Coal seam water management strategy

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Santos GLNG Gas Field Development Project

Coal Seam Water Management Strategy

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1 Introduction

The objective of the Santos GLNG Gas Field Development Project (GFD Project) coal seam water management strategy is to outline how Santos GLNG proposes to manage coal seam water within the regulatory framework established by the Queensland and Commonwealth Governments.

The strategy recognises that the volume and quality of coal seam water will vary over time and across the GFD Project area, and that technology and requirements of potential beneficial users are also likely to change or evolve over the expected project life. Flexibility and adaptation are key elements of the strategy, and monitoring and ongoing stakeholder engagement will be important in its implementation.

The strategy is consistent with the *Coal Seam Gas Water Management Policy* (DEHP 2012), which "encourages the beneficial use of coal seam water in a way that protects the environment and maximises its use a valuable resource".

The strategy seeks to build on the increased level of understanding within government, business and community of the potential benefits and liabilities associated with coal seam water extraction. The strategy proposes usage of lifecycle feasibility assessments to determine sustainable outcomes for coal seam water management. The feasibility assessments are proposed to be evaluated using a Multi-Criteria Assessment (MCA) approach, where water management options are assigned a score based on performance against weighted criteria. The key criteria include environmental, social, technical and economic considerations.

The strategy is to be implemented in conjunction the Santos Environmental, Health and Safety Management System (EHSMS) and the GFD Project water resource management and waste management plans.

This strategy, in conjunction with the Draft EM Plan, addresses the requirements of Section 126 of the EP Act in relation to information regarding the management of coal seam water.

The GFD Project will include the following components:

- Production wells
- Potentially underground gas storage wells, fluid injection wells and monitoring bores
- Gas and water gathering lines
- Gas and water transmission pipelines
- Gas compression and treatment facilities
- Water storage and water management facilities
- Access roads and tracks
- Accommodation facilities and associated services
- Maintenance facilities, workshops, construction support, warehousing, and administration buildings
- Utilities such as water and power generation and supply
- Laydown, stockpile and storage areas
- Borrow pits and quarries
- Communications

The final number, size and location of these components will be determined progressively over the life of the GFD Project.

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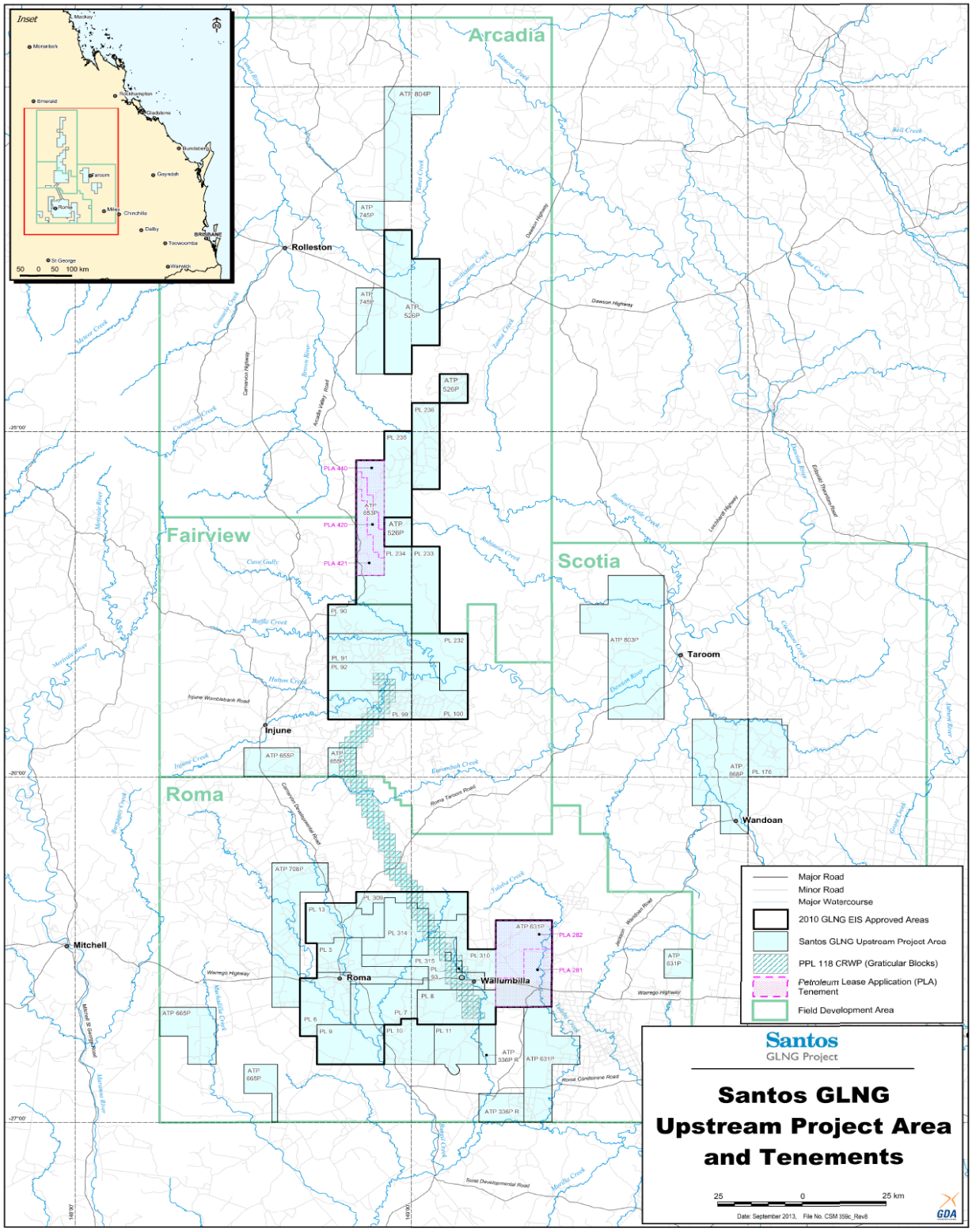

Figure 2-1: The Santos GLNG GFD Project Area and Tenures

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2 Santos Environment, Health and Safety Management System

The Santos EHSMS provides a framework for environmental and safety practices across Santos operations (Figure 3-1). The framework has been developed to be consistent with AS 4801:2000 Occupational Health and Safety Management Systems and AS/NZS ISO 14001:2004 Environmental Management Systems. The Coal Seam Water Management Strategy complements the requirements of the EHSMS.

This Coal Seam Water Management Strategy also builds upon the implementation experience and understanding gained through the GLNG Project. In accordance with this framework and the regulatory context, the existing Santos GLNG Project has environmental management plans and procedures in place to avoid, minimise or mitigate the risk of adverse impacts to environmental values.

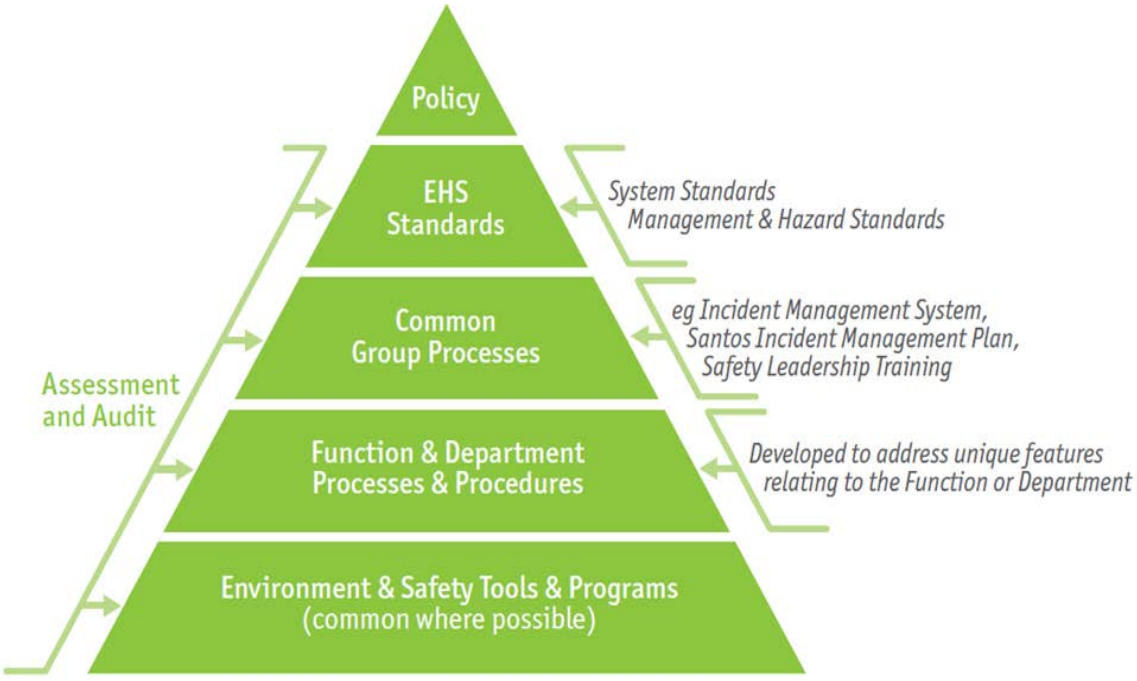

Figure 3-1: Santos Approach to Environmental Management

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3 Regulatory Framework

An overview of the key legislation considered in the development of the Coal Seam Water Management Strategy is provided in Table 1.

Table 1: Summary of Key Applicable Legislation and Policies

Legislation, policy or guideline	Relevance to the GFD Project
Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act)	This Act is the central piece of environmental legislation at the Commonwealth level. It provides for the protection of environmental values, including matters of national environmental significance (MNES). Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process under the EPBC Act. Recent amendments to the EPBC Act have made water resources a MNES in relation to certain resource development projects. This means that projects such as the GFD Project that have potential for significant impacts on water resources must be referred to the Department of the Environment for assessment under the EPBC Act.
Environmental Protection Act 1994 (Queensland) (Qld) (EP Act)	The EP Act is the principal legislation for the protection and management of environmental values within Queensland. The Act aims to protect the natural environment and associated ecological systems and processes, while allowing for sustainable development. The EP Act sets forth regulatory instruments such as the Environmental Protection (Water) Policy 2009 (Qld) (EPP (Water)). It includes provisions for the management and disposal of water produced from gas operations.
Environmental Protection (Water) Policy 2009 (Qld) (EPP Water)	EPP Water aims to protect Queensland's waters while allowing for ecologically sustainable development. It provides a framework for identifying environmental values for aquatic ecosystems and human uses and determining water quality guidelines and objectives to enhance or protect the environmental values.
Coal Seam Gas Water Management Policy 2012 (EHP, 2012)	This policy guides operators in managing coal seam water, including beneficial use in a way that protects the environment and maximises its productive use as a valuable resource.
Petroleum Act 1923 (Qld) *Petroleum and Gas (Production and Safety) Act 2004 (Qld) (P&G Act)*	Provide rights to conduct petroleum activities within the GFD Project tenements, including provisions for extraction and management of groundwater associated with those petroleum activities.

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Legislation, policy or guideline	Relevance to the GFD Project
Water Act 2000 (Qld) *The Act regulates the development of water resource plans (WRPs) and resource operations plans (ROPs) for major river catchments in Queensland.*	The Act regulates the development of water resource plans (WRPs) and resource operations plans (ROPs) for major river catchments in Queensland. WRPs establish a framework for sharing water between human consumptive needs and environmental values. ROPs are developed in parallel with WRPs and provide a framework for implementing WRPs. The Act provides for the management of impacts on groundwater caused by the extraction of water by petroleum tenure holders, including the 'make good' obligations.
National Water Quality Management Strategy (NWQMS)	Provide guideline values (water quality objectives) to assess the existing water quality within the surface water environment sourced from guidelines developed under the NWQMS (e.g. ANZECC 2000).
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)	The guidelines are the recognised standard for protecting ambient water quality in Australia and New Zealand.
Queensland Water Quality Guidelines (QWQG) (EHP, 2013)	The QWQG is a set of technical guidelines for the protection of Queensland's aquatic ecosystems including fresh, estuarine and marine waters.

Further discussion regarding key legislation and policies is provided in Sections 4.1 and Section 4.2. The regulatory approval process for the Santos GLNG GFD Project EIS in relation to coal seam water management is depicted in Figure 4-1.

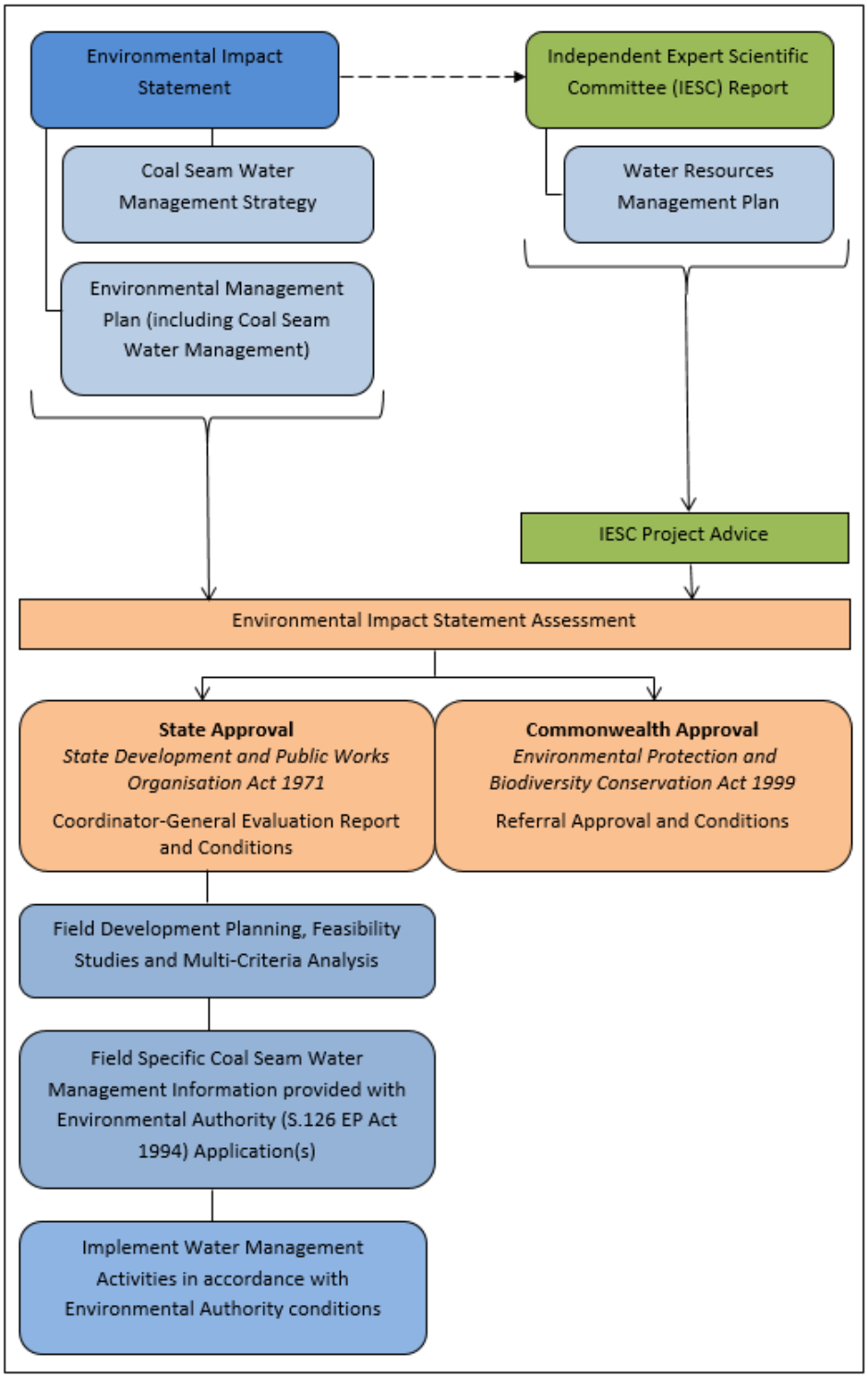

Figure 4-1: Regulatory Approval Process – Coal Seam Water Management

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3.1 Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) (EPBC Act)

The EPBC Act provides for the management and protection of national and international flora and fauna of environmental significance, referred to as Matters of National Environmental Significance (MNES).

The nine MNES under the EPBC Act are as follows:

- World heritage properties
- National heritage places
- Wetlands of international importance (often called 'Ramsar' wetlands after the international treaty in which such wetlands are listed)
- Nationally threatened species and communities
- Migratory species
- Commonwealth marine areas
- The Great Barrier Reef Marine Park
- Nuclear actions (including uranium mining)
- A water resource, in relation to coal seam gas development and large coal mining development.

In November 2012, the GFD Project was referred to the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities (SEWPaC) in accordance with the provisions of the EPBC Act. The EPBC Act requires actions likely to have a significant impact on matters of national environmental significance (MNES) to be referred to Commonwealth Government for assessment and approval. On 3 December 2012, SEWPaC (now the Department of the Environment (DOE)) deemed the GFD Project to be a controlled action (reference number EPBC 2012/6615). Hence the GFD Project requires assessment and approval under Part 9 of the EPBC Act before it can proceed. The controlling provisions under the EPBC Act are:

- Wetlands of international importance
- Listed threatened species and communities
- Listed migratory species

In October 2013, Santos GLNG was advised by the DOE that an additional controlling provision relating to the impact of coal seam gas development on water resources also applied to the GFD Project.

GFD Project activities that have the potential to impact on MNES (water resources and groundwater dependant ecosystems) require specific management and mitigation measures. Santos GLNG has therefore also developed a Water Resource Management Plan for the GFD Project, which outlines management commitments to avoid, minimise and mitigate the risk of potential adverse impacts to MNES (water resources and groundwater dependant ecosystems) within the GFD Project area.

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3.2 Environmental Protection Act (Queensland)

Management of coal seam water extracted during Coal Seam Gas (CSG) production is regulated under the *Environmental Protection Act 1994* (EP Act). In accordance with the EP Act, an application for an Environmental Authority (EA) (Chapter 5 Activities) must include specific information regarding the management of coal seam water (Section 126 of the EP Act) and must consider the Coal Seam Water Management Policy (DEHP, 2012) (refer Section 4.2.2). Based on this application, the EA may authorise specific coal seam water management options. Alternatively, select management options may be authorised under a Beneficial Use Approval (BUA).

3.2.1 Environmental Protection Act

The EP Act includes the following requirements specific to coal seam water management:

Section 126 Requirements for site-specific applications—CSG activities

(1) A site-specific application for a CSG activity must also state the following—

(a) the quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity;

(b) the flow rate at which the applicant reasonably expects the water will be generated;

(c) the quality of the water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out;

(d) the proposed management of the water including, for example, the use, treatment, storage or disposal of the water;

*(e) the measurable criteria (the **management criteria**) against which the applicant will monitor and assess the effectiveness of the management of the water, including, for example, criteria for each of the following—*

(i) the quantity and quality of the water used, treated, stored or disposed of;

(ii) protection of the environmental values affected by each relevant CSG activity;

(iii) the disposal of waste, including, for example, salt, generated from the management of the water;

(f) the action proposed to be taken if any of the management criteria are not complied with, to ensure the criteria will be able to be complied with in the future.

(2) The proposed management of the water cannot provide for using a CSG evaporation dam in connection with carrying out a relevant CSG activity unless—

(a) the application includes an evaluation of—

(i) best practice environmental management for managing the CSG water; and

(ii) alternative ways for managing the water; and

(b) the evaluation shows there is no feasible alternative to a CSG evaporation dam for managing the water.

In accordance with the approvals process depicted in Figure 4.1, Santos GLNG will address these requirements in the field-specific EA applications as required.

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3.2.2 Coal Seam Water Management Policy (DEHP 2012)

The objective of the policy is to encourage management of coal seam water in a way that protects the environment and maximises its productive use as a resource. To achieve this objective, the management and use of coal seam water should be consistent with the following hierarchy:

- Priority 1 – coal seam water should be used for a purpose that is beneficial to one or more of the following: the environment, existing or new water users, and existing or new water-dependant industries.
- Priority 2 – after feasible beneficial use options have been considered, coal seam water should be treated and disposed of in a way that firstly avoids, and then minimises and mitigates, impacts on environmental values.

The following hierarchy applies for managing saline waste:

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

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4 Coal Seam Water Extraction

In coal seams, natural gas and water are stored in the cleats (fractures) that naturally occur in coal. However, the majority of the gas is adsorbed in the coal matrix. The gas is held in place by confining pressure from the overlying rock, and groundwater (hydrostatic pressure).

When recovering natural gas from coal seams, the coals remain in place. Gas is produced by drilling a well into the coal seam and removing groundwater from the coal seam to reduce the confining hydrostatic pressure. This allows the gas to separate from the coal (desorb) and flow through fractures within the coal seams to the well and on to the surface. In general, producing natural gas from coal seams does not require all of the groundwater to be removed from the coal seam – typically hydrostatic pressure is reduced only to the extent required to achieve consistent gas flow.

The rate of groundwater extracted from coal seams reduces relatively quickly; however, given the large volumes of gas adsorbed on the coal, it can take more than 20 years for the coal seam to completely deliver its producible gas.

Generally, commercial development of coal seam gas fields occurs incrementally. The development cycle for a prospective area includes exploration, appraisal, production well and infrastructure construction, production operations, and then decommissioning and rehabilitation. New information gained from ongoing exploration, appraisal and production activities is used to inform future field development planning.

The overall water production characteristics from a gas field can be forecast using established techniques and field data. The forecast (often termed the water production profile) provides the rate and total volume of coal seam water extracted over a gas field area.

Figure 5-1 presents the annual volume of coal seam water extracted for the Roma, Fairview, Arcadia Valley and Scotia gas fields of the GFD Project based on the maximum development scenario defined for the EIS. The same information expressed in daily extraction rates is shown in Figure 5-2.

Based on the maximum development scenario used in the EIS, the total volume of water forecast to be extracted over the life of the GFD Project is 219 GL. This volume is comparable to the amount extracted by all other non-petroleum groundwater users in the Surat Cumulative Management Area in a single year (215 GL) (QWC, 2012).

The quality of coal seam water primarily depends on the hydrogeological characteristics of the area in which the production wells are located. A breakdown of total dissolved solids (generally a measure of salinity) across the fields is provided in Table 5-1.

Table 5-1: Range of Total Dissolved Solids in coal seam water across the GFD Project Tenures

Field	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)
Fairview	500	7,850	2,850
Roma	1,240	7,010	2,530
Arcadia	8,930	9,700	9,310
Scotia	700	6,300	4,200

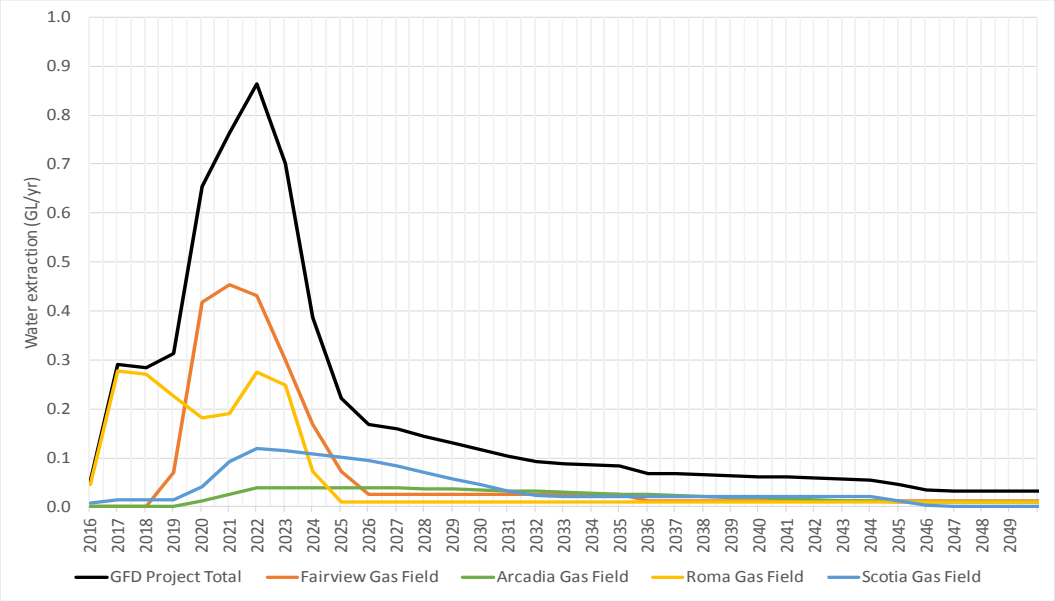

Figure 5-1: Estimated annual coal seam water extraction volume (GFD Project, Maximum Development Scenario)

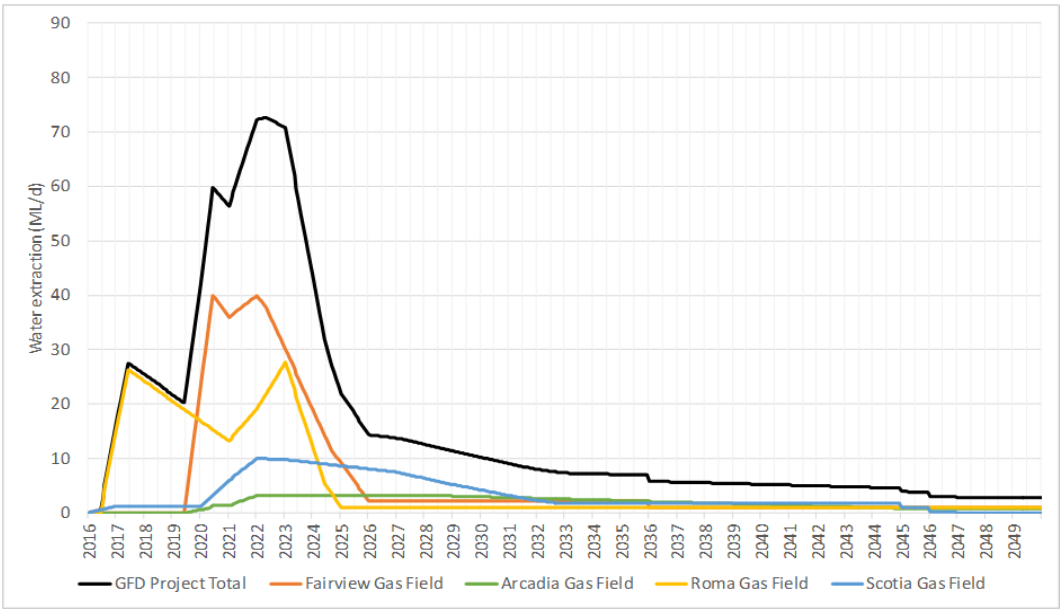

Figure 5-2: Estimated daily coal seam water extraction rate (GFD Project, Maximum Development Scenario)

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5 Coal Seam Water Management

5.1 Water Management Options

The Coal Seam Gas Water Management Policy recognises that the volume of coal seam water produced at each well and across a CSG project will change over time and that the management of coal seam water is likely to include a number of solutions. The solutions may vary over the life of the project and between geographical areas of the project. As anticpated in the policy, due to the geographic extent of gas production activities Santos GLNG will adopt a range of water management options to achieve outcomes in accordance with the regulatory framework. The coal seam water management strategy for the GFD Project has adopted the policy's management hierarchy:

Priority 1 – Beneficial Use

Coal seam water should be used for a purpose that is beneficial to existing users including GFD Project requirements and to meet "make good" obligations, new water users, and / or existing or new water-dependant industries. Management solutions will be determined based on an evaluation framework that includes full lifecycle assessments of potential benefits and liabilities associated with each option or suite of options. The objective of the framework is to identify feasible options which maximise beneficial use and minimise environmental impacts.

Priority 2 – Disposal

After feasible beneficial use options have been considered, coal seam water will be disposed of in a way that firstly avoids, and then minimises and mitigates, impacts on environmental values.

5.1.1 Beneficial Use

Potential beneficial uses that will be prioritised include:

- Make Good – Utilising water extracted from coals seams for "make good" arrangements under the Water Act.
- Operational Use - Using water extracted from coal seams for operational purposes to maximise benefit to the Project whilst minimising the take from other water supplies. This may include uses such as construction, compaction, drilling and completions, dust suppression, heat exchange and rehabilitation where appropriate.
- Substitution of water allocation - Providing water extracted from coal seams directly to a third party to reduce or cease their take on a water resource as an option to minimise or mitigate an adverse impact to an environmental value associated with project activities.
- Depleted coal seam injection - Injecting water extracted from coal seams into a depleted coal seam as an option to minimise or mitigate the risk of an adverse impact associated with project activities to an environmental value or water resource.
- Aquifer injection – Injecting water extracted from coal seams into an aquifer as an option to minimise or mitigate the risk of an adverse impact to a water resource (i.e. spring) associated with project activities.

Coal seam water remaining after meeting requirements for make good arrangements and project uses will be utilised for other beneficial purposes where feasible. These beneficial use options may include activities such as:

- Landholder activities - Providing water extracted from coal seams under a contractual arrangement for use by the landholder. This may include activities such as stock watering and irrigation.
- Regional users - Providing water extracted from coal seams under a contractual arrangement to a third-party. These may include new or existing users of water such as irrigators, feed lots, industry, council road construction and mining etc.
- Surface water release - Releasing water extracted from coal seams to a watercourse to provide a benefit to the environment or downstream users of water.
- Aquifer injection - Injection of water extracted from coal seams into an aquifer to minimise or mitigate impacts to a water resource as a result of non-project related activities.

5.1.2 Disposal

If a beneficial use option is not feasible other management options will be considered. Other management options may include activities such as:

- Surface water release – release of water extracted from coal seams to surface water where it does not mitigate impacts of the Project or provide a benefit to downstream users or the environment.
- Aquifer injection – Injection of water extracted from coals seams into a target formation with appropriate characteristics to receive the water where it does not mitigate impacts of the Project nor provide a benefit to users of water or the environment.
- Evaporation of water extracted from coal seams in purpose built and engineered structures.

5.2 Water Treatment

Treatment of coal seam water will be undertaken to provide water of suitable quality for the proposed use or disposal option. For some coal seam waters and proposed uses, treatment is not required to meet relevant standards. Full lifecycle impacts (particularly energy intensity and the generation of other wastes) associated with some treatment options will be considered in determining the appropriate level of treatment.

Water treatment solutions could include one or more of the following:

- Desalination using reverse osmosis to separate a portion of the total dissolved solids and other constituents into a concentrated waste stream (brine) and a permeate stream
- Amendment using chemical dosing to lower the sodium adsorption ratio and pH/residual alkalinity of coal seam water
- Temperature and ionic balance adjustment
- Filtration removing suspended solids (lowering the turbidity), bio-toxic elements and nutrients that can lead to algal blooms from the water
- Sterilisation to remove bacteria

- De-oxygenation
- Blending of separate water streams of differing quality to achieve a target water quality.

5.3 Brine and Salt Management

Where desalination (e.g. reverse osmosis) is required a waste stream (RO concentrate or brine) is generated that will require appropriate management and subsequent disposal in accordance with regulatory requirements.

In line with the Coal Seam Gas Water Management Policy, the options available for management of the brine stream can be divided into two broad categories; commercial salt recovery and brine or salt disposal.

5.3.1 Commercial Salt Recovery

Commercial recovery of saleable salt product requires an assessment of a number of critical factors such as technical feasibility, environmental impacts, market proximity and economic factors. Currently this option is not considered feasible for Santos GLNG due to the 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.

5.3.2 Brine or Salt Disposal

Brine may be disposed of through deep well injection into suitable geological formations. This is already occurring in accordance with regulatory approvals within the GLNG Project and trials at other localities are ongoing.

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 may be used to reduce the volume of brine requiring final management or to sufficiently concentrate brine to allow crystallisation of solid salt. Various technologies are available to be utilised, each with advantages and challenges to feasibility including thermal evaporation. These technologies have differing energy intensity, environmental footprint, technical complexity, operability and economics.

5.4 Existing Santos GLNG Project

The Santos GLNG Project undertakes a range of water management options in accordance with existing regulatory approvals. A summary of the current management options for each gas field and associated supporting infrastructure capacity is provided in the sections below. Where feasible, Santos GLNG will utilise existing management options and associated infrastructure for the GFD Project.

5.4.1 Fairview Gas Field

The current water management options include dust suppression and construction purposes, operational purposes, irrigation and discharge to surface water (Dawson River). The current storage capacities are for 1,060 ML of water storage and 1,400 ML of brine storage. The current treatment capacities comprises of 26 ML/day of reverse osmosis and 16 ML/day of water amendment.

5.4.2 Roma Gas Field

The current water management options include dust suppression and construction purposes, operational purposes, irrigation and managed aquifer recharge. The current storage capacities comprise 1,930 ML of water storage and 1,200 ML of brine storage. The current treatment capacities comprise 13 ML/day of reverse osmosis and 2 ML/day of water amendment.

5.4.3 Arcadia Gas Field

The current water management options include dust suppression and construction purposes and operational purposes. The current storage capacities comprise 720 ML of water storage. The current treatment capacities comprises of 0.6 ML/day of reverse osmosis.

5.4.4 Scotia Gas Field

The current water management options include dust suppression and construction purposes and operational purposes. The current storage capacities comprise 8 ML of water storage and 15 ML of brine storage. The current treatment capacities comprises of 0.4 ML/day of reverse osmosis.

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6 Feasibility Evaluation Framework

To maximise the beneficial use of water and minimise environmental impacts, an evaluation framework involving full lifecycle impact assessments (potential benefits and liabilities) and defined evaluation criteria will be utilised to determine feasible water management outcomes.

The feasibility evaluations are proposed to be conducted using a Multi-Criteria Assessment (MCA) approach, where water management options are assigned a score based on performance against weighted criteria. The criteria include environmental, social, technical and economic considerations with an example list provided in Table 6.1. Weightings on each criterion may vary between gas fields or regions within a gas field according to relevant circumstances. An example outcome from an evaluation assessment is provided in Figure 6-1.

Table 6-1: Example Feasibility Evaluation Criteria

Category	Criterion	Definition
Technical	Schedule and timing	The ability of an option to be designed and constructed to meet the schedule requirements associated with the water production profile and requirements of potential water users
	Reliability and technical feasibility	The feasibility of construction of an option and the likelihood of it achieving water management objectives, the reliability of operation, and compliance with regulatory requirements for water management
Social	Social Impact – to landholders and the community	The short and long term effects on landholders and other stakeholders
	Safety, Hazard and Risk (workforce and the community)	The occupational health and safety hazards and risks from the proposed option
Environment	Impacts associated with disturbance to the natural environment	The scale and effects of an option upon the local and regional natural environment including vegetation, fauna, soils, water and land resources
	Impacts of emissions and effluents, generation of wastes and greenhouse gases	Full lifecycle assessment of the potential future environmental benefits and liabilities associated with waste generation, energy utilization, greenhouse gas emissions, and discharges to land, water or air
Economic	Cost - CAPEX	The capital cost for the design and construction of an option, including consideration of the confidence associated with cost estimation
	Cost - OPEX	The costs associated with the operation, decommissioning and rehabilitation of an option

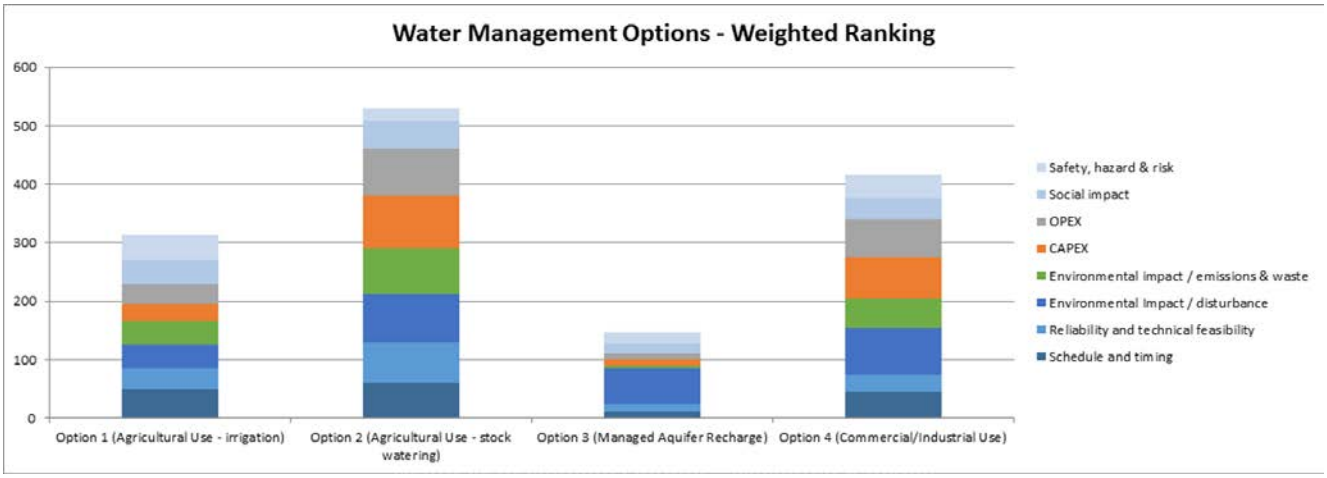

Figure 6-1: Example feasibility evaluation framework outcome