bore located in a zone of lower permeability (i.e. >10m deep, <10m from irrigation area, or appropriate to subsurface conditions) (bi-annual)	- Groundwater detected in the monitoring bore (baseline bore condition is expected to be dry, with no groundwater present) - Monitoring bore may be used for both groundwater and surface water resource monitoring attribute and method if appropriate based on hydrogeological impact assessment.	- Continue to monitor groundwater levels in monitoring bore (biannually) - Sample groundwater and analyse for geochemical indicators (see Table 20) - Review and revise hydrogeological impact assessment, if required	Water quality analysis of seepage water verifies presence of irrigation water along pathway (see Section 6.1)	- Re-sample to confirm the result after 3 months - Report the confirmed results to DCCEE (within 30 business days) - Review and revise hydrogeological impact assessment, if required - Assess need to implement contingency irrigation areas to reduce irrigation volumes at that location - Install receptor monitoring bore(s) and commence receptor monitoring biannually (see Table 20 and Section 6.1)	Detection of irrigation water at receptor (receptor monitoring only installed once trigger threshold exceeded) (see Table 20 and Section 6.1)
	Irrigation water migrates to surface water	Subsurface migration of irrigation water to surface water resource	Change in surface water quality	Groundwater along horizontal migration pathway via seepage monitoring bore	Seepage detection along horizontal migration pathways via multiple shallow monitoring bores (i.e. <10m deep, <250m from irrigation area, or appropriate to subsurface conditions) (bi-annual).					

Proposed action	Unwanted event / causal factor	Complete or potentially complete pathway	Potential adverse impact	Attribute to monitor	Method	Early Warning Indicator (EW) monitoring result	EW management response	Trigger Threshold (TT) monitoring result	TT management response	Limit for detecting impact
	Irrigation water disperses the soil	Direct application	Impact to soil structure	- Applied irrigation volume and water quality	- Soil surface coring / sampling, laboratory analysis (bi-annual). - Visual inspection of soil in irrigation areas (weekly) - Refer to EMP	Visual inspection identifies soil dispersion within irrigation area	- Implement adaptive management and remedial actions (e.g. application of additional land amendment, mechanical tilling of the soil surface) - Continue visual monitoring to evaluate effectiveness	Soil surface coring / sampling and laboratory results identify surface average SAR within the irrigation area >30 and / or pH >8.4	- Implement adaptive management and remediation (e.g. application of additional amendments, and mechanical tilling of the soil surface) - Increase soil coring / sampling across irrigation area - Continue visual monitoring to evaluate effectiveness - Assess need to implement contingency irrigation areas to reduce irrigation volumes at that location	- Visual monitoring or soil surface core / sample analysis indicates significant dispersion across the irrigation area (>25% of locations)
	Irrigation water disperses the soil, rainfall runoff erodes and transports sediment to a water resource	Overland flow of sediment to surface water resource	Change in surface water quality	- Soil condition and chemistry in irrigation area						
	Irrigation water affects crop, e.g. foliar damage, osmotic effects or toxicity to plant health	Direct application of irrigation water	Impact to crop health	- Crop health and plant tissue condition - Soil chemistry in irrigation area	- Visual inspection of crop health (weekly) - Plant tissue sampling and laboratory analysis (annual) - Soil coring, sampling and laboratory analysis (bi-annual) - Refer to EMP	Visual inspection identifies localised indicators of plant stress	- Implement adaptive management and remedial actions (e.g. application of additional amendments, induce additional deep drainage and or alter duration, frequency or time of irrigation)	Visual inspection identifies significant indicators of plant stress (>25%)	- Investigate and identify most likely causal factor (e.g. using plant tissue results and soil sampling results) - Implement adaptive management and remediation (e.g. application of additional amendments, induce additional deep drainage and or alter duration, frequency or time of irrigation) - Assess need to implement contingency irrigation areas to reduce irrigation volumes at that location	- Visual inspection identifies significant indicators of plant stress (>50%)
Dust suppression of coal seam water	Dust suppression water migrates to a watercourse	Direct application Run-off to adjacent area	Change in surface water quality	Applied surface	Visual inspection of application areas if undertaken within 200m of a watercourse.	Visual inspection - pooling or run-off	Cease application or continue application at a reduced rate.	Visual inspection – soil dispersion adjacent to roads	Assess need for and execute remediation, if required	Application of irrigation water outside of approved areas
	Dust suppression water migrates to a sensitive habitat	Direct application Run-off to adjacent area	Impact to health of flora or fauna							
	Residual drilling material	Direct application	Change in surface water quality	Applied volume, rate and quality		Visual inspection – run-off and	- Continue application at a reduced rate.	Visual inspection – application in non-	--Cease application	Visual inspection identifies residual

Proposed action	Unwanted event / causal factor	Complete or potentially complete pathway	Potential adverse impact	Attribute to monitor	Method	Early Warning Indicator (EW) monitoring result	EW management response	Trigger Threshold (TT) monitoring result	TT management response	Limit for detecting impact
Application of residual drilling material to land	migrates to surface water	Run-off to adjacent areas			<ul style="list-style-type: none"> - Measure application volume (each spreading / application event) - Visual inspection of application area - Sample and test 10% of residual drilling material 	evidence of residual drilling material within a drainage feature	-Continue visual monitoring to evaluate effectiveness	target areas and run-off	<ul style="list-style-type: none"> - Implement adaptive management (e.g. adapt application volume, duration, frequency, time of day) - Increased frequency of visual monitoring to evaluate effectiveness of management 	drilling material within drainage feature
	Residual drilling material migrates to a sensitive habitat	Direct application Run-off to adjacent areas	Impact to health of flora or fauna			Visual inspection –run-off	Continue application at a reduced rate. -Continue visual monitoring to evaluate effectiveness	Visual inspection – application in non-target areas and run-off	<ul style="list-style-type: none"> --Cease application - Implement adaptive management (e.g. adapt application volume, duration, frequency, time of day) - Increased frequency of visual monitoring to evaluate effectiveness of management 	Visual inspection identifies residual drilling material within sensitive habitat
	Residual drilling material disperses the soil	Direct application	Impact to soil structure	<ul style="list-style-type: none"> - Applied volume, rate and quality Characterisation of soils 12 months post application and one wet season 		<ul style="list-style-type: none"> - Visual inspection identifies soil dispersion within application areas - Soil sample results confirm the source of dispersion to be attributed to residual drilling material. 	<ul style="list-style-type: none"> - Implement adaptive management and remedial actions (e.g. application of additional land amendment, mechanical tilling of the soil surface) - Continue visual monitoring to evaluate effectiveness and collect soil samples as required. 	<ul style="list-style-type: none"> - Visual inspection identifies significant soil dispersion (>10% of locations) - Soil sample results consistently exceed parameters in comparison to analogue site 	<ul style="list-style-type: none"> - Investigate and identify most likely causal factor (e.g. using soil sampling results) - Implement adaptive management and remediation (e.g. application of additional amendments, induce additional deep drainage) - Continue visual monitoring for effectiveness. 	Visual monitoring or soil analysis indicate significant dispersion across applied surfaces (>25% of locations)
	Residual drilling material affects crop / pasture e.g. toxicity to plant health	Direct application	Impact to plant health	Plant health and condition		Visual inspection identifies localised indicators of plant stress	<ul style="list-style-type: none"> - Implement adaptive management and remedial actions (e.g. application of additional amendments, mechanical tilling of the soil surface) 	Visual inspection identifies significant indicators of plant stress (>25% of applied area after wet season)	<ul style="list-style-type: none"> - Investigate and identify most likely causal factor (e.g. using soil sampling results) - Implement adaptive management and remediation (e.g. application of additional amendments, induce additional deep drainage) - Continue visual monitoring for effectiveness. 	Visual inspection identifies significant indicators of plant stress (>50% after wet season)

Table 19: Analytes for groundwater samples collected from proposed irrigation early warning seepage bores, groundwater bores and receptor monitoring bores

Analyte	Units	Level of detection	Trigger threshold value	Indicator type
Electrical conductivity ¹	µS/cm	1	920	Receptor monitoring
Total dissolved solids (TDS)	mg/L	1	Presence of irrigation water	Geochemical Indicator / Evaluation
Major anions	mg/L	1		
Major cations	mg/L	1		
Alkalinity (bicarbonate, carbonate and total)	mg/L	1		
Aluminium* ²	mg/L	0.01	0.027	Receptor monitoring
Boron* ²	mg/L	0.001	0.09	
Cadmium* ²	mg/L	0.0001	0.06	
Chromium (total)* ²	mg/L	0.001	0.001 (0.00001)	
Copper* ²	mg/L	0.001	0.001	
Lead* ²	mg/L	0.001	0.001	
Manganese* ²	mg/L	0.001	1.2	
Mercury* ²	mg/L	0.0001	0.0001 (0.00006)	
Nickel* ²	mg/L	0.001	0.008	
Selenium* ²	mg/L	0.001	0.005	
BTEX ²	µg/L	2	200	
Poly-aromatic hydrocarbons ²	µg/L	1	2	

*Dissolved

¹ Conversion from ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)

² ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)

6.1. Detection of groundwater in irrigation monitoring bores

If groundwater is identified in irrigation monitoring bores, then samples will be collected and analysed for the geochemical indicators shown in Table 19. The laboratory analytical results will be assessed using geochemical evaluation methods. The purpose of this evaluation is to identify whether the sampled water comprises irrigation water or is naturally occurring in the environment using multiple lines of evidence. To achieve this, the evaluation may include analytical results from the following locations:

- Irrigation seepage bore(s);
- Background groundwater monitoring bore(s); and/or
- Other groundwater or surface water monitoring locations.

The evaluation will also consider subsurface conditions (e.g. baseline, post-baseline results and monitoring bore construction records) and the findings of the hydrogeological impact assessment. Where water is present in groundwater monitoring bores (e.g. background monitoring bores), the geochemical evaluation methods can be used to identify potentially negative changes to water quality and trends overtime. Evaluation tools used will include Stiff Plots and/or Piper Diagrams (described in sections below).

If the evaluation identifies that the water present within the monitoring bore is irrigation water, then the relevant early warning or trigger response will be initiated. If the trigger threshold management response resample confirms the presence of irrigation water along the pathway, the minister will be notified of the trigger threshold exceedance in accordance with Table 18 and Section 9.2 and receptor monitoring will commence. An environmental assessment will commence to define the receptor monitoring locations, in consideration of the subsurface conditions, and monitoring will commence biannually, post-construction of monitoring bore(s), for the receptor monitoring indicators presented in Table 19. The receptor monitoring indicators may be revised, dependent on the receptor (i.e. surface water / groundwater), in accordance with the Water Quality Management Framework (Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG), 2018).

6.1.1. Stiff plots

Similar to a Schoeller diagram, a Stiff plot can be used to compare different water quality samples and to monitor changes in water chemistry both temporally and spatially. Results are plotted in meq/L, and the polygon presented is broken up into halves. The left-hand side of the polygon plots a summary of cation data, while the right-hand side displays that of anions. As a result, these diagrams are typically used as a quick comparison of waters from different sources.

6.1.2. Piper diagram

A Piper Diagram graphically displays the nature of a water sample in terms of cations, anions and total ions, and can be used to differentiate the types of water in a given aquifer or collection of aquifers and to compare temporal, spatial and source changes (depending on zone isolation, etc.). The lower left triangle (presented on the left of the tab) summarises cations in the form of $\text{Na}^+ + \text{K}^+$, Ca^{2+} and Mg^{2+} , while the lower right triangle (on the right of the display) focuses on anions in the form of SO_4^{2-} , Cl^- and HCO_3^{2-} . The data displayed on the two cation/anion triangles are then combined, and plotted on the quadrilateral plot, displayed in the centre of the tab. Concentrations on Piper diagrams are expressed as % meq/L.

7. Exceedance Response and Reporting

This section meets the following Condition 25B (e) EPBC Approval 2012/6615, which requires that this plan must include:

- Details of a risk-based exceedance response for the activities the approval holder will undertake, and the timeframes in which these actions will be undertaken, if early warning indicators, trigger threshold values or limits are exceeded, including reporting of the location and severity of exceedance/s to the Minister.

7.1. Risk-based exceedance responses

Monitoring and management controls are implemented by Santos GLNG to manage and mitigate against the risks presented in Table 14 to Table 17.

The monitoring and response approach outlined in Table 14 to Table 17, and justified below, is conservative in respect of detecting a change in the potential for impact far in advance of any impact actually occurring.

No significant impacts to MNES are expected. The proposed management responses are adaptive. If justified, re-assessment and revision of this monitoring and management plan may be required if new information becomes available that justifies a less conservative approach (see Section 9).

Table 18 presents the Early Warning and Trigger Threshold values and proposed management responses that comprise risk-based exceedance responses for the assessed project activities.

The following sections justify the risk-based approach to the monitoring and management. All monitoring requirements and frequency of monitoring are outlined in the relevant management documents, including the relevant Environmental Authority, RMMP, Residual Drill Material Management Plan and Procedure, End of Waste Code(s) and this plan. Refer Section 10 for a list of supporting documentation.

7.1.1. Storage of produced water in ponds

The risk-based exceedance response plan for the storage of produced water in water ponds relies on pond water level monitoring and the monitoring of leak detection and / or seepage systems.

This design and operation of these ponds adheres to relevant Australian standards or regulatory obligations imposed by the Queensland Government. The monitoring approach outlined ensures that pond leakage and overtopping is adequately managed. Furthermore, the location of these storage ponds, being sited away from potential water resources, means the risk to water resources or other MNES due to a loss of containment is extremely low.

7.1.2. Irrigation

The risk-based exceedance response plan for irrigation produced water is complex. The various approaches that are shown in Table 18 are unique to the causal factor, migration pathway and potential adverse impact. The approaches are summarised and justified under the following headings:

- Adverse impacts due to over land migration
- Adverse impacts due to subsurface migration
- Adverse soil dispersion impacts
- Adverse impacts to crop health and yield.

7.1.2.1. Adverse impacts due to over-land migration

The risk-based exceedance response plan for the irrigation of produced water, in respect of the risk of produced water migration to water resources via overland flow, relies on monitoring of application rates and visual inspection of the pivot areas and its surrounds.

An observational approach to the management of irrigation water at, or immediately adjacent to the irrigation areas, will directly prevent the loss of irrigation water and risk of migration to receptors via surface run-off. This approach recognises that many factors combine to affect soil infiltration rates, for example antecedent rainfall, crop condition, temperature and humidity, and so an adaptive and observational approach to application rates is both practical and reliable.

7.1.2.2. Adverse impacts due to subsurface migration

The risk-based exceedance response plan in respect of subsurface migration of irrigation to both groundwater and surface water resources, depends on groundwater monitoring.

This approach is justified by the findings of the hydrogeological risk assessments (see Section 10). These reports show that the risk to water resources due to subsurface migration of irrigation water is low because:

- the horizontal migration pathway to surface water resources is incomplete (i.e. the rate and duration of application is not sufficient enough to allow irrigation water to migrate more than around ~50 m (Roma) to ~200 m (Scotia) from the irrigation areas over 30 years).
- the rate of vertical migration will be so slow that the potential impact to groundwater resource quality is mitigated by the exceedingly slow rate of release of irrigation water towards groundwater.
- the top of the first groundwater resource is encountered at depth greater than 10 m at Fairview, 20 m at Roma and 60 m at Scotia. Groundwater aquifers are not present in the Arcadia Valley where Bottle Tree Irrigation Area occurs.

This approach is conservative in respect of managing potential impacts to water resources because:

- The detection of irrigation water along either the vertical or horizontal pathways is not expected throughout the life of the project due to irrigation design and irrigation management.
- Early detection of irrigation water in these groundwater piezometers can derive and inform adaptive management response that may result in more information becoming available that may justify an amendment to the hydrogeological impact assessment (see Table 19). New information that may justify an amendment of this plan might include (see Section 9):

- a review of the hydrogeological risk assessment (e.g. validation of the modelled condition using the observed condition) and, if necessary, a revision of the risk assessment and this plan (in accordance with commitments in Section 9).
- the installation of monitoring locations further afield, i.e. to confirm the extent that irrigation has migrated vertically or horizontally, or
- an alteration of irrigation practices the effect of which may continue to be monitored in the currently proposed monitoring locations.

7.1.2.3. Adverse soil dispersion impacts

The risk-based exceedance response plan for irrigation in respect of adverse impacts due to soil dispersion, depends on the visual inspection and a periodic laboratory testing of the soil chemistry.

This approach is justified by the RMMPs (references provided in Section 10). These reports describe the expected attributes of both the irrigation water and the soil. They derive a methodology for ensuring the stability of the soil is maintained throughout the life of the project. The approach requires the application of established agricultural principles and practices.

7.1.2.4. Adverse impacts to crop health and yield

The risk-based exceedance response plan for irrigation in respect of adverse impacts to crop health and yield, depends on the visual inspection of the crop condition and periodic laboratory testing of plant tissue and soil chemistry.

This approach is justified by the RMMPs (full references provided in Section 10). These reports describe the expected attributes of both the irrigation water and the soil. They derive a methodology for ensuring the stability of the soil is maintained throughout the life of the project. The approach requires the application of established agricultural principles and practices.

7.1.3. Dust suppression with produced water

The risk-based exceedance response plan for the re-use of produced water for dust-suppression activities relies on observation of the application areas by the operator, and the avoidance of application in defined areas. This includes avoiding dust suppression within or adjacent to watercourses or other MNES values.

This approach is supported by the approved Environmental Protocol for Constraints Planning and Field Development.

7.1.4. Application of residual drilling material

The risk-based exceedance response plan for the application of residual drilling material relies on regular sampling and characterisation of residual drilling material, application of material in defined areas and observation of the application areas by the operator. Further soil samples are taken at areas where land application has occurred approximately 12 months after the application and after a wet season.

This approach ensures residual drilling material is of a quality and applied in quantities that will not pose unacceptable risks to the environment. This includes ensuring the material is not applied adjacent to watercourses or springs. The approach is justified by the Land Application Method and the outcomes of chemical risk assessments undertaken in accordance with the approved CRAF.

7.2. Timeframes for management actions and reporting

The timeframe to implement the management responses to exceedances of the early warning indicators and trigger thresholds for surface water and groundwater quality is outlined in Table 20. Where there is an exceedance of a Trigger threshold limit outlined in Table 20 this will be reported to the Minister within 10 business days.

Reporting will include an assessment of the location and severity of exceedance. Santos will cease the activity associated with the exceedance if directed in writing by the Minister (condition 26A) and where required undertake corrective actions as directed. The activity will not recommence until the Minister has indicated it is able to in writing. Any external audits will be conducted as instructed by the Authority.

Table 20: Timeframes for management action and reporting

Monitoring result	Timeframe to management response	Reporting monitoring exceedances to minister
Early warning indicator exceeded	Within 30 business days	Annual report
Trigger threshold exceeded	Within 10 business days	Within 30 business days of monitoring event

8. Coal Seam Water and Waste Production

This section meets the following Condition 25B (b) EPBC Approval 2012/6615, which requires that this plan must include:

- Monitoring to measure the amount of CSG water and waste products produced during the life of the action.

Santos GLNG uses flowmeters to measure produced water rates from production wells or at inlets to or from facilities for gathering networks.

Produced water volumes are reported to the Queensland Department of Resources (DOR) biannually in accordance with the *Petroleum and Gas (Production and Safety) Act 2004* and the *Petroleum Act 1923*, as well as to the Office of Groundwater Impact Assessment in accordance with the *Water Act 2000*.

Volume indicators on vehicles transporting residual drilling material to off-site licensed disposal facilities or to land application areas are used to calculate quantities of residual drilling material produced.

Where residual drilling material is disposed off-site, regulated waste tracking records are required to be completed and submitted to the Department of Environment and Science in accordance with the *Environmental Protection Act 1994*.

Where residual drilling material is being applied to land, a record of the quantity applied at each location must also be recorded.

9. Plan Amendment

In accordance with Condition 36 of approval 2012/6615 issued under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), Santos GLNG may choose to revise this management plan when:

- Additional activity (or action) (including additional management controls) is proposed relating to the management of CSG waste that is not already described or referred to in this plan.
- New information is available that justifies amendment of the plan, including changes to key supporting documentation provided for in Section 10.

9.1. Additional activity (including management controls)

If the proposed additional action is likely to have a new or increased impact, or if Santos proposes to amend the early warning indicators, trigger threshold values or limits for detecting impacts (Table 18), Santos GLNG will submit a revised plan to the regulating authority for approval, in accordance with the conditions of approval 2012/6615 issued under the EPBC Act.

If Santos seeks to dispose of waste by any other means (i.e. by a method not outlined in this plan), it will need to revise this plan. It is an operational constraint for Santos to ensure it has all the necessary approvals to manage waste. That includes, for example, brine and salt waste disposal, which has not been proposed in this plan.

If the proposed action in accordance with the revised plan would not be likely to have a new or increased impact, Santos GLNG would be required to, in accordance with Condition 36 of approval 2012/6615:

- notify DCCEEW in writing that the approved plan has been revised and provide the DCCEEW with:

1. an electronic copy of the revised plan marked up with track changes to show the differences between the approved plan and the revised plan
 2. an explanation of the differences between the approved plan and the revised plan
 3. the reasons the approval holder considers that taking the action in accordance with the revised plan would not be likely to have a new or increased impact
 4. written notice of the date on which the approval holder will implement the revised plan (revised plan implementation date), being at least 20 business days after the date of providing notice of the revision of the action management plan, or a date agreed to in writing with the Department.
- Implement the revised plan from the date that the plan is submitted to the DCCEEW.

9.2. New information

Santos GLNG may revise this plan if new information (such as interpreted operational data or environmental monitoring data) is made available or if key supporting documents that inform content in this plan are updated and that the new information or change justifies an amendment to the plan. For example, conditions in an Environmental Authority regulating the storage and disposal of CSG produced water and waste products are amended to change the way in which the activities are managed.

In this situation, Santos GLNG may submit a revised plan to DCCEEW in accordance with Condition 36 of approval 2012/6615 issued under the EPBC Act.

10. Supporting Documentation

ANZECC and ARMCANZ Water Quality Guidelines, Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000

0007-650-PLA-0007_Environmental Protocol for Constraints Planning and Field Development – GFD (Santos, 2016T)

End of Waste Code Irrigation of Associated Water (including coal seam gas water) (ENEW075467018) Waste Reduction and Recycling Act 2011 (DETSI, 2025) and Resource Monitoring and Management Plans (RMMPs) required under code:

- 1724-220-EMP-0001 RMMP: Bottle Tree Irrigation Area
- 0027-220-EMP-0001 RMMP: AWAFA1
- 0030-220-EMP-0001 RMMP: Avalon (Scotia)
- 1704-220-EMP-0001 RMMP: Pleasant Hills
- 4120-220-EMP-0001 RMMP: Kia Ora
- [6317-220-EMP-0001 RMMP: PL 92 & PL 100 LAI](#)
- 6367-220-EMP-0001 RMMP: IR8 LAI
- 7601-220-EMP-0001 RMMP: RM07-03
- 7667-220-EMP-0001 RMMP: The Bend South
- 7667-220-EMP-0001 RMMP: Belbri East
- 7691-220-EMP-0001 RMMP: Roleen
- 7608-220-EMP-0001 RMMP: Tantatton
- 6317-220-EMP-0001 RMMP: IR3, IR4, IR5(2) and IR6(3) Irrigation Areas

Irrigation Hydrogeological and Risk Assessments:

- Santos Pleasant Hills LAI Landscape Salinity Risk Assessment. Golder, August 2016.

- Bend South Irrigation Hydrogeological Risk Assessment, Santos GLNG. Golder, July 2018
- Belbri Irrigation Hydrogeological Risk Assessment, Santos GLNG. Golder, July 2018.
- Scotia Irrigation Hydrogeological and Risk Assessment (Golder, 2017)
- Fairview Irrigation Hydrogeological and Landscape Salinity Risk Assessment, Santos GLNG. Golder, January 2020

End of Waste Code Associated Water (including coal seam gas water) (ENEW0757018) (DETSI 2025)

Scotia Area Hydrogeological Conceptual Model (Golder 2011)

0007-650-PLA-0015 Eastern Queensland Residual Drill Material Management Plan (Santos 2024)

0007-220-PRO-0026 Residual Drill Material: Land Application Procedure (Santos 2022)

0007-650-EMP-0029 Environmental Contingency and Emergency Response Plan (Santos 2022)

Surat Underground Water Impact Report (UWIR) for the Surat Cumulative Management Area (Queensland Office of Groundwater Impact Assessment (OGIA 2019)

Chemical Risk Assessment Framework (CRAF), Santos Gas Field Development Project, EPBC 2012/6615, Version 1, April 2021 (Santos 2021).

Coal Seam Gas - Joint Industry Framework (JIF) - Managing impacts to groundwater resources in the Surat Cumulative Management Area under EPBC Act approvals. Endorsed by DAWE on 17 March 2021

Environmental Authority EPPG00928713 (Fairview Arcadia Project Area)

Environmental Authority EPPG00898213 (Roma Shallow Gas Project Area)

Environmental Authority EPPG00662213 (Roma Shallow Gas Project Area East)

Environmental Authority EPPG03515915 (Scotia Project Area)

Environmental Authority EA0001210 (Maisey Project Area)

Appendix A1 – Coal seam water quality

The tables below present water composition data for wells in the Walloon Coal Measures in the Roma area (Table A1-1), Fairview area (Table A1-2), Scotia area (Table A1-3), Arcadia area (Table A1-4) and the Upper Baralaba coal measures in the Scotia area (Table A1-5).

Table A1-1: Water quality composition of Walloon Coal Measures in the Roma Area

Analyte	Dissolved or total	Limit of detection	Min.	P10	Median	P90	Max.	Sample count
Boron (mg/L)	T	0.05	0.08	0.4	0.58	1.09	4.68	1079
Calcium (mg/L)	D	1	1	3	5	15	84	1462
Chloride (mg/L)	N/A	1	92	508.1	795	2520	4490	1462
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	1300	2960	3970	8572	13100	1459
Fluoride (mg/L)	N/A	1	0.7	1.8	2.6	3.4	7.9	1089
Magnesium (mg/L)	D	1	1	1	1	4	10	1462
pH – Lab	N/A	0.01	7.84	8.35	8.63	8.832	9.23	489
Potassium (mg/L)	D	1	1	6	18	46	80	1459
Sodium (mg/L)	D	1	296	665	880	1882	3160	1459
Sodium Adsorption Ratio-	N/A	0.01	59.3	90.1	105	128	238	398
Strontium (mg/L)	T	0.001	0.574	0.9292	2.35	2.414	2.43	3
Sulfate as SO ₄ ²⁻ (mg/L)	D	1	1	1	1	1	28	1462
Total Dissolved Solids (Calc.) (mg/L)	T	10	845	1718	2280	3020	4760	269

Table A1-2: Water quality composition of Walloon Coal Measures in the Fairview Area

Analyte	Dissolved or total	Limit of detection	Min.	P10	Median	P90	Max.	Sample count
Boron (mg/L)	T	0.05	0.05	0.79	1.41	7.67	16.1	417
Calcium (mg/L)	D	1	1	1	6	24	154	425
Chloride (mg/L)	N/A	1	1	97.6	984	2884	8140	417
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	30	1880	5760	12600	27000	451
Fluoride (mg/L)	N/A	1	0.1	1.3	3.5	8.2	11.1	419
Magnesium (mg/L)	D	1	1	1	1	4	10	425
pH – Lab	N/A	0.01	6.72	7.306	8.34	8.68	9.33	169
Potassium (mg/L)	D	1	1	2.6	7	44	77	417
Sodium (mg/L)	D	1	1	444.6	1270	2894	6040	417
Sodium Adsorption Ratio-	N/A	0.01	58.3	78.35	104	203	206	26
Strontium (mg/L)	T	0.001	0.413	0.5527	1.1115	1.6703	1.81	2
Sulfate as SO ₄ ²⁻ (mg/L)	D	1	1	1	1	3	125	419
Total Dissolved Solids (Calc.) (mg/L)	T	10	1460	1622	2040	2632	2830	10

Table A1-3: Water quality composition of Walloon Coal Measures in the Scotia Area

Analyte	Dissolved or total	Limit of detection	Min.	P10	Median	P90	Max.	Sample count
Boron (mg/L)	T	0.05	4.18	4.245	8.55	14.05	14.2	6
Calcium (mg/L)	D	1	10	10	17	20.5	21	6
Chloride (mg/L)	N/A	1	834	962	1170	1275	1290	6
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	4700	5180	5770	6190	6280	6
Fluoride (mg/L)	N/A	1	0.4	0.4	0.5	0.55	0.6	6
Magnesium (mg/L)	D	1	5	5	6.5	7.5	8	6
pH – Lab	N/A	0.01	7.54	7.632	7.86	7.996	8.06	5
Potassium (mg/L)	D	1	25	26.5	35.5	60	69	6
Sodium (mg/L)	D	1	1060	1180	1350	1420	1420	6
Sodium Adsorption Ratio-	N/A	0.01	-	-	-	-	-	-
Strontium (mg/L)	T	0.001	-	-	-	-	-	-
Sulfate as SO ₄ ²⁻ (mg/L)	D	1	1	1	1	1	1	6
Total Dissolved Solids (Calc.) (mg/L)	T	10	-	-	-	-	-	-

Table A1-4: Water quality composition of Walloon Coal Measures in the Arcadia Area

Analyte	Dissolved or total	Limit of detection	Min.	P10	Median	P90	Max.	Sample count
Boron (mg/L)	T	0.05	1.79	1.842	2.135	3.576	3.74	12
Calcium (mg/L)	D	1	10	11.4	17	22.9	25	12
Chloride (mg/L)	N/A	1	1210	1354	2215	3293	4100	12
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	6670	7059	8880	11360	13000	12
Fluoride (mg/L)	N/A	1	1.9	1.97	3.65	6.07	6.5	12
Magnesium (mg/L)	D	1	1	1.1	2	3.9	5	12
pH – Lab	N/A	0.01	7.58	7.636	8.23	8.651	8.71	24
Potassium (mg/L)	D	1	13	16.2	21	28.7	45	12
Sodium (mg/L)	D	1	1660	1784	2125	2652	3030	12
Sodium Adsorption Ratio-	N/A	0.01	114	120.1	131.5	143.4	148	12
Strontium (mg/L)	T	0.001	1.7	2.112	2.815	4.016	4.91	12
Sulfate as SO ₄ ²⁻ (mg/L)	D	1	1	1	1	1	1	12
Total Dissolved Solids (Calc.) (mg/L)	T	10	-	-	-	-	-	-

Table A1-5: Water quality composition of Upper Baralaba coal measures in the Scotia area

ANALYTE NAME	DISSOLVED OR TOTAL	LIMIT OF DETECTION	UNIT	Recorded Water Quality (well data)		
				P10	P50	P90
Electrical Conductivity @ 25°C	N/A	1	µS/cm	4210	6440	8790
Total Dissolved Solids @180°C	T	10	mg/L	1644.8	3810	3930
Electrical Conductivity - Field	N/A	1	µS/cm	5272.6	5700	6092.4
Dissolved Oxygen - Field	N/A	0.001	mg/L	1.226	2.51	3.364
Mercury	D	0.0001	mg/L	<0.0001	<0.0001	<0.0001
Mercury	T	0.0001	mg/L	<0.0001	<0.0001	<0.0001
Calcium	D	1	mg/L	7	11	19.8
Magnesium	D	1	mg/L	4	6.5	10
Potassium	D	1	mg/L	14.2	40	172.2
Sodium	D	1	mg/L	841.3	1405	1914
Silica SiO2	D	1	mg/L		31.7	31.7*
Sulfate as SO4 2-	D	1	mg/L	<1	4	33.5
Sodium Adsorption Ratio	N/A	0.01	-	66.06	86.4	105
Chloride	N/A	1	mg/L	855	1340	2420
Fluoride	N/A	0.1	mg/L	0.2	0.4	0.7
pH - Lab	N/A	0.01	pH Unit	8	8.41	8.63
Nitrite as N	N/A	0.01	mg/L	<0.01	<0.01	<0.01
Nitrate as N	N/A	0.01	mg/L	<0.01	0.02	0.066
Total Kjeldahl Nitrogen as N	N/A	0.1	mg/L	2.32	3.75	7.3
Total Nitrogen as N	N/A	0.1	mg/L	2.32	3.75	7.39
Nitrite + Nitrate as N	N/A	0.01	mg/L	0.018	0.04	0.174
Reactive Phosphorus as P	N/A	0.01	mg/L	<0.01	0.02	0.12
Aluminium	D	0.01	mg/L	<0.01	<0.01	0.019
Aluminium	T	0.01	mg/L	<0.01	0.015	2.395
Arsenic	T	0.001	mg/L	<0.001	<0.001	0.01
Barium	T	0.001	mg/L	0.885	3.145	4.9
Beryllium	T	0.001	mg/L	<0.001	<0.001	<0.001
Boron	T	0.05	mg/L	1.91	2.71	4.38
Cadmium	T	0.0001	mg/L	<0.0001	<0.0001	<0.0001
Chromium	T	0.001	mg/L	<0.001	<0.001	0.055
Cobalt	T	0.001	mg/L	<0.001	<0.001	<0.001
Copper	T	0.001	mg/L	<0.001	<0.001	0.04

ANALYTE NAME	DISSOLVED OR TOTAL	LIMIT OF DETECTION	UNIT	Recorded Water Quality (well data)		
				P10	P50	P90
Iron	T	0.05	mg/L	0.325	4.685	18.6
Lead	T	0.001	mg/L	<0.001	<0.001	0.01
Lithium	T	0.001	mg/L	0.03	0.04	0.067
Manganese	T	0.001	mg/L	0.01	0.065	0.31
Molybdenum	T	0.001	mg/L	<0.001	<0.001	0.011
Nickel	T	0.001	mg/L	<0.001	<0.001	0.04
Selenium	T	0.01	mg/L	<0.01	<0.01	<0.01
Strontium	T	0.001	mg/L	0.74	1.875	2.82
Uranium	T	0.001	mg/L	<0.001	<0.001	<0.001
Vanadium	T	0.01	mg/L	<0.01	<0.01	<0.01
Zinc	T	0.005	mg/L	0.01	0.01	0.11
>C10 - C16 Fraction	N/A	100	µg/L	<100	<100	314
>C10 - C16 Fraction minus Naphthalene (F2)	N/A	100	µg/L	<100	<100	<100
>C10 - C40 Fraction (sum)	N/A	100	µg/L	<100	110	2494
>C16 - C34 Fraction	N/A	100	µg/L	<100	110	1708
>C34 - C40 Fraction	N/A	100	µg/L	<100	<100	582
C10 - C14 Fraction	N/A	50	µg/L	<50	<50	2810
C10 - C36 Fraction (sum)	N/A	50	µg/L	<50	100	14800
C15 - C28 Fraction	N/A	100	µg/L	<100	<100	7370
C29 - C36 Fraction	N/A	50	µg/L	<50	<50	4330
Benzene	N/A	1	µg/L	<1	<1	2
C6 - C10 Fraction	N/A	20	µg/L	<20	<20	26
C6 - C10 Fraction minus BTEX (F1)	N/A	20	µg/L	<20	<20	<20
C6 - C9 Fraction	N/A	20	µg/L	<20	<20	<20
Ethylbenzene	N/A	2	µg/L	<2	<2	<2
meta- & para-Xylene	N/A	2	µg/L	<2	<2	<2
Naphthalene	N/A	5	µg/L	<5	<5	<5
ortho-Xylene	N/A	2	µg/L	<2	<2	<2
Toluene	N/A	2	µg/L	<2	<2	<2
Total Xylenes	N/A	2	µg/L	<2	<2	<2
Acenaphthene	N/A	1	µg/L	<1	<1	<1
Acenaphthylene	N/A	1	µg/L	<1	<1	<1
Anthracene	N/A	1	µg/L	<1	<1	<1

ANALYTE NAME	DISSOLVED OR TOTAL	LIMIT OF DETECTION	UNIT	Recorded Water Quality (well data)		
				P10	P50	P90
Benz(a)anthracene	N/A	1	µg/L	<1	<1	<1
Benzo(a)pyrene	N/A	0.5	µg/L	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ (WHO)	N/A	0.5	µg/L	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ (zero)	N/A	0.5	µg/L	<0.5	<0.5	<0.5
Benzo(b)fluoranthene	N/A	1	µg/L	<1	<1	<1
Benzo(g,h,i)perylene	N/A	1	µg/L	<1	<1	<1
Benzo(k)fluoranthene	N/A	1	µg/L	<1	<1	<1
Chrysene	N/A	1	µg/L	<1	<1	<1
Dibenz(a,h)anthracene	N/A	1	µg/L	<1	<1	<1
Fluoranthene	N/A	1	µg/L	<1	<1	<1
Fluorene	N/A	1	µg/L	<1	<1	<1
Indeno(1,2,3,cd)pyrene	N/A	1	µg/L	<1	<1	<1
Naphthalene	N/A	1	µg/L	<1	<1	<1
Phenanthrene	N/A	1	µg/L	<1	<1	<1
Pyrene	N/A	1	µg/L	<1	<1	<1
Sum of polycyclic aromatic hydrocarbons (PAHs)	N/A	0.5	µg/L	<0.5	<0.5	0.5

Appendix A2 – Irrigation water quality

The tables below present the median irrigation water quality for the Scotia (A2-1) and Roma (Tables A2-2–5) Irrigation Areas.

Table A2-1: Measured irrigation water quality in the Scotia area (19/12/2017 – 12/06/2020)

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Aluminium	mg/L	D	0.01	0.01	10
Aluminium	mg/L	T	0.01	0.01	11
Arsenic	mg/L	D	0.001	0	10
Arsenic	mg/L	T	0.001	0	11
Barium	mg/L	D	0.001	1.42	10
Barium	mg/L	T	0.001	1.48	11
Benzene	µg/L	N	1	1	21
Beryllium	mg/L	D	0.001	0	10
Beryllium	mg/L	T	0.001	0	11
Bicarbonate Alkalinity as CaCO ₃	mg/L	N	1	504	46
Boron	mg/L	D	0.05	1.94	10
Boron	mg/L	T	0.05	2.16	11
Cadmium	mg/L	D	0.0001	0	10
Cadmium	mg/L	T	0.0001	0	11
Calcium	mg/L	D	1	8	46
Carbonate Alkalinity as CaCO ₃	mg/L	N	1	44.5	46
Chloride	mg/L	N	1	758.5	46
Chromium	mg/L	D	0.001	0	10
Chromium	mg/L	T	0.001	0	11
Cobalt	mg/L	D	0.001	0	10
Cobalt	mg/L	T	0.001	0	11
Copper	mg/L	D	0.001	0	10
Copper	mg/L	T	0.001	0	11
Dissolved Organic Carbon	mg/L	N	1	36.5	10
Electrical Conductivity - Field	µS/cm	N	1	3201	44
Electrical Conductivity @ 25°C	µS/cm	N	1	3315	46
Fluoride	mg/L	N	0.1	0.4	46
Ionic Balance	%	N	0.01	2.16	46
Iron	mg/L	D	0.05	0.2	10
Iron	mg/L	T	0.05	0.81	11

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Lead	mg/L	D	0.001	0	10
Lead	mg/L	T	0.001	0	11
Lithium	mg/L	D	0.001	0.02	10
Lithium	mg/L	T	0.001	0.03	10
Magnesium	mg/L	D	1	3	46
Manganese	mg/L	D	0.001	0.01	10
Manganese	mg/L	T	0.001	0.03	11
Mercury	mg/L	D	0.0001	0	10
Mercury	mg/L	T	0.0001	0	11
Molybdenum	mg/L	D	0.001	0	10
Molybdenum	mg/L	T	0.001	0	10
Naphthalene	µg/L	N	5	5	21
Nickel	mg/L	D	0.001	0	10
Nickel	mg/L	T	0.001	0	11
pH - Field	pH Unit	N	0.01	8.95	44
pH - Lab	pH Unit	N	0.01	8.61	46
Potassium	mg/L	D	1	42	46
Selenium	mg/L	D	0.01	0.01	10
Selenium	mg/L	T	0.01	0.01	11
Sodium	mg/L	D	1	664.5	46
Sodium Adsorption Ratio	-	N	0.01	51.2	46
Sulfate as SO4 2-	mg/L	D	1	1	46
Toluene	µg/L	N	2	2	21
Total Alkalinity as CaCO3	mg/L	N	1	545.5	46
Total Anions	meq/L	N	0.01	33.15	46
Total Cations	meq/L	N	0.01	31.55	46
Total Hardness as CaCO3	mg/L	N	1	32	10
Total Organic Carbon	mg/L	N	1	37.5	10
Vanadium	mg/L	D	0.01	0.01	10
Vanadium	mg/L	T	0.01	0.01	11
Zinc	mg/L	D	0.005	0.01	10
Zinc	mg/L	T	0.005	0.01	11

Table A2-2: Measured irrigation water quality in Grafton Range Dam (1/01/2018 – 24/06/2020)

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Bicarbonate Alkalinity as CaCO ₃	mg/L	N	1	381.5	22
Calcium	mg/L	D	1	2	24
Carbonate Alkalinity as CaCO ₃	mg/L	N	1	177.5	22
Chloride	mg/L	N	1	930	22
Dissolved Oxygen - Field	mg/L	N		8.47	10
Electrical Conductivity - Field	µS/cm	N		3965.8	10
Electrical Conductivity @ 25°C	µS/cm	N	1	3870	22
Fluoride	mg/L	N	0.1	1.8	21
Ionic Balance	%	N	0.01	1.28	22
Magnesium	mg/L	D	1	1	24
pH - Field	pH Unit	N		8.73	10
pH - Lab	pH Unit	N	0.01	9.19	21
Potassium	mg/L	D	1	24	24
Sodium	mg/L	D	1	845.5	24
Sodium Adsorption Ratio	-	N	0.01	126	21
Sulfate as SO ₄ 2-	mg/L	D	1	1	22
Total Alkalinity as CaCO ₃	mg/L	N	1	563	22
Total Anions	meq/L	N	0.01	37.75	22
Total Cations	meq/L	N	0.01	37.45	22
Aluminium	mg/L	T	0.01	0.17	2
Arsenic	mg/L	T	0.001	0	2
Boron	mg/L	T	0.05	0.88	2
Cadmium	mg/L	T	0.0001	0	2
Chromium	mg/L	T	0.001	0	2
Cobalt	mg/L	T	0.001	0	2
Copper	mg/L	T	0.001	0.02	2
Iron	mg/L	T	0.05	0.22	2
Lead	mg/L	T	0.001	0	2
Lithium	mg/L	T	0.001	0.05	2
Manganese	mg/L	T	0.001	0.01	2
Mercury	mg/L	T	0.0001	0	2
Molybdenum	mg/L	T	0.001	0	2
Nickel	mg/L	T	0.001	0	2
Zinc	mg/L	T	0.005	0.01	2

Table A2-3: Measured irrigation water quality in Pleasant Hills Dam (1/01/2018 – 24/06/2020)

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Bicarbonate Alkalinity as CaCO ₃	mg/L	N	1	662	115
Calcium	mg/L	D	1	4	117
Carbonate Alkalinity as CaCO ₃	mg/L	N	1	164	115
Chloride	mg/L	N	1	767	115
Dissolved Oxygen - Field	mg/L	N		9.01	96
Electrical Conductivity - Field	µS/cm	N		3778.55	96
Electrical Conductivity @ 25°C	µS/cm	N	1	3780	115
Fluoride	mg/L	N	0.1	2.8	115
Ionic Balance	%	N	0.01	1.49	115
Magnesium	mg/L	D	1	1	117
pH - Field	pH Unit	N		8.75	96
pH - Lab	pH Unit	N	0.01	8.98	115
Potassium	mg/L	D	1	26	117
Sodium	mg/L	D	1	851	117
Sodium Adsorption Ratio	-	N	0.01	102	115
Sulfate as SO ₄ 2-	mg/L	D	1	1	115
Total Alkalinity as CaCO ₃	mg/L	N	1	860	115
Total Anions	meq/L	N	0.01	38.6	115
Total Cations	meq/L	N	0.01	37.7	115
Aluminium	mg/L	T	0.01	0.16	7
Arsenic	mg/L	T	0.001	0	7
Boron	mg/L	T	0.05	0.7	7
Cadmium	mg/L	T	0.0001	0	7
Chromium	mg/L	T	0.001	0	7
Cobalt	mg/L	T	0.001	0	7
Copper	mg/L	T	0.001	0.02	7
Iron	mg/L	T	0.05	0.29	7
Lead	mg/L	T	0.001	0	7
Lithium	mg/L	T	0.001	0.04	7
Manganese	mg/L	T	0.001	0.01	7
Mercury	mg/L	T	0.0001	0	7
Molybdenum	mg/L	T	0.001	0	7
Nickel	mg/L	T	0.001	0	7
Zinc	mg/L	T	0.005	0.01	7

Table A2-4: Measured irrigation water quality in Raslie Dam (1/01/2018 – 24/06/2020)

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Bicarbonate Alkalinity as CaCO ₃	mg/L	N	1	587	113
Calcium	mg/L	D	1	4	115
Carbonate Alkalinity as CaCO ₃	mg/L	N	1	130	113
Chloride	mg/L	N	1	741	113
Dissolved Oxygen - Field	mg/L	N		8.44	96
Electrical Conductivity - Field	µS/cm	N		3491.35	96
Electrical Conductivity @ 25°C	µS/cm	N	1	3670	113
Fluoride	mg/L	N	0.1	2.2	113
Ionic Balance	%	N	0.01	1.83	113
Magnesium	mg/L	D	1	1	115
pH - Field	pH Unit	N		8.83	96
pH - Lab	pH Unit	N	0.01	8.99	113
Potassium	mg/L	D	1	26	115
Sodium	mg/L	D	1	817	115
Sodium Adsorption Ratio	-	N	0.01	96.8	113
Sulfate as SO ₄ 2-	mg/L	D	1	1	113
Total Alkalinity as CaCO ₃	mg/L	N	1	680	113
Total Anions	meq/L	N	0.01	37	113
Total Cations	meq/L	N	0.01	36.2	113
Aluminium	mg/L	T	0.01	0.06	7
Arsenic	mg/L	T	0.001	0	7
Boron	mg/L	T	0.05	0.71	7
Cadmium	mg/L	T	0.0001	0	7
Chromium	mg/L	T	0.001	0	7
Cobalt	mg/L	T	0.001	0	7
Copper	mg/L	T	0.001	0	7
Iron	mg/L	T	0.05	0.08	7
Lead	mg/L	T	0.001	0	7
Lithium	mg/L	T	0.001	0.04	7
Manganese	mg/L	T	0.001	0.01	7
Mercury	mg/L	T	0.0001	0	7
Molybdenum	mg/L	T	0.001	0	7
Nickel	mg/L	T	0.001	0	7
Zinc	mg/L	T	0.005	0.01	7

Table A2-5: Water quality in Roma ROP2 Desalinated Water Pond (1/01/2018 – 24/06/2020)

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Aluminium	mg/L	D	0.01	0.05	14
Aluminium	mg/L	T	0.01	0.08	14
Arsenic	mg/L	D	0.001	0	14
Arsenic	mg/L	T	0.001	0	14
Barium	mg/L	D	0.001	0.17	12
Barium	mg/L	T	0.001	0.21	14
Beryllium	mg/L	D	0.001	0	12
Beryllium	mg/L	T	0.001	0	12
Bicarbonate Alkalinity as CaCO ₃	mg/L	N	1	331.5	48
Boron	mg/L	D	0.05	0.67	14
Boron	mg/L	T	0.05	0.71	14
Cadmium	mg/L	D	0.0001	0	14
Cadmium	mg/L	T	0.0001	0	14
Calcium	mg/L	D	1	2.5	50
Carbonate Alkalinity as CaCO ₃	mg/L	N	1	84	48
Chloride	mg/L	N	1	741.5	50
Chromium	mg/L	D	0.001	0	14
Chromium	mg/L	T	0.001	0	14
Cobalt	mg/L	D	0.001	0	12
Cobalt	mg/L	T	0.001	0	12
Copper	mg/L	D	0.001	0	14
Copper	mg/L	T	0.001	0	14
Dissolved Oxygen - Field	mg/L	N	0.1	8.16	52
Electrical Conductivity - Field	µS/cm	N	1	2998.5	52
Electrical Conductivity @ 25°C	µS/cm	N	1	2960	50
Fluoride	mg/L	N	0.1	1.3	50
Ionic Balance	%	N	0.01	1.72	48
Iron	mg/L	D	0.05	0.05	14
Iron	mg/L	T	0.05	0.06	14
Lead	mg/L	D	0.001	0	14
Lead	mg/L	T	0.001	0	14
Lithium	mg/L	D	0.001	0.03	12
Lithium	mg/L	T	0.001	0.03	12
Magnesium	mg/L	D	1	1	50

Analyte	Unit	Dissolved, Normal or Total	Limit of Detection	Median values	Sample Count
Manganese	mg/L	D	0.001	0	14
Manganese	mg/L	T	0.001	0.01	14
Mercury	mg/L	D	0.0001	0	14
Mercury	mg/L	T	0.0001	0	14
Molybdenum	mg/L	D	0.001	0	12
Molybdenum	mg/L	T	0.001	0	14
Nickel	mg/L	D	0.001	0	14
Nickel	mg/L	T	0.001	0	14
pH - Field	pH Unit	N	0.01	8.92	52
pH - Lab	pH Unit	N	0.01	8.97	50
Potassium	mg/L	D	1	21	50
Selenium	mg/L	D	0.01	0.01	14
Selenium	mg/L	T	0.01	0.01	14
Sodium	mg/L	D	1	623.5	50
Sodium Adsorption Ratio	-	N	0.01	85.85	48
Sulfate as SO ₄ ²⁻	mg/L	D	1	1	50
Total Alkalinity as CaCO ₃	mg/L	N	1	422	48
Total Anions	meq/L	N	0.01	29.2	48
Total Cations	meq/L	N	0.01	28.35	48
Total Hardness as CaCO ₃	mg/L	N	1	6	14
Zinc	mg/L	D	0.005	0.01	14
Zinc	mg/L	T	0.005	0.01	14