Santos

Coal Seam Gas Waste Management Plan

Project Stage 2 - Maisey (PL1021)

EPBC (2012/6615)

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10-08-18	0	Issued to DoEE for approval	DG	LD	PW
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1. Background

1.1. Introduction

The Santos Gas Field Development (GFD) Project extends the Santos GLNG development area from 6,887 km^2 to 10,676 km^2. It will see the development of up to 6,100 production wells (and associated infrastructure) beyond the currently authorised 2,650 production wells. The area of the 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

The Coal Seam Waste Management Plan Project Stage 2 - Maisey (PL1021) (CSWMP) has been prepared to satisfy the conditions of approval 2012/6615 issued under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This plan specifically satisfies requirements of Condition 25B. This condition relates to the potential impact of coal seam water extraction on Matters of National Environmental Significance (MNES) from Project Stage 2.

Other activities of the GFD Project that may pose a potential risk of significant adverse impact to groundwater resources are addressed by Groundwater Monitoring and Management activities, which address the potential effects of coal seam depressurisation, and Water Quality Monitoring and Management activities, which address the lifecycle management of anthropogenic chemicals used for CSG well construction, well stimulation activities and in the treatment of CSG water as well as geogenic constituents (total effluent toxicity).

The monitoring and management for these other activities is addressed in the following plans which have been prepared to satisfy conditions of the EPBC (2012/6615) approval:

• Stage 2 Groundwater Monitoring and Management Plan (Condition 22B)

• Stage 2 Water Quality Management Plan (Condition 29C)

The Water Quality Management Plan assesses risk to MNES from the full life cycle of drilling operations, specifically the treatment, recycling, re-use and disposal of drilling waste. This scope is not duplicated in this plan, the CSG Waste Management Plan.

Furthermore, the planning of CSG development activity locations, and the types of actions permitted at any location is bound to the Environmental Protocol for Constraints Planning and Field Development – GFD (Santos, 2016) (the Constraints Protocol). The Constraints Protocol was prepared to satisfy Condition 7 of the EPBC (2012/6615) approval. This overlaps considerably with the requirements of this Project Stage 1 CSG Waste Management because by carefully selecting the location of project activities, risks to MNES are avoided and risks minimized. This is discussed further within this plan.

1.3. Project scope

This plan assesses coal seam waste water management activities and residual drilling materials (drilling cuttings and fluids) relating to Project Stage 2. This project stage comprises the installation and operation of up to 180 production wells on PL1021 (the Maisey block).

This plan may be updated over the life of the GFD Project. The process for updating this plan is outlined in Section 10 and aligns to the requirement of Condition 36 of EPBC Approval 2012/6615.

Santos GLNG will not commence extraction of water or coal seam gas from wells other than the 180 wells comprising Project Stage Maisey (PL1021) until a revised version of this Plan which assess the contribution of additional wells is approved in writing by the Minister. The revised Plan will contain detailed information regarding how waste will be monitored and managed, addressing the advice provided by the Department.

Figure 1 shows the approved GLNG and GFD Project tenures and the relative size and location of Maisey PL1021.

1.4. Previously approved plans

The Coal Seam Waste Management Plan Project Stage 1 – Scotia (PL176) is an existing and approved plan that considers activities located approximately more than 85 km to the north-east of the PL1021.

In reference to condition 25B (f), there are no cumulative impacts on MNES that need to be addressed by Coal Seam Waste Management Plan Project Stage 2 - Maisey (PL1021). This is because water management activities on PL1021 and PL176 are entirely independent of each other due to geographical separation.

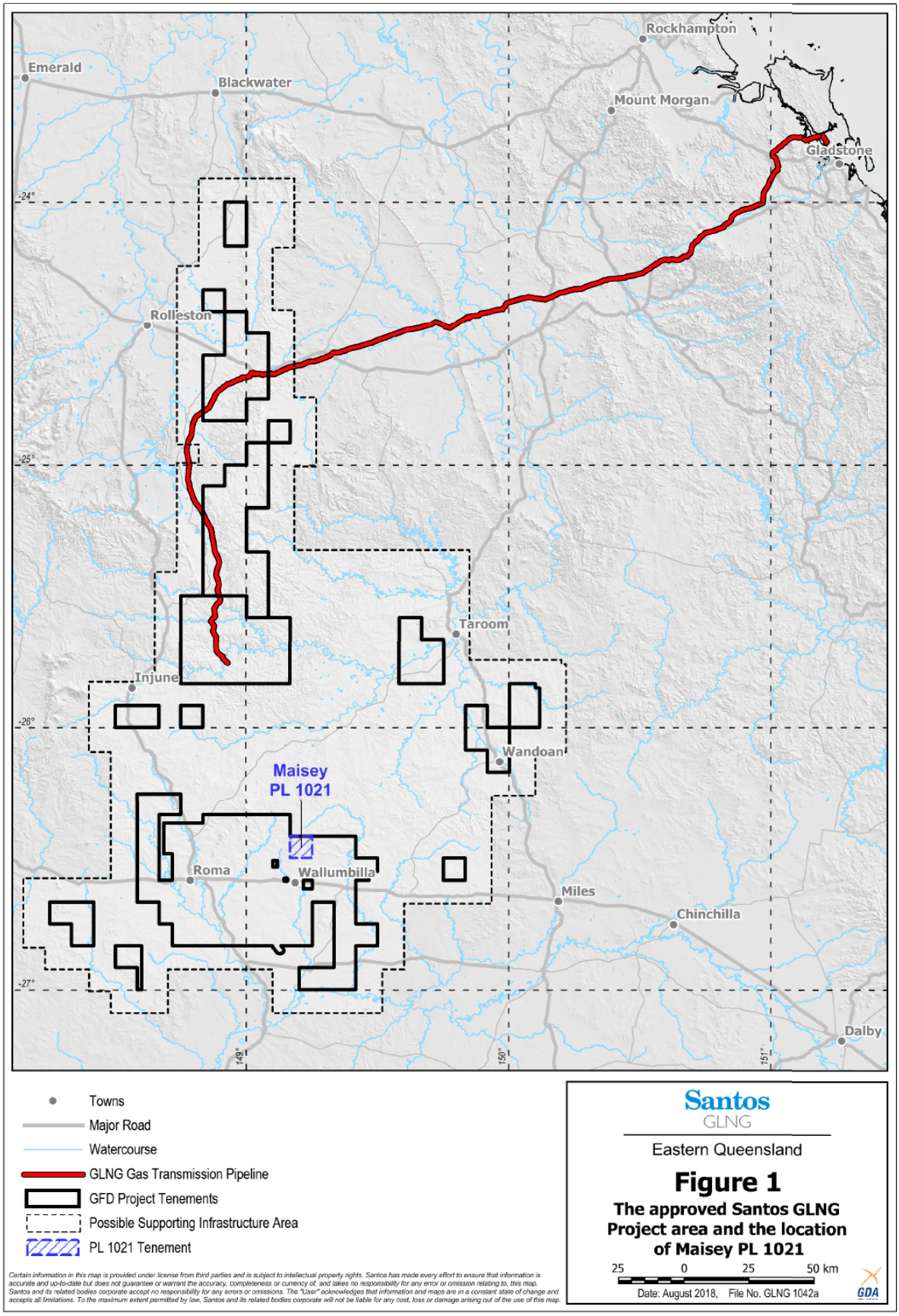

Figure 1: The approved Santos GLNG and GFD Project areas and the location of Maisey PL 1021

2. Regulatory Context

Several Acts and Regulations govern the management of coal seam gas water (and its derivatives) and residual drilling material by the petroleum and gas industry in Queensland. This includes:

- Water and residual drilling material management - existing conditions for water and residual drilling material management granted in Environmental Authorities issued by the Queensland Department of Environment and Science under the *Environmental Protection Act 1994*, and

- Waste management – Beneficial Use Approval (BUA) conditions issued 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. Water and Residual Drilling Material Management

Santos GLNG manages produced water and residual drilling material in accordance with relevant regulatory frameworks and policy. 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 & Gas 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 water, the EA primarily deals with the management of 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 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 environmental risk assessment and a resulting management and monitoring plan commensurate to the risk identified.

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

Most notably, the Environmental Authority granted for the Maisey development prohibits impacts to water resources (and therefore implicitly MNES) associated with produced water and waste management and disposal activities through specific imposed conditions.

2.2. Waste Management

The Department of Environment and Science (DES) regulates the management and disposal of wastes in Queensland under the provisions of the EP Act, the *Waste Reduction and*

Recycling Act 2011 (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 GLNG waste management hierarchy has been developed in accordance with the management approaches detailed within the policy.

To ensure the appropriate management and disposal of waste products, Santos GLNG 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 assist Santos GLNG 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 2.

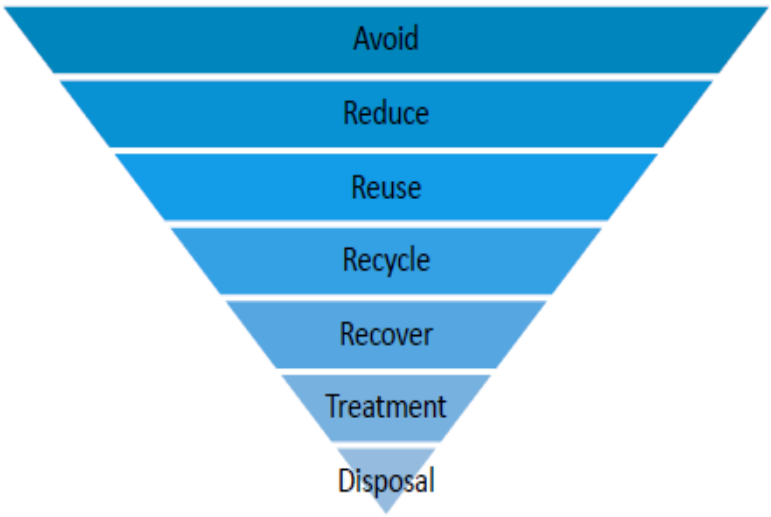

Figure 2 Waste Management Hierarchy

3. CSG Water Management Activities

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

Detail the storage, management and disposal of CSG produced water and waste products,

The following sections describe how coal seam gas water and residual drilling material from Maisey PL1021 is managed. A description of the proposed storage, treatment, end use and disposal of coal seam 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.

3.1. Water Management – Maisey PL1021

Santos GLNG aims to maximise fit-for-purpose beneficial re-use of produced water where feasible whilst avoiding the unnecessary generation of other waste (such as brine) and minimising the potential risk of adverse impacts to the environment.

Coal seam gas water will be gathered from CSG wells located on Maisey PL1021 and transferred to centralised water treatment and beneficial use on other petroleum tenures in the Roma area. The location of these facilities is shown in Figure 4. Figure 3 provides a flow chart showing the inter-connectivity of the water management network in the Roma area which is described throughout this section.

The operation of the facilities described in the following sections and shown in Figure 4 (i.e. on PLs 309, 310, 314 and 315), which are all outside the area of PL1021, is currently authorised under referral EPBC 2008/4059, and the approved water management plans (i.e. Stage 2 CSG Water Monitoring and Management Plan). All the PLs shown in Figure 4 are part of the GFD Project.

3.1.1. 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.

Right-of-way inspections are undertaken every 5 years. 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 (leak 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.)

Water from PL1021 will be transferred to the Angry Jungle coal seam water storage pond, or else transferred to the water treatment facilities at Roma Hub 2.

An overview of the quality of coal seam water that is gathered is provided in Appendix B.

The predicted rate and volume of water that is expected to be gathered from CSG wells across Maisey PL1021 and the across the Roma area is shown in Figures 5 and 6.

3.1.2. Water treatment facilities

There are no CSG water treatment facilities proposed on PL1021.

CSG water from PL1021 is gathered and directed to centralised water treatment located at Roma Hub02 on PL314. The facilities comprise fines and sludge removal and a reverse osmosis plant (ROP). ROPs significantly improve the quality of raw coal seam water by reducing water salinity. Water treated this way is referred to as RO permeate. The waste water stream is referred to as RO concentrate (ROC).

Coal seam water may be directly blended with RO permeate to achieve the required water quality objectives for the intended beneficial use of the water.

3.1.3. Storage ponds

There are no proposed storage ponds proposed to manage CSG water produced on Maisey PL1021.

The location of water storage ponds which may receive water from Maisey PL1021 is shown in Figures 3 and 4. Key attributes of the various water storage facilities are shown in Table 1. All the water storages in Table 1 are designed and operated as 'regulated structures' in accordance with requirements of the Queensland Environmental Protection Act (1994).

The maximum volume of fluid that can be stored in each pond is shown in Table 1. The total volume of fluid that is produced may be greater, depending on storage losses such as beneficial use and evaporation.

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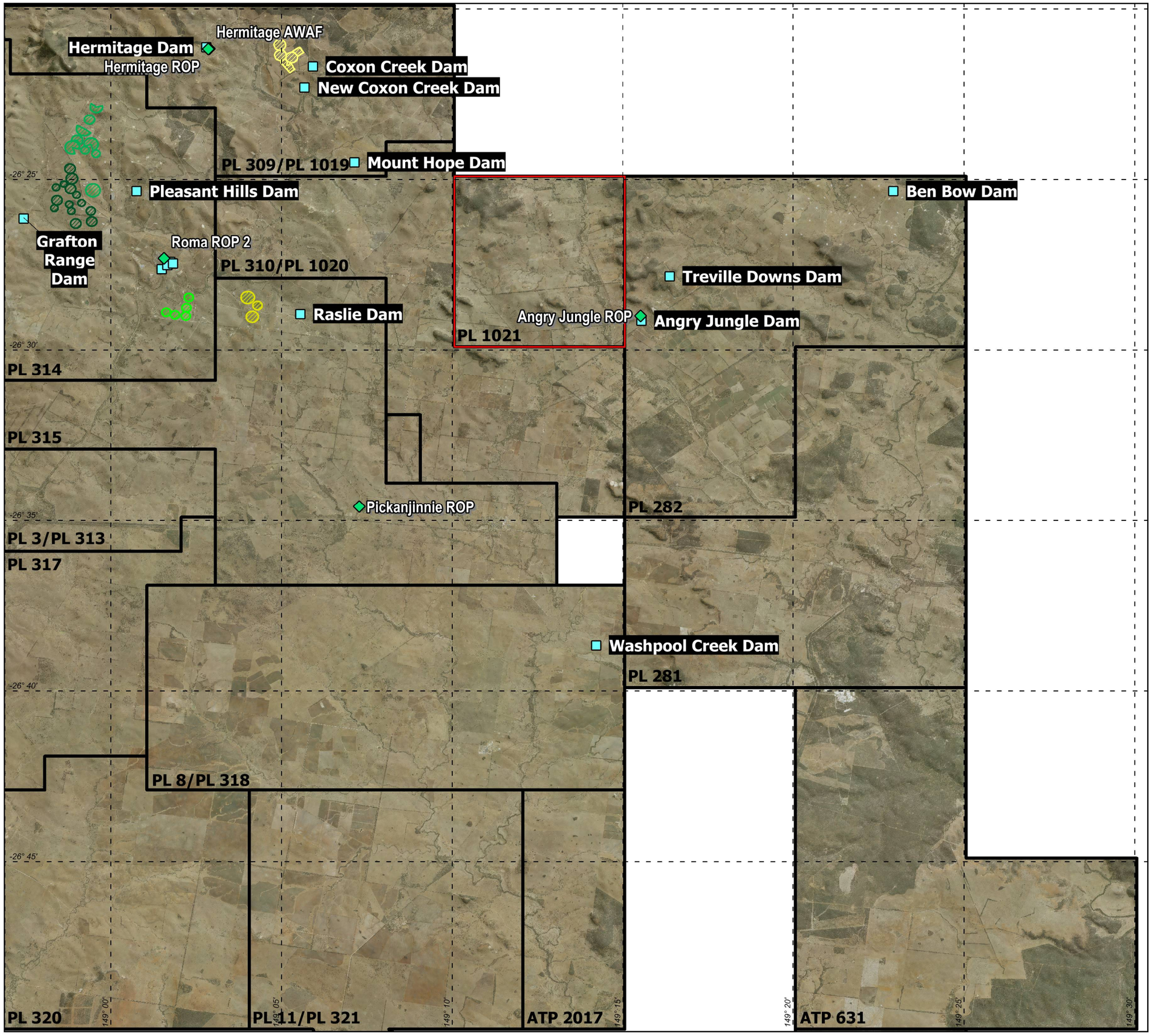
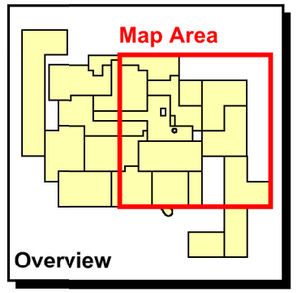
Table 1: Regulated water storage ponds at Roma Hub02 on PL314

Asset	Purpose	Dam construction	Liner composition	Leak Detection type	Measured salinity* (µS/cm)	Maximum allowable storage volume (ML)
ROMA ROP2 CSG Water Management Pond	Coal seam water storage	In ground and above ground	Clay and HDPE	Leak detection layer & shallow groundwater bores	3 550	116
ROMA ROP2 Desalinated Water Pond	RO permeate water storage	In ground and above ground	Clay and HDPE	Shallow Groundwater Bores	2 590	155
ROMA ROP2 Brine Containment Pond A	RO concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer & shallow groundwater gores	27 400	300
Roma ROP2 Brine Containment Pond B	RO concentrate storage	In ground and above ground	Clay and HDPE	Leak detection layer & shallow groundwater gores	N/A**	300
Angry Jungle Dam	Coal seam water storage	In ground and above ground	Clay and HDPE	Shallow groundwater bores	N/A***	180
Pleasant Hills Dam	Irrigation water storage	In ground & above Ground	Clay and HDPE	Shallow groundwater bores	3 910	170
Raslie Dam	Irrigation water storage	Above ground	Clay and HDPE	Shallow groundwater bores	3 220	185
Grafton Range Dam	Irrigation water storage	In ground and above ground	Clay and HDPE	ELIMS testing	N/A****	170
Old Coxon Creek Dam	Irrigation water storage	In ground and above ground	Natural fill	Nil	2 030	30
Hermitage Dam	Construction water storage	Above ground	HDPE	Shallow groundwater bores	6 410	180
Mount Hope Dam	Construction water storage	In ground & above ground	Clay and HDPE	Shallow groundwater bores	7 030	120

* Salinity measured between 21/05/2018 and 12/06/18
** Dam is currently empty
*** Currently not in use, will hold coal seam water from wells on Maisey PL1021 and Roma East projects once they are online.
**** Currently not in use, will hold irrigation water destined for Belbri/Somerset irrigation areas once they are constructed.





- Water Treatment Facility
- Regulated Dam
- Drainage
- Mount Hope irrigation area
- Roleen irrigation area
- Bend South irrigation area
- Pleasant Hills irrigation area
- Belbri/Somerset irrigation area

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Figure 4

Location of PL1021 and GLNG water management infrastructure in Roma

2 0 2 4 6 km

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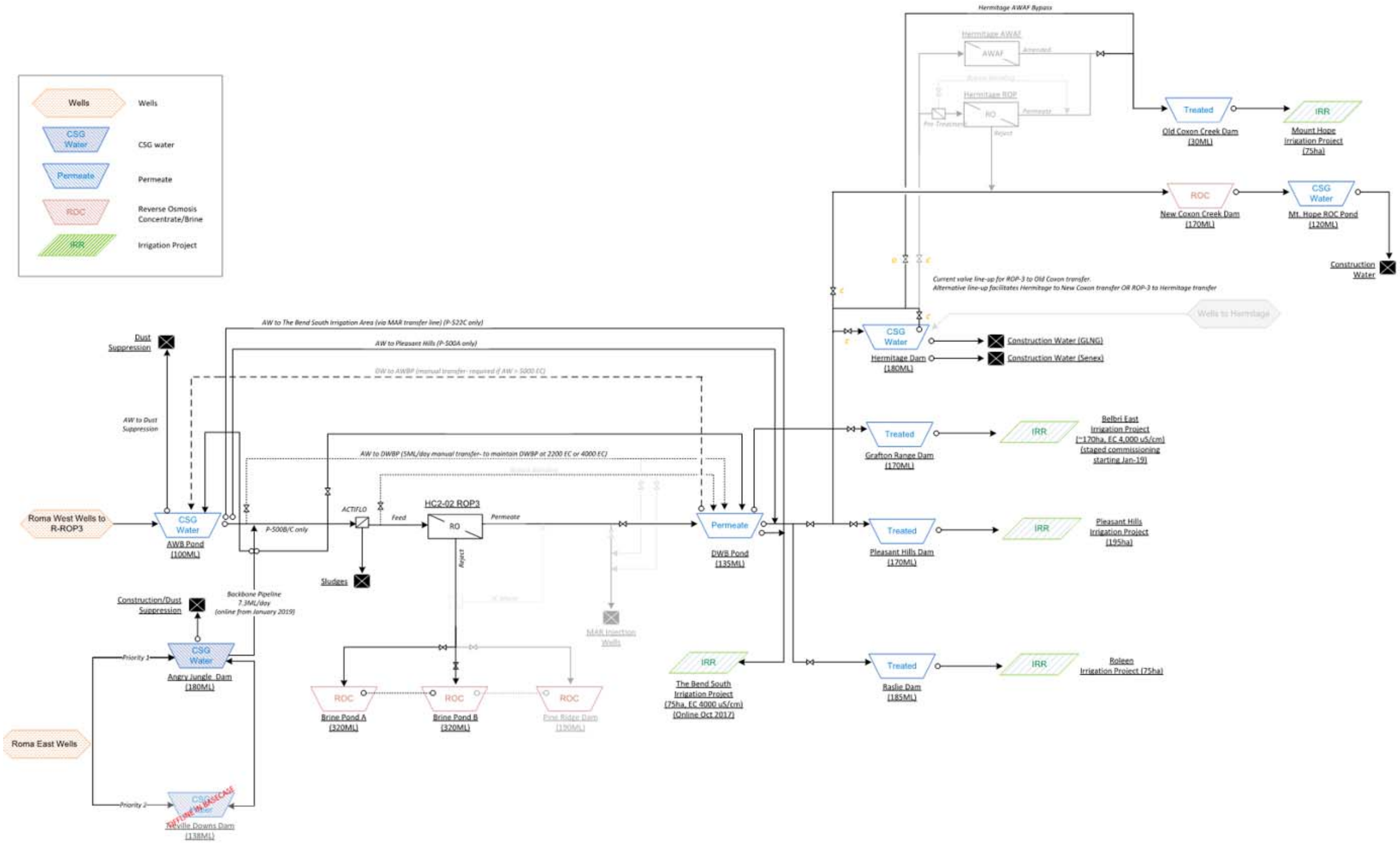


Figure 3: Santos Roma water management schematic

Note: Coal seam water from Maisey PL1021 is referred to in this schematic as “Roma East Wells”

3.1.4. Beneficial Re-use - Operational Purposes

Operational re-use of CSG water on Maisey PL1021 reduces the need to source water from elsewhere. Operation 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 any of the water storage facilities shown in Table 1 where it meets the required water quality objective for the intended use.

3.1.5. Beneficial Re-use - Irrigation

There are no proposed irrigation activities located on Maisey PL1021.

All water from Maisey PL1021 will be gathered and directed to centralised water handling facilities located at Roma Hub02 on PL314. At this location water may be distributed to a number of irrigation areas as shown in Figures 3 and 4. These areas are all operated in accordance according to the principles of Land Amendment 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 will be irrigated with irrigation management activities maintaining soil salinity (ECse) within the tolerances stated within the ANZECC 2000 guidelines (<10.1 dS/m).

The total combined irrigation area is approximately 630 hectares. This area is required to maximise the beneficial use from all water directed through the centralised facilities. The design intends to beneficially re-use up to 11.5 ML/d, on average over a typical year depending largely on the prevailing climatic conditions. The expected peak contribution from CSG wells on PL1021 is approximately 2 ML/d.

The Water Quality Management Plan and the Variation Reports for the various irrigation Projects (see Section 11) demonstrate how irrigated soils can be treated with agricultural amendments to manage the potential risks to soil structure and plant health.

The irrigated Rhodes grass will be 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 CSG water re-use by Santos GLNG within the Roma CSG field. Irrigation has been selected by Santos GLNG as it aligns with Queensland water management policy, complies with regulatory approval conditions and provides an economic benefit through grazing, the main land use in the broader region.

Beneficial re-use via LAI 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.

A map showing the location of the irrigation area and the location of potential MNES receptors is provided in Figures 7, 8 and 9. The areas are also described in Table 2.

Table 2: Land amendment irrigation areas

LAI area	Area (Ha)	Expected irrigation capacity* (ML/year)	Maximum application salinity** (µS/cm)
Pleasant Hills	195	1312	4500
Belbri / Somerset	210	1428	4500
Bend South	75	510	4500
Roleen	75	510	4500
Mount Hope	75	510	4500

* For a typical year assuming 6.8 ML/ha/year;
** Average long-term value, as determined by General Beneficial Use Approvals or the Beneficial Use Approval Variation Reports, see Section 11.

3.1.6. Aquifer reinjection

There will be no reinjection of CSG water from PL1021. There are no plans to operate reinjection facilities at any centralised water treatment facilities within Roma.

3.1.7. RO concentrate storage

There is no requirement to store brine within PL1021.

RO concentrate will be produced as water is desalinated in preparation for beneficial re-use at centralised water treatment facilities located on PL314 at Roma Hub02.

The storage facilities are described in Section 3.1.3 and Table 1.

3.1.8. Brine and salt disposal

A waste stream of RO concentrate (ROC) is generated where desalination (e.g. reverse osmosis) is required to reduce the salinity of coal seam water to allow it to be beneficially re-used. As it enters the storage ponds ROC is typically somewhere around 3,000-29,000 mg/L depending on the source of the water and the level of treatment it has received. ROC storage is stored appropriately, as described in Sections 3.1.3.

Ultimate management and subsequent disposal 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 40,000 mg/L or higher.

The Queensland Coal Seam Gas Water Management Policy 2012 sets out the following management hierarchy for prioritising management of brine (saline waste):

- 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 3.1.3.

3.1.9. 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 in accordance with EA conditions.
- Dust suppression – water and residual drilling materials (fluids) are blended and applied to roads and access tracks 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 licenced waste management facility.

The disposal of residual drilling materials and the potential unmitigated and mitigated risks of adverse impact to MNES is quantitatively assessed for PL1021 in the Water Quality Management Plan (see Section 11). Through the implementation of the Constraints Planning Protocol (i.e. activity location selection, see Appendix A) and based on the outputs of assessment conducted within the Water Quality Management Plan, inclusive of the associated management controls, no significant risk of adverse impact to MNES was identified.

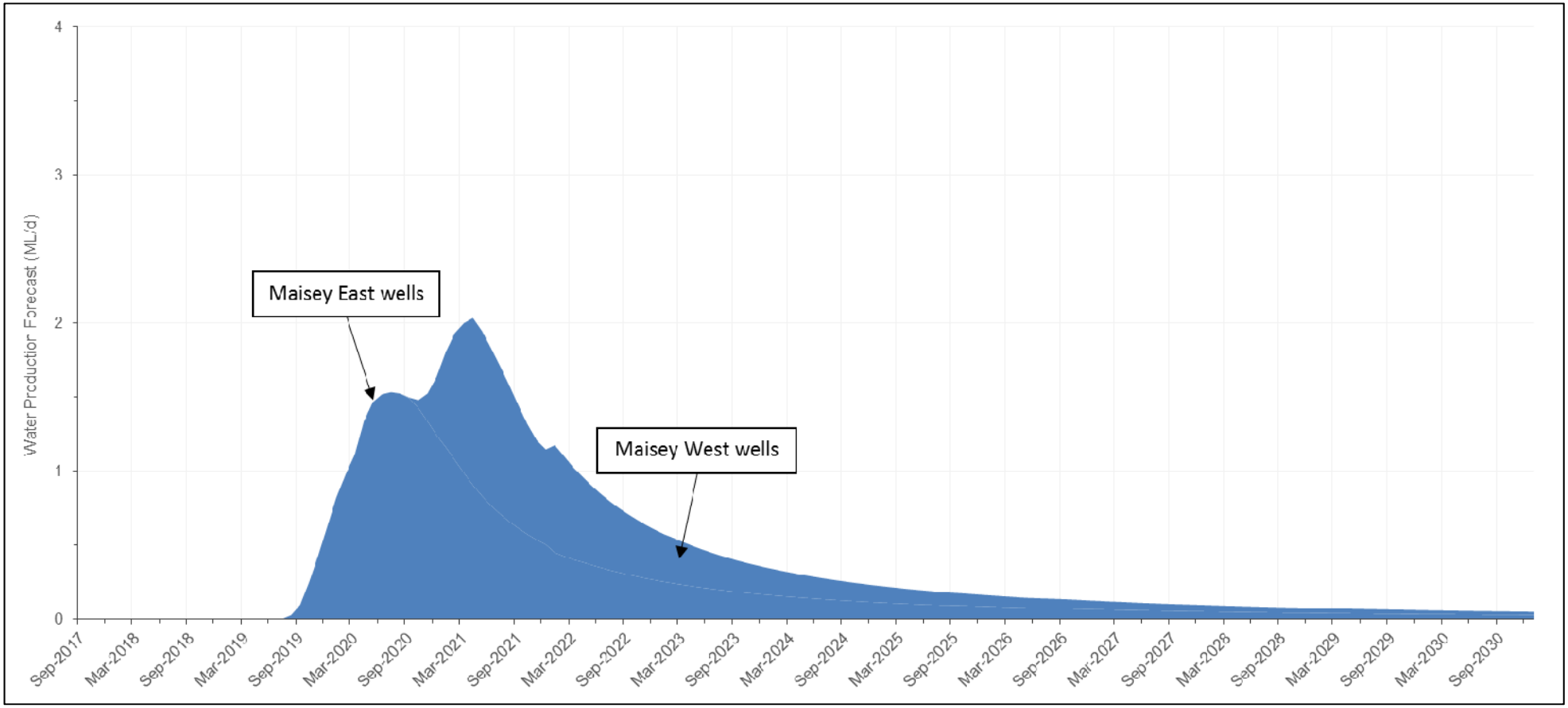


Figure 5: Predicted long-term coal seam water production profile from wells on Maisey PL1021

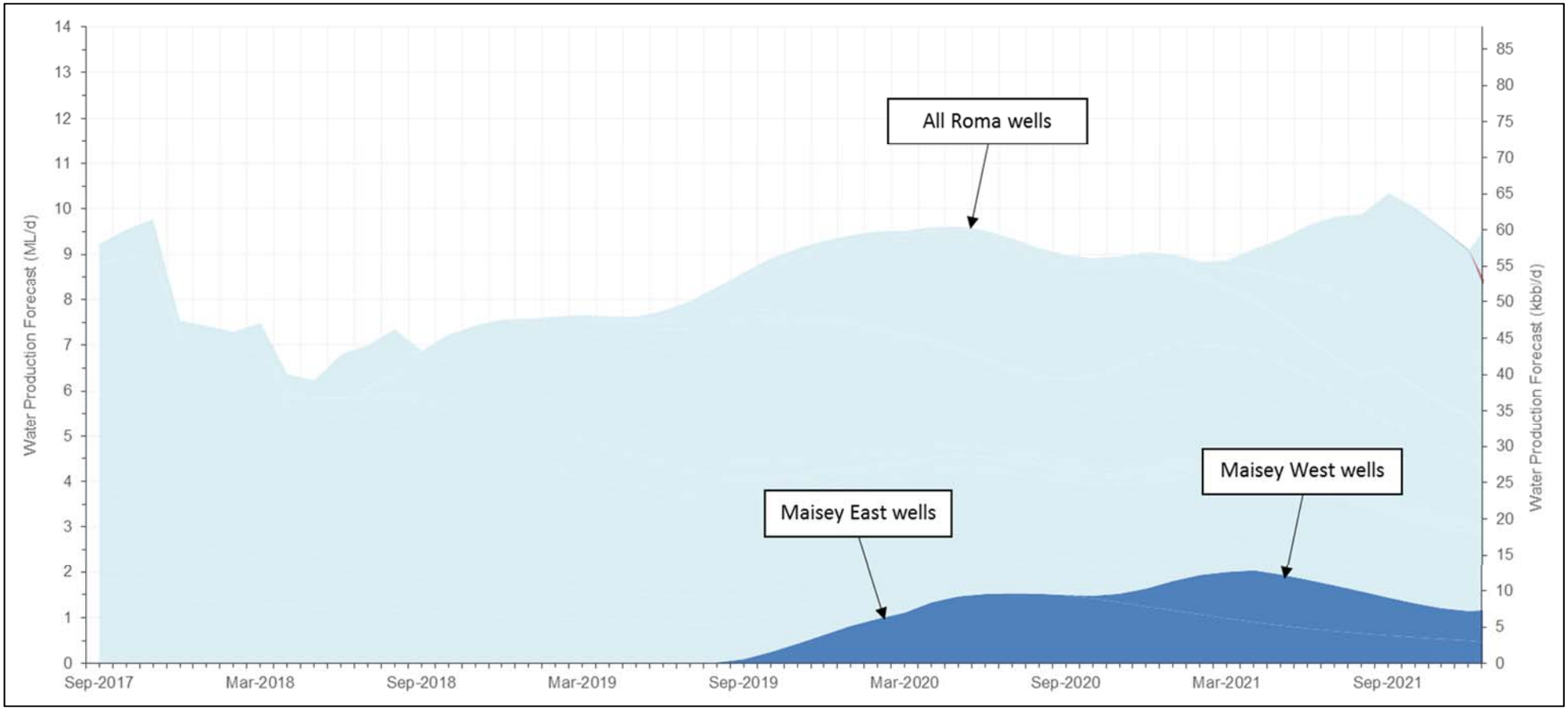


Figure 6: Predicted five-year coal seam water production profile for all Roma wells showing contribution from wells on Maisey PL1021

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
- 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 in Maisey (PL1021) is quantitatively assessed in the GFD Project, Project Stage 2 Water Quality Management Plan. Please refer to this document for detailed exposure pathway analysis.

4.1. Produced Water / Waste Sources

Produced water from Maisey PL1021 is gathered and transferred to centralized water handling facilities on PL314. Based on the activities described in Section 3, there are no potential sources on PL1021, except for produced water which may be used for (or transferred back onto Maisey PL1021 to be used for) dust suppression and civil construction activities.

Otherwise all the produced water from CSG wells on Maisey PL1021 is transferred to Roma Hub02 on PL314. The following sources have been identified:

- The water stored in the storage ponds listed in Table 1,
- The water applied to irrigation areas listed in Table 2,
- The water applied to engineered surfaces during construction and dust suppression.

NOTE: The risk of significant adverse impacts to MNES associated with drilling and completion activities (including hydraulic fracturing) are addressed in the Water Quality Management Plan (see Section 11).

4.2. MNES Receptors

Description of potential MNES receptors within PL 1021, the water handling facilities listed in Table 1 and adjacent to the proposed irrigation areas in Table 2, as shown in Figures 7, 8 and 9.

4.2.1. Habitat for a MNES listed species

The only threatened flora species with potential to occur within the project area is Belson's panic (*Homopholis belsonii*). Field surveys within the vicinity of the project disturbances and the immediate surrounds have failed to identify this species. The proposed irrigation activities occur in areas of historic clearing that are dominated by exotic pasture grasses. This species is not expected to be present within the irrigation and adjacent areas.

A number of different vegetation communities and unique fauna habitats are present within the project area including Blyth Creek and its tributaries. These vegetation communities provide

suitable habitat values for a number of MNES threatened fauna species. Six MNES fauna species are predicted or known to be present within the project area. These six species and their corresponding distribution and known habitat uses are provided in Table 3.

Table 3: Distribution and known habitat use of MNES Fauna within the PL314 and PL1021

Common Name	Scientific Name	EPBC Act Status	Distribution and Known Habitat Use
Australian Painted Snipe	*Rostratula australis*	E	Forages at shallow edges and adjacent vegetated margins of freshwater wetlands (DoEE 2017) and is able to use both artificial and natural ephemeral and permanent wetlands (Marchant and Higgins 1993).
South-eastern Long-eared Bat	*Nyctophilus corbeni*	V	The distribution and habitat preferences of this species are very poorly known; it inhabits a range of dry forest types in south central Queensland (Reardon 2012).
Koala	*Phascolarctos cinereus*	V	This species requires eucalypt woodland and forest habitat with suitable food trees (primarily *Eucalyptus* spp.) (DoEE 2017). Woodlands containing food trees in riparian/alluvial areas are particularly favoured (Melzer et al. 2014). Potential food trees occurring within the Site include *Eucalyptus tereticornis*, *E. camaldulensis*, *E. populnea*, *E. melanophloia*, *E. orgadophila* and *E. crebra*. (Boobook 2017)
Collared Delma	*Delma torquata*	V	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' known range with several records from locations north-west of Roma (ALA 2017).
Yakka Skink	*Egernia rugosa*	V	Lives in a range of woodland and open forests dominated by Eucalyptus, Acacia and *Callitris* spp.; also grassland with regrowth trees (DoEE 2017). Requires suitable soils for burrows or shelters in sinkholes, abandoned rabbit warrens or large fallen/piled woody material (Eddie 2012).
Dunmall's Snake	*Furina dunmalli*	V	Occupies woodlands and open forests; may be reliant on presence of abundant fallen woody debris (Hobson 2012a).

4.2.2. Threatened Ecological Communities

One EPBC Act Threatened Ecological Community (TEC): Brigalow (*Acacia harpophylla* dominant and co-dominant) occurs as within the project area. At the closest point, this TEC is known to be present in proximity to Belbri, Bend South and Mount Hope irrigation areas (see Figures 7, 8 and 9).

4.2.3. Riparian vegetation and referable wetland

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

- 1.2km south of Mount Hope irrigation area
- 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. Groundwater resource

There are several groundwater bores registered within the State of Queensland that are adjacent to Santos' coal seam 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 Mount Hope area is underlain by outcropping units of the Orallo Sandstone. 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.

Groundwater 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 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 16km north-east of the Mount Hope irrigation area. The spring source aquifer for Barton Spring complex is understood to be the Gubberamunda Sandstone (OGIA, 2016).

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

4.3. Potential Complete Exposure Pathways

Based on the outcomes of the Source and Receptor assessment, the following pathways have been assessed:

4.3.1. Irrigation Activities:

- Brigalow TEC – Some minor areas of Brigalow TEC occur down topographic gradient of the irrigation area. Application rates must be managed to ensure all irrigation water infiltrates the ground. But this exposure pathway is potentially complete.

- Blythe Creek and associated wetlands, located ~100m of the Bend South Irrigation area. Given the presence of drainage features in proximity to the irrigation area, this pathway is considered as potentially complete.

- Riparian vegetation, mapped as Regional Ecosystem 11.3.25: River Red Gum (*Eucalyptus camaldulensis*) open forest to woodland, located approximately 100m to the west of 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 20m 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.

4.3.2. Dust suppression and Construction Activities:

- 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.

- Riparian vegetation, mapped as Regional Ecosystem 11.3.25: River Red Gum (*Eucalyptus camaldulensis*) open forest to woodland. 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.

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 Sections 5, 6 and 7.

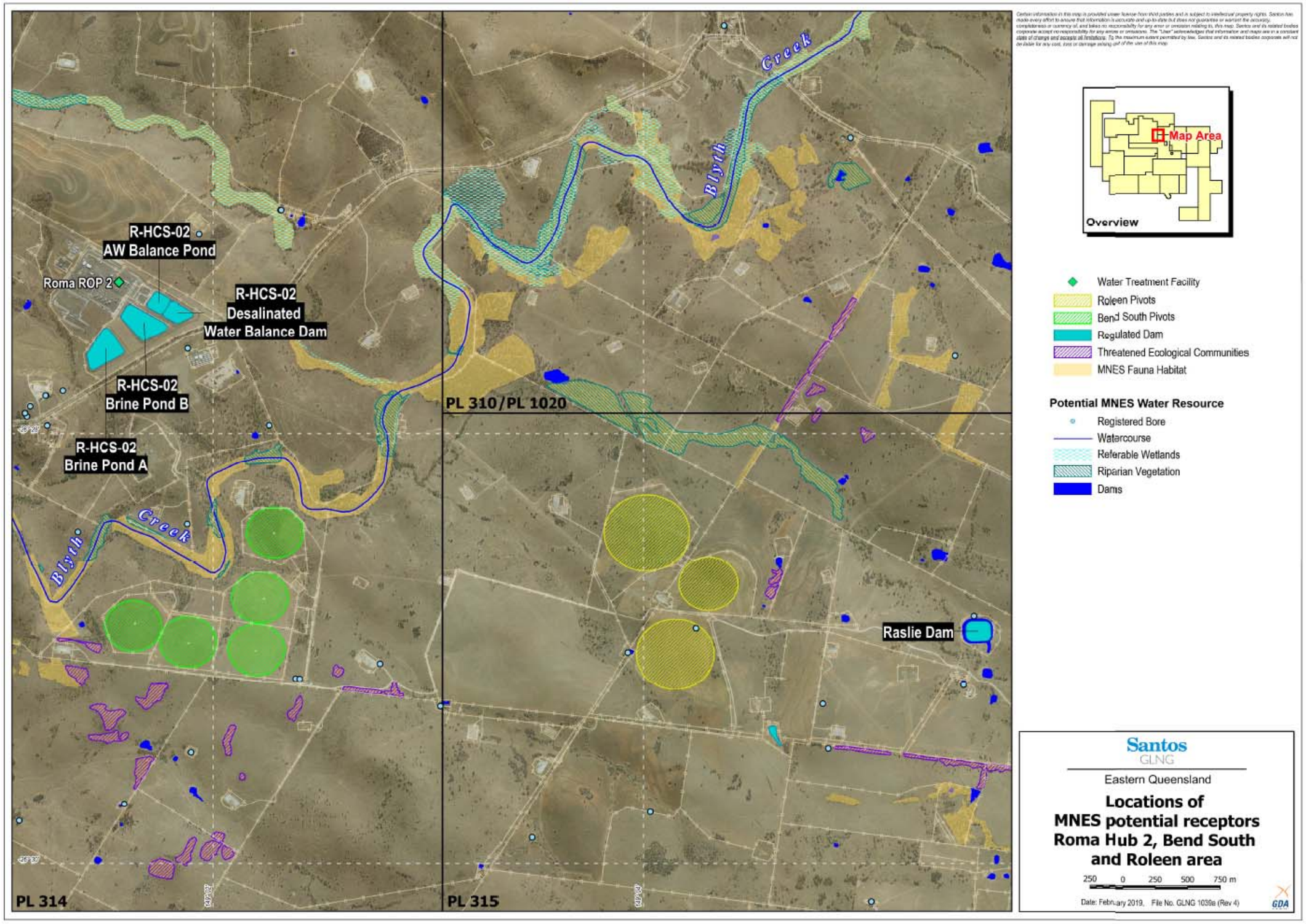


Figure 7: Locations of MNES potential receptors Roma Hub2, Bend South and Roleen area

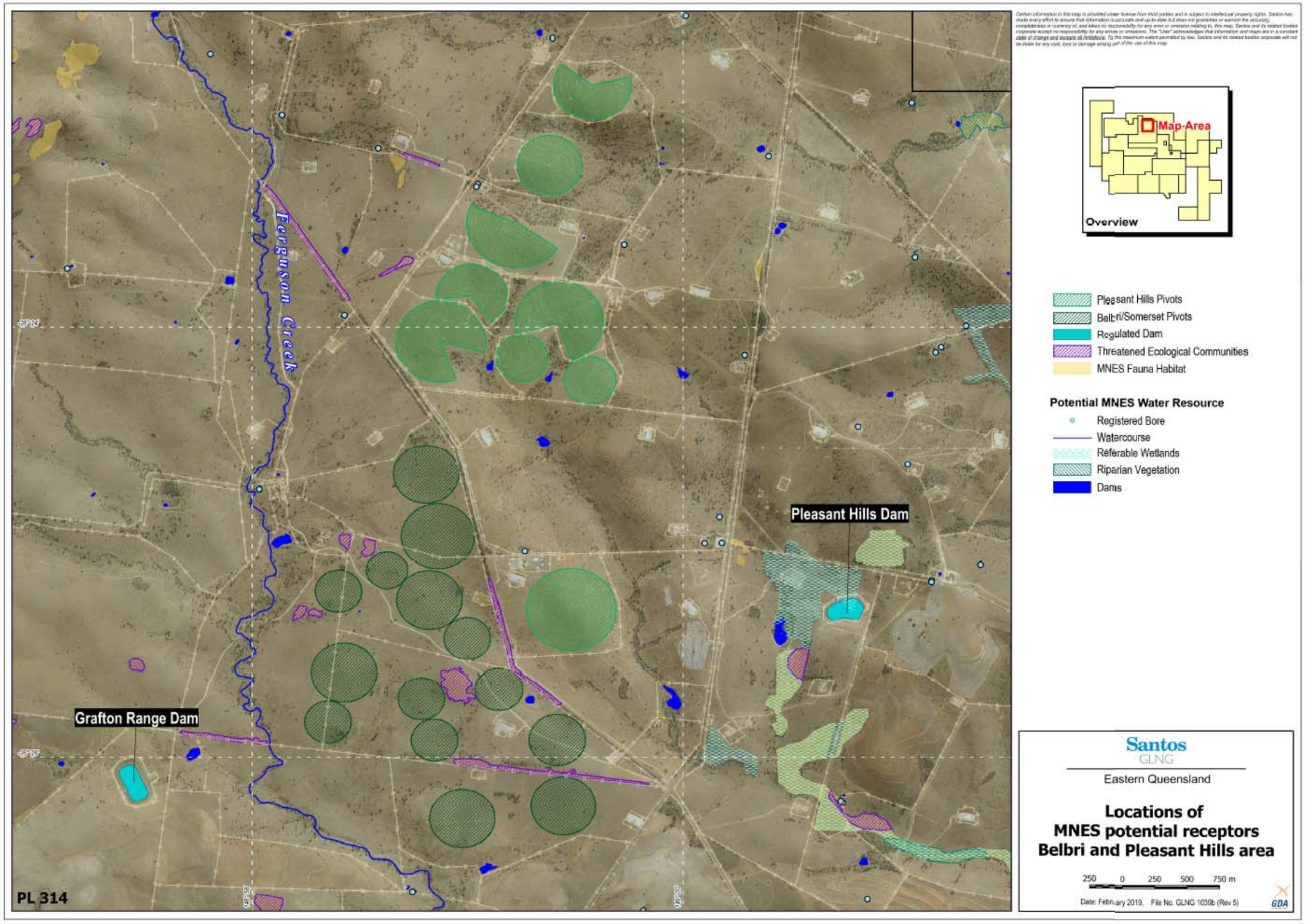


Figure 8: Location of MNES receptors Belbri and Pleasant Hills area

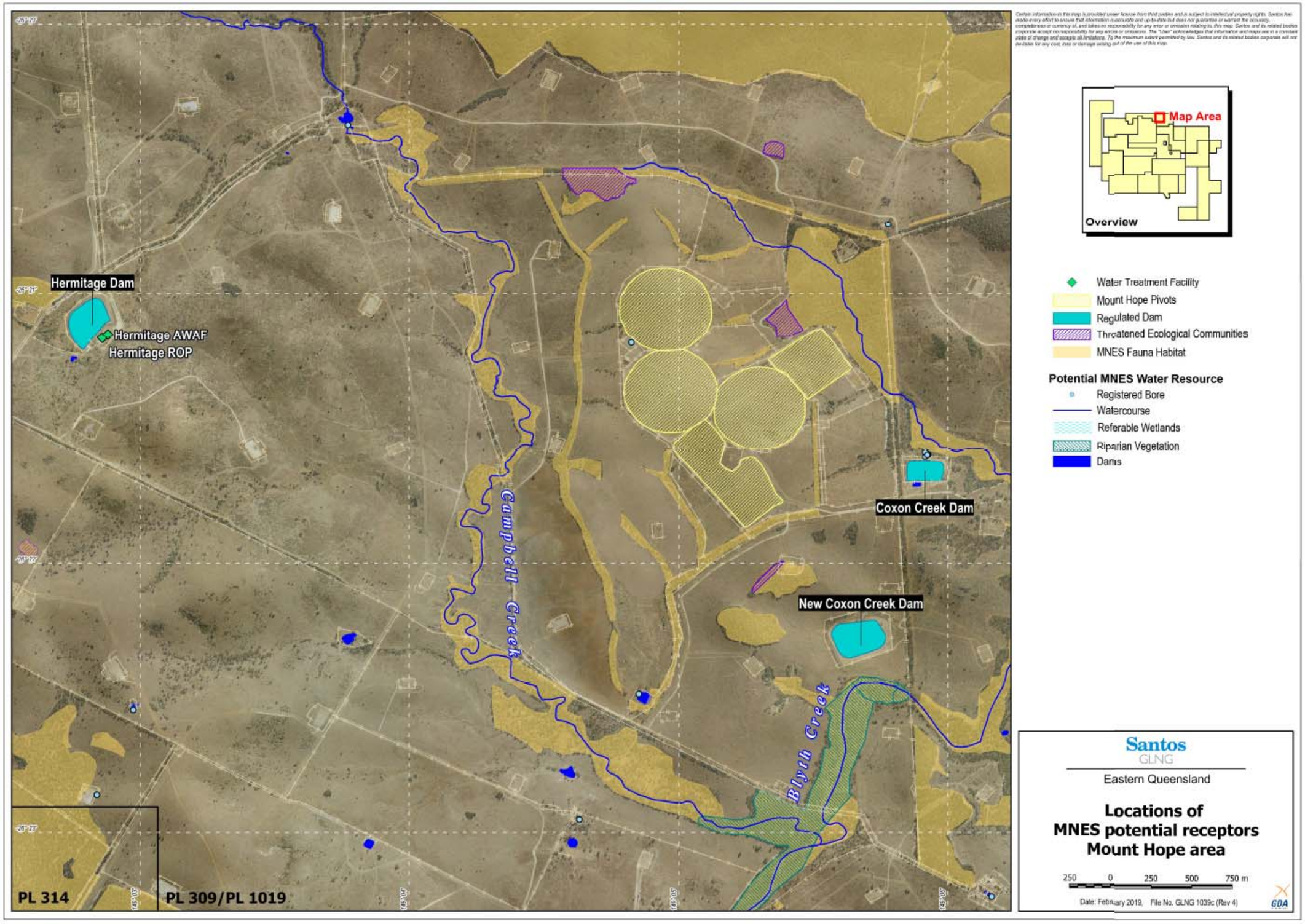


Figure 9 Locations of MNES potential receptors – Mount Hope area

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:

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 production, 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 on Maisey PL1021. In summary, that section:

- describes the various mechanisms and processes by which an adverse impacts to a water resource may occur 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 will be implemented to avoid, mitigate and manage impacts to surface and groundwater resources

5.1. Constraints to development

All project activities listed in Section 3 have the potential to impact surface and groundwater resources, EPBC threatened species, EPBC migratory species and EPBC communities.

However adverse impacts to EPBC threatened species, communities and migratory species can be avoided or minimised by ensuring that construction, operation and decommissioning activities do not occur on or near to ecologically sensitive areas.

The Santos GLNG constraints planning process plays a vital role in the avoidance of potential impacts to surface water environmental values, without the need for further mitigation or management. Appendix A provides an outline of the level of constraint associated with particular activities that will be applied to protect surface water environmental values.

The need for additional mitigation and management of activities in the following section is determined after the application of the avoidance measure of first avoiding undertaking any action in an environmentally sensitive area, as set out in Appendix A.

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 project on Maisey PL1021. These focus on avoiding uncontrolled releases of water or residual drilling material.

Based on the outcomes of the exposure / pathway assessment, Table 4 presents 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.

Table 4 then references 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 will be implemented to avoid, mitigate and manage impacts to surface and groundwater resources and associated receptors.

5.2.1. Water storage ponds

The storage ponds include leak detection systems to manage the risk of seepage to both groundwater and the surface environment.

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

5.2.2. Land amendment irrigation

In Queensland, criteria for irrigation water quality are defined in *General Beneficial Use Approval – Irrigation of Associated Water (including coal seam gas water)* (EHP, 2014). This provides general approval conditions for 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, a *Variation Report* is required. A Variation Report:

- 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

No adverse environmental impact outside of the irrigation area includes a water monitoring plan that ensures these outcomes are achieved over the life of the project.

Variation Reports have been produced for each of the Land Amendment Irrigation areas shown in Table 2 and as described in Section 3.1.5. Monitoring of irrigation water quality, soil structure and chemistry, crop health and soil infiltration rates is specified in that Variation Report.

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 11) 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, GDEs, aquifers, registered groundwater bores, springs and terrestrial receptors. The reports conclude that the risk of vertical and horizontal migration is very low and can be managed through irrigation management and monitoring.

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. Where it reaches 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 table. 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.

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. Groundwater piezometers will be installed and sampling undertaken to detect if horizontal or vertical migration is occurring within the subsurface.

Early warning, trigger thresholds and limits for managing the risk of adverse impact to surface water and groundwater resources due to the operation of irrigation activities are provided in Section 6. A risk based exceedance response plan is presented in Section 7.

5.2.3. Operational re-use of coal seam water

Without adequate management controls in place the beneficial re-use of produced water for operational re-use, particularly dust suppression of roads, has the potential to cause localised impact to surface water receptors (and shallow groundwater at these locations). This is because dust suppression could take place within or adjacent to the surface water receptor, where project activities (roads, construction activities) intersect.

To manage this risk, Santos GLNG will not undertake dust suppression activities within or adjacent to watercourses. Further, the Constraints Protocol avoids project activities, including dust suppression within or adjacent to areas of wetlands and 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 from PL1021 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 cause localised impact to surface water receptors. 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 Land Application Method Statement and Work Plan – Roma Shallow Gas Project Areas and Roma Shallow Gas Project Area East (EHS2017) (the Land Application Method) specifies the methods used to manage risks to environmental receptors, as required by the Environmental Authority approval conditions. This method outlines the application methods, volumes, application areas and monitoring which are required. Risk of exposure to MNES receptors is assessed in the GFD Project Stage 2 Water Quality Management Plan.

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 (Project Stage 2 Water Quality Management Plan);
- 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.

Table 4: Assessment methodologies and management controls of potential impacts to MNES due to the proposed CSG waste management action on Maisey PL1021

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 1 and 3.1.3.	Water over-tops or leaks from pond	Overland flow to surface water resource	Change in surface water resource quality		Constraints planning protocol	- 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 Table 2 and Section 3.1.5.	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 General Beneficial Use Approval: Variation Reports (refer to Section 11).	- 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 Irrigation Environmental Monitoring Plans[1]) - Grazing and land management practices hat 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 - Hydrogeological risk assessment	General Beneficial Use Approval: Variation Reports (refer to Section 11). Irrigation Hydrogeological and Risk Assessments (refer to Section 11).	- 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			
		Irrigation water disperses the soil	Direct application	Impact to soil structure	- Threshold electrolyte concentration (TEC) calculation - Soil chemistry modelling - Calculation of stoichiometric quantities of amendment chemicals	General Beneficial Use Approval: Variation Reports (refer to Section 11).	- Irrigation location selection (soil type) - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Irrigation Environmental Monitoring 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			
		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)	General Beneficial Use Approval: Variation Reports (refer to Section 11).	- Crop selection - Monitoring, observation and adaptive management of irrigation application rates to avoid run-off (see Irrigation Environmental Monitoring Plans[1])
Dust Suppression	Within all development and operational areas in the Roma area	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	GFD Stage 2 Project Area Water Quality Management Plan Land Application Method Statement and Work Plan – Roma Shallow Gas Project Areas and Roma Shallow Gas Project Area East (EHS2017)	- 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] Irrigation Environmental Monitoring Plans are an appendix to the General Beneficial Use Approval: Variation Reports.

6. Early warning indicators, trigger thresholds and limits for detecting impact

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

Details of proposed early warning indicators, trigger thresholds and limits for detecting impacts on surface water and groundwater quality [sic]

Table 5 describes the early warning indicators, triggers thresholds and limits for detecting impacts on surface and groundwater quality.

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 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 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.

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 10 if a revision of the values are required.

Table 5: Proposed Early Warning, Threshold Triggers and Limits for detecting risk of impact related to management of CSG waste water on Maisey PL1021

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	CSG 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[1]	- 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 identify 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	Seepage detection (vertical migration pathways) via a monitoring bore located in a zone of lower permeability (>10m deep, <10m from irrigation area) (bi-annual) Indicative location shown on Figures 10-14.	Groundwater detected in the piezometer (baseline piezometer readings are expected to be dry, with no groundwater present)	- Continue to monitor groundwater pressure - Sample groundwater and analyse for contaminants (see Table 6) - 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 DoEE (within 30 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)	Detection of irrigation water at receptor (receptor monitoring only installed once trigger exceeded)
	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	Seepage detection along horizontal migration pathways via multiple shallow monitoring bores (<10m deep, <250m from irrigation area) (bi-annual). Indicative location shown on Figures 10-14.					
	Irrigation water disperses the soil	Direct application	Impact to soil structure	- Applied irrigation volume and water quality - Soil condition and chemistry in irrigation area	- Soil coring / sampling, laboratory analysis (bi-annual). - Indicative location shown on Figures 10-14. - Visual inspection of soil in irrigation areas (weekly) - Refer to EMP[1]	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 coring and laboratory results identify average SAR within the irrigation area >30 and / or pH >8	- Implement adaptive management and remediation (e.g. application of additional amendments, and mechanical tilling of the soil surface) - Continue visual monitoring to evaluate effectiveness - Assess need to implement contingency irrigation areas to reduce irrigation volumes at that location	- Visual monitoring or soil core analysis indicate 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							
	Irrigation water affects crop, e.g. foliar damage, osomotic 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) - Indicative location shown on Figures 10-14. - Refer to EMP[1]	Visual inspection identify 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 identify 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 identify significant indicators of plant stress (>50%)

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*
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							
Application of residual drilling material to land	Residual drilling material migrates to surface water	Direct application Run-off to adjacent areas	Change in surface water quality	Applied volume, rate and quality	- Measure application volume (each spreading / application event) - Visual inspection of application area - Sample and test 10% of residual drilling material	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	--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 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	--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	- Applied volume, rate and quality Characterisation of soils 12 months post application and one wet season		Visual inspection identifies soil dispersion within application areas	- 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	- Visual inspection identifies significant soil dispersion (>10% of locations) - Soil sample results identify consistently exceed parameters defined in the Land Application Method	- 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 identify localised indicators of plant stress	- Implement adaptive management and remedial actions (e.g. application of additional amendments, mechanical tilling of the soil surface)	Visual inspection identify significant indicators of plant stress (>25%of applied area after wet season)	- 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 identify significant indicators of plant stress (>50% after wet season)

[1] Irrigation Environmental Monitoring Plans are an appendix to the General Beneficial Use Approval: Variation Reports.

Table 6: Analytes for groundwater samples collected from the proposed LAI early warning piezometers.

Analyte	Units	Level of detection	Trigger threshold value	Source of trigger value
Electrical conductivity	µS/cm	1	920	Conversion from ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Major anions	mg/L	1	Presence of irrigation water	Geochemical Evaluation
Major Cations	mg/L	1	Presence of irrigation water	Geochemical Evaluation
Aluminium*	mg/L	0.01	0.027	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Boron*	mg/L	0.001	0.09	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Cadmium*	mg/L	0.0001	0.06	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Chromium (total)*	mg/L	0.001	0.001 (0.00001)	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Copper*	mg/L	0.001	0.001	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Lead*	mg/L	0.001	0.001	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Manganese*	mg/L	0.001	1.2	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Mercury*	mg/L	0.0001	0.0001 (0.00006)	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Nickel*	mg/L	0.001	0.008	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Selenium*	mg/L	0.001	0.005	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
BTEX	µg/L	2	200	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)
Poly-aromatic hydrocarbons	µg/L	1	2	ANZECC (*high reliability* trigger values for freshwater, Table 3.4.1)

* Dissolved

6.1. Detection of groundwater in irrigation groundwater monitoring bores

If groundwater is identified in the LAI groundwater monitoring bores, then samples will be collected and analysed for the analytical suite shown in Table 6. The laboratory analytical results will be compared with irrigation water monitoring laboratory analytical results 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. Evaluation tools will comprise one or more of the following methods:

- Stiff Plot
- Piper Diagram

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.

Further explanation of these evaluation tool is provided below.

6.1.1. Stiff Plots

Similarly to a Schoeller diagram, a Stiff plot can be used 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 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 Na^+ + 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 CO_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.

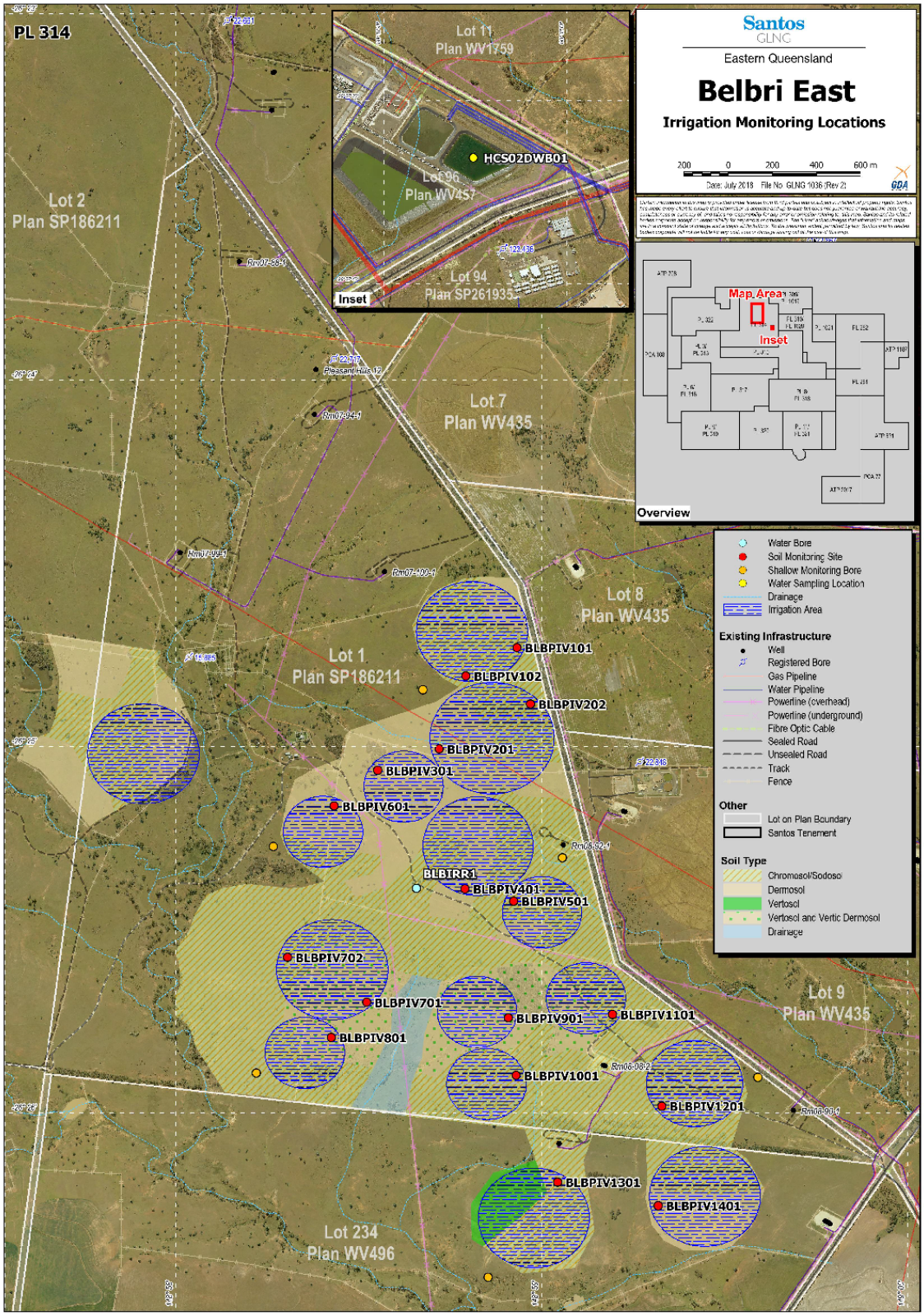


Figure 10: Monitoring locations for the Belbri Irrigation area

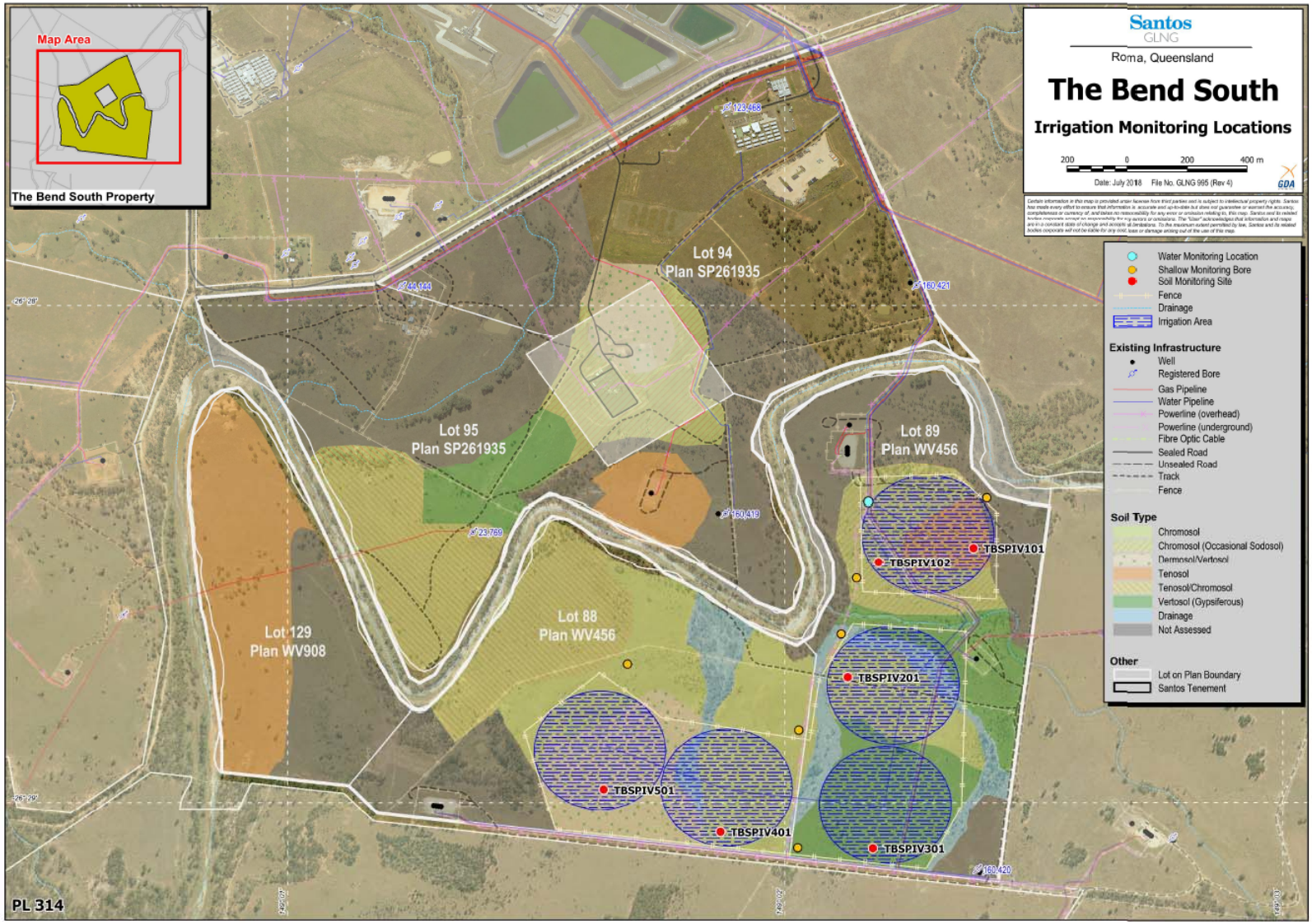
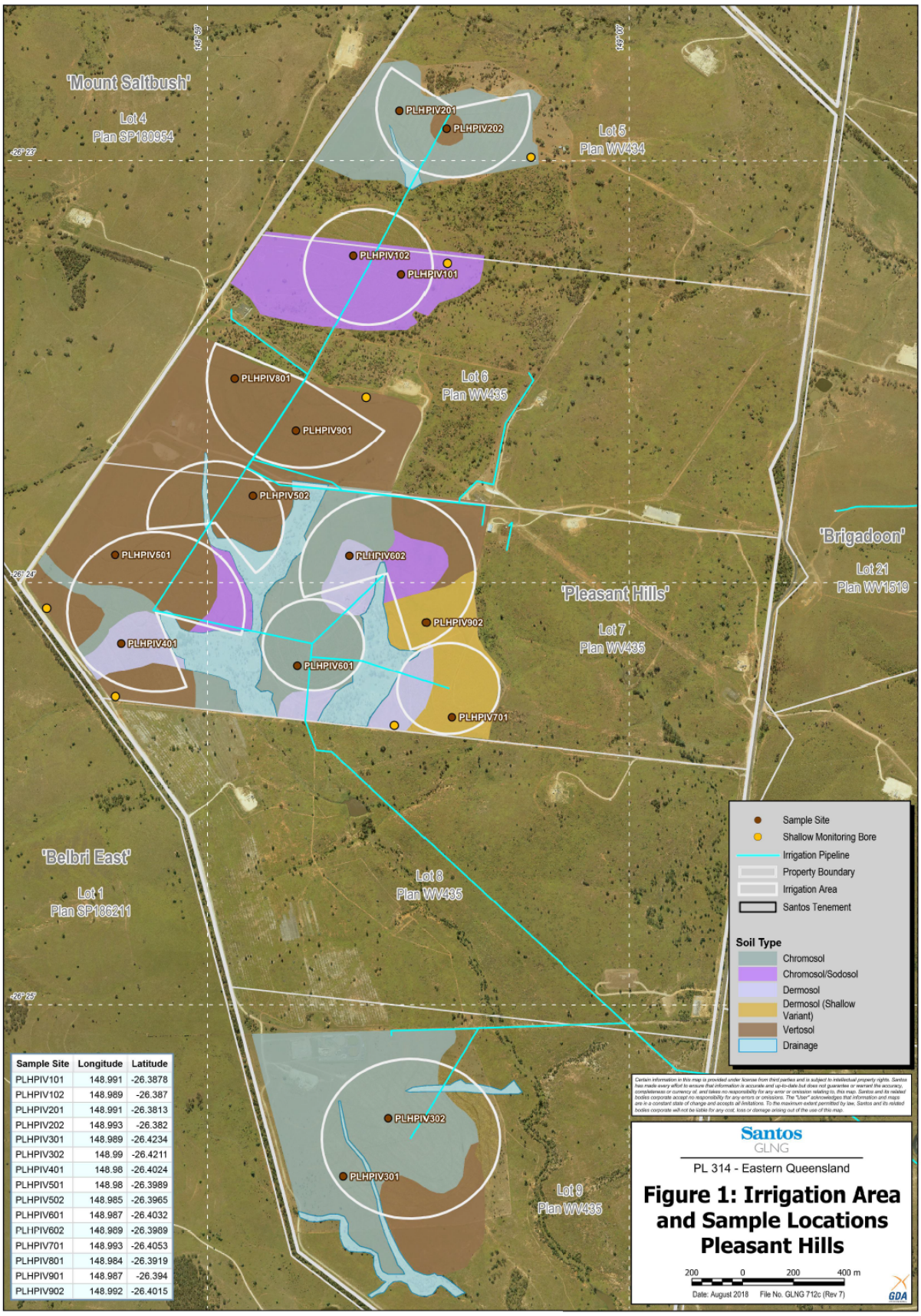


Figure 11: Monitoring locations for the Bend South Irrigation area



Sample Site	Longitude	Latitude
PLHPIV101	148.991	-26.3878
PLHPIV102	148.989	-26.387
PLHPIV201	148.991	-26.3813
PLHPIV202	148.993	-26.382
PLHPIV301	148.989	-26.4234
PLHPIV302	148.99	-26.4211
PLHPIV401	148.98	-26.4024
PLHPIV501	148.98	-26.3989
PLHPIV502	148.985	-26.3965
PLHPIV601	148.987	-26.4032
PLHPIV602	148.989	-26.3989
PLHPIV701	148.993	-26.4053
PLHPIV801	148.984	-26.3919
PLHPIV901	148.987	-26.394
PLHPIV902	148.992	-26.4015

Figure 12: Monitoring locations for the Pleasant Hills Irrigation area

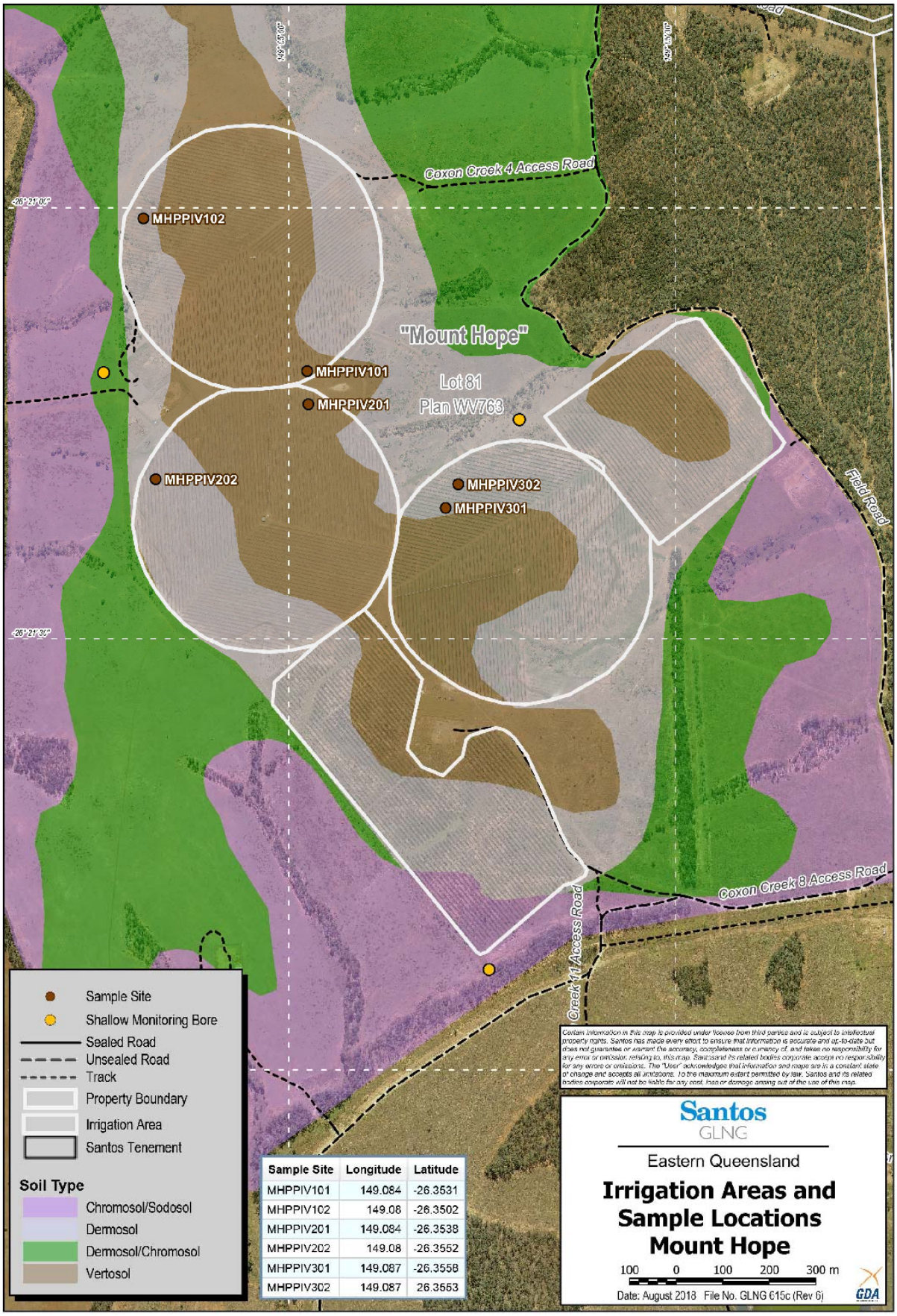


Figure 13: Monitoring locations for the Mount Hope Irrigation area

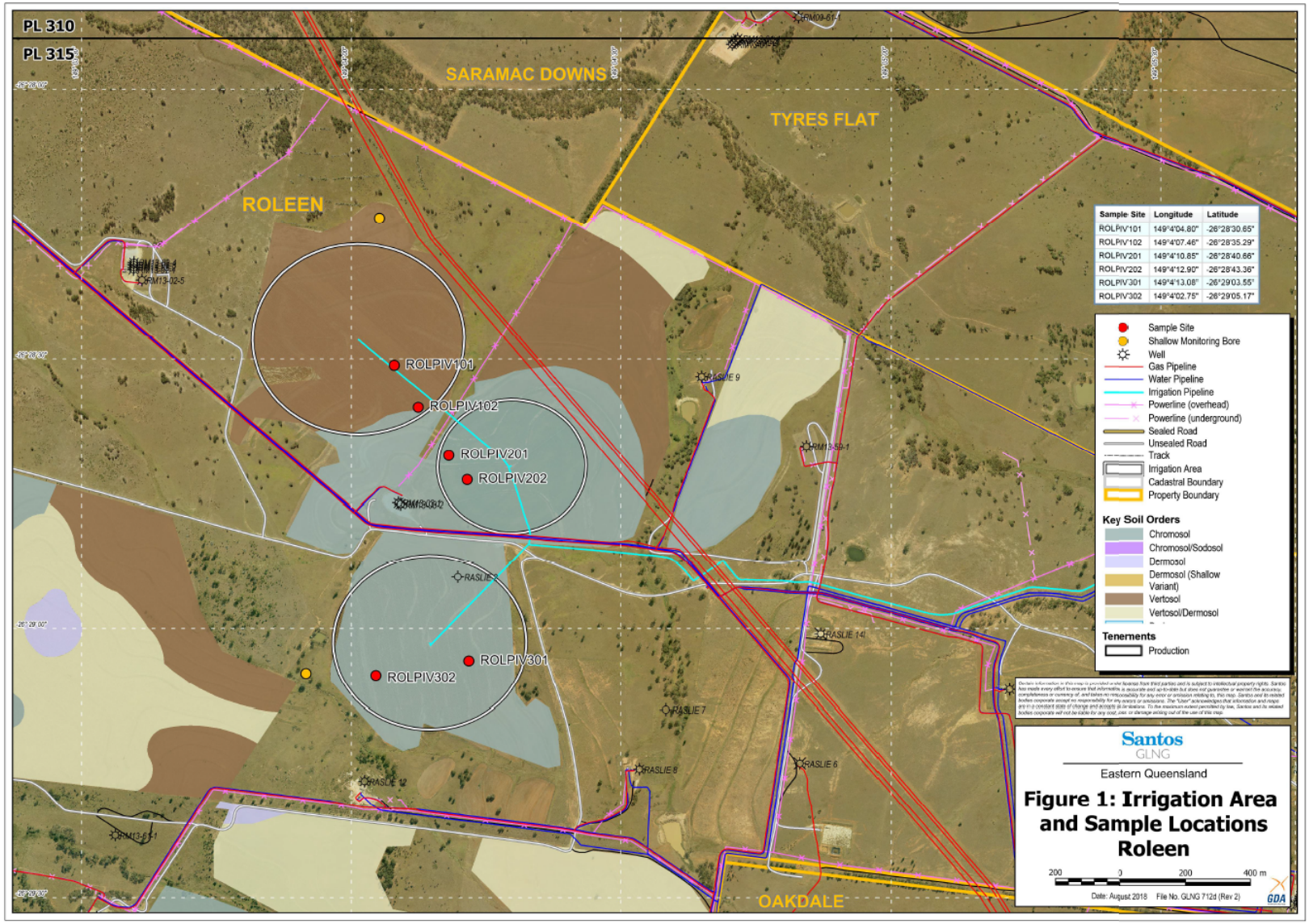


Figure 14 Monitoring locations for the Roleen Irrigation area

7. Exceedance response and reporting

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

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

7.1. Risk based exceedance responses

Monitoring and management controls will be implemented by Santos GLNG to manage and mitigate against the risks presented in Table 4 and Table 5.

The monitoring and response approach outlined in Table 4 and Table 5, 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 impacts to water resources are expected. The proposed management responses are adaptive. If justified, re-assessment and revision of this monitoring and management plan may be justified if new information becomes available that justifies a less conservative approach (see Section 10).

Table 5 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.

7.1.1. Storage of produced water in ponds

The risk based exceedance response plan for the storage of coal seam water in water ponds relies on pond water level monitoring and the monitoring of leak detection systems.

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

7.1.2. Land amendment irrigation

The risk based exceedance response plan for LAI of coal seam water is complex. The various approaches that are shown in Table 5 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

Adverse impacts due to over-land migration

The risk based exceedance response plan for the LAI of coal seam water, in respect of the risk of coal seam 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.

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 11). 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 ~50m 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.

Groundwater monitoring will be located close to the irrigation areas relative to the location of the potential water resource receptors:

- The vertical monitoring points will be installed adjacent to the pivots, more than around 10m deep in the first zone of lower permeability. The top of the first groundwater resource is encountered at depth greater than 20 metres.
- The horizontal monitoring points will be installed <100m horizontally from the pivots above the first low permeability layer, where the nearest surface water resource is located beyond the location of the monitoring points (i.e. typically landholder dams, and the drainage features that may drain into them).

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 this plan (see Section 10). New information that may justify an amendment of this plan might include:

- 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 10).
- 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.

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 Variation Reports (references provided in Section 11). 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.

Adverse impacts to crop health and yield

The risk based exceedance response plan for irrigation in respect of adverse impacts 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 Variation Reports (full references provided in Section 11). 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 of coal seam water

The risk based exceedance response plan for the re-use of coal seam 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 Constraints Planning Protocol.

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 will be 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 quantitative risk assessment presented in the GFD Project Stage 2 Water Quality Management Plan.

7.2. Timeframes for management action and reporting

The timeframe to implement the management responses to exceedances of the early warning indicators and trigger thresholds outlined in Table 5 is provided in Table 7.

Reporting will include an assessment of the location and severity of exceedance.

Table 7: 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:

Detail monitoring to measure the amount of CSG water and waste products produced

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

Produced water volumes are reported to the Queensland Department of Natural Resources Mines and Energy (DNRME) 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 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.

All data will be replicated and submitted annually to the DoEE for all the CSG wells on Maisey PL1021 (see Section 9).

9. Annual report

Santos GLNG will provide an annual report on the anniversary date that this report is approved by DoEE.

This annual report will provide information and data relating to:

- Coal seam water and waste products production volumes (see Section 8)
- Record of any data that demonstrates that any Early Warning Indicators, Trigger Thresholds or Limits have been exceeded, as defined in Table 5 (see section 6).
- Descriptions and any available evidence of the nature and extent of risk based exceedance responses taken (see Section 7).

10. 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.

This is may occur when:

- Additional activity (or action) is proposed relating to the management of CSG water that is not already described or referred to in this plan.

- New information is available that justifies amendment of the plan.

10.1. Additional activity

If the proposed additional action is likely to have a new or increased impact, 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 water by any other means (i.e. by a method not outlined in this plan), it would need to revise this plan. It is an operational constraint for Santos to ensure it has all the necessary approvals to manage CSG water. 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 the regulating authority in writing that the plan has been revised, and provide a copy of the revised plan to the regulating authority

- Implement the revised plan from the date that the plan is submitted to the regulating authority

- For the life of approval 2012/6615, maintain a record of the reasons that Santos GLNG considers that taking the action in accordance with the revised plan would not be likely to have a new or increased impact.

10.2. New information

Santos GLNG may revise this plan if new information (such as interpreted operational data or environmental monitoring data) is made available that justifies amendment to the plan.

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

11. Supporting documentation

Water Quality Management Plan (EHS Support, 2018) – plan required prepared to satisfy EPBC approval 2012/6615, Condition 29C.

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

General Beneficial Use Approval – Associated Water (including coal seam gas water) (Queensland Department of Environment and Heritage Protection (DEHP), 2014)

General Beneficial Use Approval – Irrigation of Associated Water (including coal seam gas water) (Queensland Department of Environment and Heritage Protection (DEHP), 2014)

General Beneficial Use Approval: Variation Reports:

- 1704-220-REP-0001_General_BUA_Variation_Report_Pleasant_Hills
- 1726-465-REP-0001_Belbri_East_Irrigation_Area_Variation_Report
- 7667-465-REP-0001_General_BUA_Variation_Report_The_Bend_South
- 0007-560-REP-0001_General_BUA_Variation_Report_Roleen
- 0027-650-REP-0004_General_BUA_Variation_Report_Mount Hope

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.

Land Application Method Statement and Work Plan – Roma Shallow Gas Project Area and Roam Shallow Gas Project Area East, EHS Support, 2017

Surat Underground Water Impact Report (UWIR) for the Surat Cumulative Management Area (Queensland Office of Groundwater Impact Assessment (OGIA), 2016)

APPENDIX A - CONTRAINTS TO DEVELOPMENT

An overarching development protocol is employed. This avoids the risk of impact to particularly sensitive environmental receptors and MNES by ensuring higher impact activities are restricted to areas of a lower environmental sensitivity, and vice versa.

This process is described in detail in Section 5 of the Significant Species Management Plan – GFD Project (Santos GLNG, 2016) and describes the process for planning and siting project activities. This process plays a pivotal role in the general avoidance of potential risk of adverse impact to environmental values by GFD Project activities.

Table A1 below provides an outline of the planning constraints which are applied to various types of mapped environmental values. For example, the construction and operation of water management facilities would generally only be developed in areas “low constrain areas” i.e. where MNES are not present and thereby avoiding risk to MNES.

Table A1: CSG water management activities undertaken as part of the Santos GFD Project

Level of constraint	Constraint mapping layer	Permitted activities
No-go area	Category A environmentally sensitive areas including national parks[1], conservation parks, and forest reserves (NC Act).	No petroleum activities are permitted
	EPBC Act-listed spring vents and complexes including primary 200 m buffer.	
	Wetlands of national importance including 200 m buffer.	
	Wetlands of high ecological significance or high conservation value (*Map of Referrable Wetlands*).	
Surface development exclusion area	Primary 200 m buffer for Category A environmentally sensitive areas.	Only low impact petroleum activities[2] are permitted
	The following Category C environmentally sensitive areas[3]: • Declared catchment areas (*Water Act 2000* (Qld)).	
	The following Category B environmentally sensitive areas: • Ramsar sites listed as wetlands of international importance.	
High constraint area	Watercourses (stream orders) including 100 m buffer.	Low impact petroleum activities and linear infrastructure[3] are permitted
	Wetland defined as 'general ecologically significant wetland' or 'wetland of other environmental value' (*Map of Referrable Wetlands*).	
	Spring vents and complexes (not protected under the EPBC Act) including primary 200 m buffer.	
Moderate constraint area	Secondary 100 m buffer for Category A environmentally sensitive areas.	Low impact petroleum activities, linear infrastructure and limited petroleum activities[4] are permitted.
	Secondary 100 m buffer for spring vents and complexes (EPBC Act).	
	Matters of national environmental significance including habitats (threatened species habitat and migratory species habitat), threatened ecological communities (derived from state regional ecosystem mapping or verified from field surveys), and flora species.	
	Endangered regional ecosystems including primary 200 m buffer.	
Low constraint areas	High value regrowth (endangered and of concern regional ecosystems)	All petroleum activities[5] are permitted
	No concern at present regional ecosystems	
	Type A species (NC Act)	
	Existing Santos GLNG infrastructure	
	Existing road, rail, pipeline and other infrastructure.	
	Remaining areas once other constraints have been applied.	

[1] *Specific and mutually beneficial activities in a (limited depth) national park may be allowed with express written permission from Department of National Parks, Recreation, Sport and Racing. Santos GLNG will only seek permission to enter a national park on limited occasions where no other feasible option exists.*

[2] *Low impact petroleum activities are limited to exploration, survey or monitoring activities that do not require clearing of native vegetation, earthworks or excavation activity that will cause significant disruption to the soil profile or permanent damage to vegetation that cannot be easily rehabilitated.*

[3] *Linear infrastructure includes (but is not limited to) gas and water gathering lines, low and high pressure gas and water transmission pipelines, power lines, communication, roads and access tracks.*

[4] *Limited petroleum activities include single-well and multiple-well leases and associated infrastructure located in the leases and camps within well leases that may involve sewage treatment works that are a no-release works.*

[5] *Petroleum activities include low impact petroleum activities, linear infrastructure, limited petroleum activities, and all other GFD Project activities including major facilities such as permanent accommodation camps, gas treatment facilities, air strips, gas compression facilities, and water management facilities such as water storage and water treatment facilities.*

APPENDIX B1 - COAL SEAM WATER QUALITY

The table below presents water composition data for wells in the 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	0.05	0.36	0.48	0.75	1.42	491
Calcium (mg/L)	D	1	1	2	4	6	37	492
Chloride (mg/L)	N/A	1	35	525.5	722	1235	5230	736
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	1340	2890	3660	5260	13600	741
Fluoride (mg/L)	N/A	1	1	1.9	2.6	3.7	6.6	491
Magnesium (mg/L)	D	1	1	1	1	1	8	492
pH – Lab	N/A	0.01	7.93	8.18	8.39	8.77	9.05	318
Potassium (mg/L)	D	1	2	4	10	28	40	491
Sodium (mg/L)	D	1	320	665	861	1070	3060	491
Sodium Adsorption Ratio-	N/A	0.01	59.9	99.52	118	138.4	183	277
Strontium (mg/L)	T	0.001	0.065	0.3476	0.58	1.104	8.57	247
Sulfate as SO4 2 (mg/L)	D	1	1	1	1	9.9	373	492
Total Dissolved Solids (Calc.) (mg/L)	T	10	1010	1941	2475	3361	7020	172

APPENDIX B2 – CALCULATED IRRIGATION WATER QUALITY

The tables below presents the calculated irrigation water quality for the Roma Irrigation Areas

Santos

Water quality in Coxon Creek Dam (3/04/18 to 17/07/18)

Analyte	Dissolved or total	Limit of detection	Min.	Median	Max.	Sample count
Calcium (mg/L)	D	1	2	4	5	9
Chloride (mg/L)	N/A	1	357	409	452	9
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	1800	1900	2030	9
Fluoride (mg/L)	N/A	1	1.6	1.7	1.8	9
Magnesium (mg/L)	D	1	2	3	4	9
pH – Lab	N/A	0.01	8.86	9.09	9.44	9
Potassium (mg/L)	D	1	8	9	10	9
Sodium (mg/L)	D	1	389	405	431	9
Sodium Adsorption Ratio-	N/A	0.01	33.6	36.7	48.4	9
Sulfate as SO4 2 (mg/L)	D	1	<1	1.5	2	9

Santos

Water quality in Pleasant Hills Dam (4/04/18 to 29/05/18)

Analyte	Dissolved or total	Limit of detection	Min.	Median	Max.	Sample count
Calcium (mg/L)	D	1	2	4	5	26
Chloride (mg/L)	N/A	1	35	666	766	26
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	1340	3645	3870	26
Fluoride (mg/L)	N/A	1	1	2.9	3.3	26
Magnesium (mg/L)	D	1	1	<1	<1	26
pH – Lab	N/A	0.01	8.84	8.93	9.1	26
Potassium (mg/L)	D	1	25	28	31	26
Sodium (mg/L)	D	1	778	847	886	26
Sodium Adsorption Ratio-	N/A	0.01	89.1	102	139	26
Sulfate as SO4 2 (mg/L)	D	1	<1	1	2	26

Santos

Water quality in Raslie Dam (4/04/18 to 17/05/18)

Analyte	Dissolved or total	Limit of detection	Min.	Median	Max.	Sample count
Calcium (mg/L)	D	1	2	4	5	16
Chloride (mg/L)	N/A	1	425	624	702	16
Electrical Conductivity @ 25°C (µS/cm)	N/A	1	1970	3210	3600	16
Fluoride (mg/L)	N/A	1	1	2	3	16
Magnesium (mg/L)	D	1	<1	<1	<1	16
pH – Lab	N/A	0.01	8.8	9.0	9.1	16
Potassium (mg/L)	D	1	21	26	28	16
Sodium (mg/L)	D	1	427	689	771	16
Sodium Adsorption Ratio-	N/A	0.01	60	88	97	16
Sulfate as SO4 2 (mg/L)	D	1	<1	1	2	16