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D3 Associated Water

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GLNG

PROJECT

Associated Water Management Plan

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1 EXECUTIVE SUMMARY

The Associated Water Management Plan (AWMP) has been developed as part of the Gladstone Liquefied Natural Gas (GLNG) Project, to ensure that associated water (AW)[1] is managed on an affordable, integrated and sustainable basis, with the further aims of (i) maximising beneficial use opportunities, (ii) minimising the potential for environmental non-compliance and resulting harm and (iii) minimising the potential for project delays which could have significant financial implications.

The AWMP report presented here builds upon the AWMS presented in the GLNG Environmental Impact Statement (EIS) Associated Water Management Strategy (URS, Jan 2009). Submissions made in relation to the EIS have requested further detail be provided in relation to the management of AW. This document, in conjunction with the Groundwater and Associated Water Impact Study (Supplement EIS, Attachment D2), is intended to respond to these submissions.

The objectives of the AWMP are to:

- Develop a viable long term plan that provides the best net environmental, social and economic outcomes for the region, whilst considering Santos' operational requirements;
- Develop an adaptive AWMP that can be updated periodically and continually improved with new AW production rates, new monitoring data and with advances in science and technology (e.g. water treatment); and
- Promote and adopt Department of Environment Resources Management (DERM) preferred uses of AW and, where ever possible, add value to the local environment and economy.

This AWMP has been developed to consider a range of AW management options which will be adapted according to the variations in quality and quantity of AW produced from the Coal Seam Gas (CSG) wells. Santos has considered and identified ways to:

- Add value to local communities, through provision of AW for beneficial use, such as irrigation of forage crops and trees that will continue to provide benefit after AW production ceases; and
- Augment existing water supplies (groundwater and surface water resources).

The plan has been developed in consultation with government, communities and other key stakeholders, as well as technical experts in environmental and water management fields.

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[1] Associated water is the primary by-product of CSG production. The term AW generally refers to water that is contained in the coal seam and bought to the surface as part of producing CSG.

The overall approach consists of a scalable system of water management ponds, pipelines and water treatment plants.

The potential impacts of the strategies/options proposed as part of this AWMP have been assessed as part of the Groundwater and Associated Water Impact Study (Golder, October 2009), (refer to Attachment D2 of the Supplementary EIS) and through work that is described upon in this report. This has been undertaken to determine if the selected management options are viable (including their priority of use) having regard to the impacts and their management in accordance with this plan.

Gathering System

The AW management gathering system consists of:

- One or more unit areas consisting of a number of CSG wells which report to a nodal pond. Nodal ponds are co-located with NCS;
- A spine (trunk) pipeline provides transfer of AW from nodal ponds to an AW management pond (co-located with HCS). Typically between 6 – 15 nodal ponds will report to an AW management pond;
- The AW management pond reports to a ROP, co-located with HCS;
- Treatment by the ROP results in separate desalinated water and brine streams, which report respectively to a desalinated water pond and the brine containment pond; and
- Associated Water Amendment Facility (AWAF) – located downstream of the ROP, where required to amend associated or desalinated water for irrigation purposes.

Treatment

Santos intends to use two primary mechanisms: Reverse Osmosis (Desalination) and amendment.

Where AW is of high salinity, the AW is passed through a ROP which removes approximately 95% of the salts and organic compounds to produce desalinated water. The desalinated water can then be used for a number of beneficial uses, including the irrigation of a range of forage, non-forage and horticultural crops. These crops can be irrigated with desalinated water over a long term period without adverse impact on the soils. The preferred plant configuration is to install pre-fabricated RO skids in to a fixed building on site.

Where AW is of a low to moderate salinity, an amendment process can be used to balance the water. The amendment process involves addition of sulphuric acid to reduce pH level, together with calcium and magnesium to balance the excess of sodium. The amended AW can be fed directly into a variety of beneficial uses (including short-term irrigation of salt tolerant crops and stock watering).

Brine Management

Options for brine management are as follows:

- Brine will be temporarily stored in containment ponds adjacent to the ROP;
- In the longer term the options are:
  - brine may be injected to deep aquifers (preferably depleted coal seams), where technically and economically the best option;
  - brine may be evaporated (or crystallised) using the storage ponds, developed in cells with enough storage for 2-5 years in advance; or
  - waste heat from co-located infrastructure (compressors, power stations) may be used wherever appropriate to accelerate brine evaporation and minimise the footprint of the operations and the need for additional cells.

Beneficial Use Options

For Fairview, the AW management options consist of (in order of preference): dust suppression, industrial supply (via discharge of desalinated water to the Dawson River for downstream industrial users), irrigation of tree plantations using amended water and irrigation of forage crops using desalinated and amended water.

For Roma, the AW management options consist of (in order of preference): dust suppression, supply of desalinated and/or amended water to local landholders, municipal use, industrial use, opportunistic projects, and as a measure of last resort, discharge of desalinated water to Bungil Creek.

For Arcadia, the AW management options consist of (in order of preference): dust suppression, supply of desalinated and/or amended water to local landholders, opportunistic projects and as a measure of last resort, discharge of desalinated water to Lake Nuga Nuga.

2 INTRODUCTION

The AWMP describes in detail the proposed management of AW in the CSG fields as part of the GLNG project.

AW refers to water that is contained in the coal seam and bought to the surface as part of gas production. In the upstream gas fields of Roma, Fairview and Arcadia Valley, AW represents a significant water resource, and whilst the quality of AW is expected to be variable, it is likely that with appropriate treatment and early planning, a variety of beneficial uses can be realised which will find support with government regulators.

The following principles underpin the AWMP:

- Santos is responsible for gathering and treatment of AW produced in the course of its activities;
- Evaporation of AW will not be used as a primary disposal option; and
- AW will not be discharged to grade or surface waters unless strict conditions are met to avoid adverse ecological impacts.

2.1 ADOPTED WATER MANAGEMENT APPROACHES

Table 2-1 shown below presents the prioritised list of AW management activities. These form the basis of Section 3 of this report.

Table 2-1 Proposed Use of Associated Water for Each CSG Field

Field	PROPOSED USE OF AW					
	Decreasing Preference ->					
	Dust Suppression	Supply Back to Landholders		Municipal/ Industrial Supply	Other Irrigation Opportunities	Contingency Release to Surface Water
	Significant periodic base load of use of AW is possible subject to quality constraints and commitments to other demands	Amended AW - to tree cropping, short term establishment of Leucaena etc	Desalinated AW - to forage cropping, non-forage cropping, horticultural crops, etc	To parks, industrial supply, potential to augment town water supply	Irrigation based on take from delivery pipelines and local lakes as buffer storages	Desalinated water discharge schemes will be developed as last resort options
Roma	✓	✓	✓	✓	✓	✓
Fairview	✓	✓	✓	✓	✓	✓
Arcadia	✓		✓		✓	✓

2.2 WATER PRODUCTION DATA

The key factual inputs to the gathering plan development process have been the AW production curves for all three fields and water quality data.

The current water curves are presented in Figure 2-1.

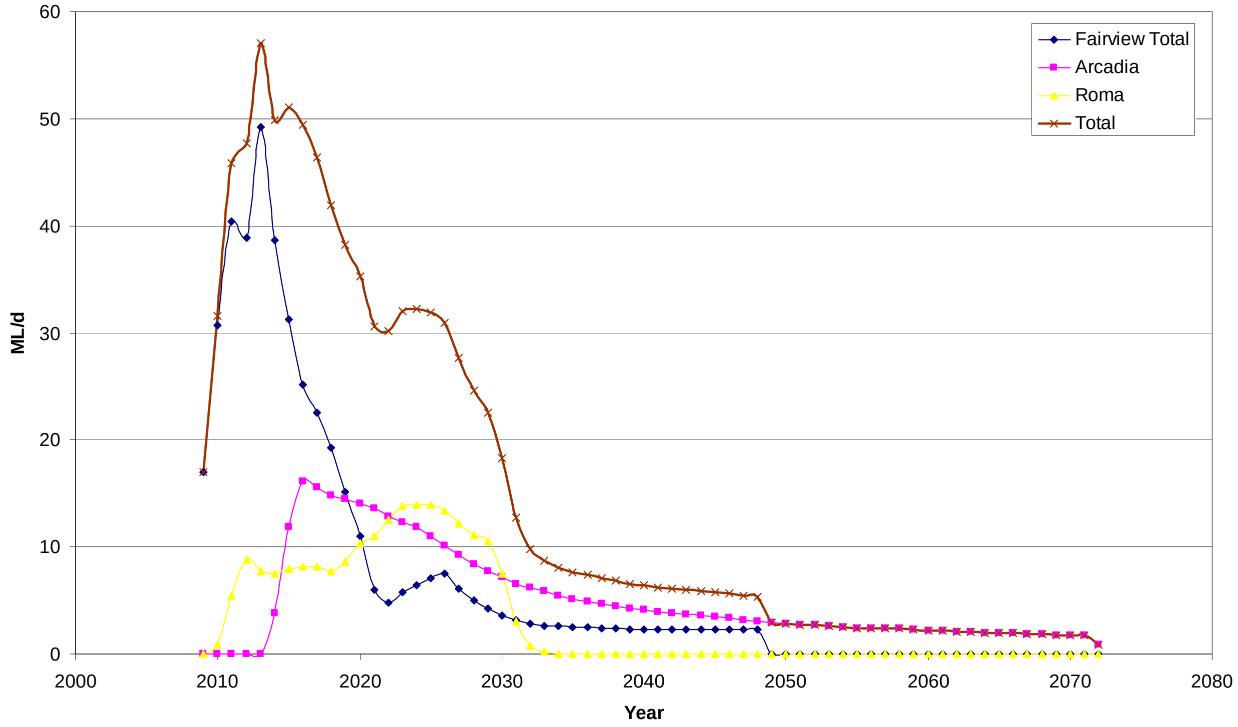

Figure 2-1 Field Water Production Rates for Fairview, Roma and Arcadia

In terms of water quality, the available monitoring data suggests that the key contaminants of concern for the proposed re-use options are Total Dissolved Solids (TDS), Fluoride and Sodium Adsorption Ratio (SAR) (i.e. relative concentrations of sodium, calcium and magnesium). Concentrations of these contaminants are generally above trigger values of the *ANZECC guidelines (2000)* for most beneficial re-use options. As such, it is likely that treatment will be required for the majority of the AW, in the form of desalination (such as RO) and/or amendment to reduce SAR, if beneficial re-use can be implemented.

Table 2-2 contains a summary of available water quality data for the Roma, Fairview and Arcadia CSG fields[2].

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[2] Water quality data current as of September 2009.

A description of each CSG Field, in terms of the number and location of established appraisal and production wells, and spatial distribution of water quality across the fields (represented by TDS) is provided below:

Fairview Field - Within the Fairview field there is an extensive network of development wells which have been established over the past 10 years (not part of the GLNG project). As a result there is a better understanding of likely water quality and quantity schedules. There is also a large network of appraisal wells which are due to be established in the near future, in preparation for the development phase of the project.

Available data from the network of development wells shows that there is a distinct gradient of increasing salinity from the north-west to south-east of the current Fairview Field (TDS ranging from 200 mg/L to 16,000 mg/L, mean 1,550 mg/L, based on 115 samples).

Roma Field - At present there are no development wells within the Roma field. A number of appraisal wells have been or are in the process of being established and these will likely be converted to development wells should the project proceed. The majority of these are located to the north east of Roma Township. Available salinity data (TDS) ranges from 1,100 mg/L to 2,500 mg/L, mean 2,050 mg/L, based on 27 samples.

Arcadia Field - At present there are no development wells within the Arcadia Valley field and a small number of appraisal wells have only recently been drilled and completed. As such, there is only limited preliminary monitoring information available on the likely quantity or quality of AW. Available salinity data (TDS) shows that salinity tends to ‘brackish’ at between 7,000 mg/L to 10,000 mg/L, mean 8,700 mg/L, based on 12 samples.

Table 2-2 Available Water Quality Data

		FAIRVIEW						ROMA						Arcadia					
	Unit	**Min**	**Max**	**Mean**	**Median**	**P75**	**Sample Count**	**Min**	**Max**	**Mean**	**Median**	**P75**	**Sample Count**	**Min**	**Max**	**Mean**	**Median**	**P75**	**Sample Count**
pH		7.17	9.20	8.69	8.70	8.83	141	8.17	9.70	8.63	8.48	8.90	26	7.60	8.02	7.88	7.87	8.00	12
Cond	uS/cm	200	21500	2560	2090	2780	142	1750	4440	3360	3530	3800	27	10700	14800	13300	13500	14300	12
TDS	mg/L	196	15600	1550	1230	1610	115	1120	2500	1980	2050	2170	27	7160	10200	8690	8510	9160	12
Ca	mg/L	0.50	39.3	2.92	2.00	3.08	122	1.80	243	30.1	4.25	10.9	27	17.0	44.0	26.3	25.0	29.0	12
Mg	mg/L	0.00	13.4	1.09	0.71	1.08	86	0.20	39.0	9.15	1.87	12.0	20	5.00	7.00	5.50	5.00	6.00	12
Na	mg/L	35.0	5160	637	519	677	142	411	990	820	874	896	27	2060	3480	3100	3220	3270	12
K	mg/L	1.00	102	5.47	3.00	5.00	142	2.30	36.0	9.66	5.00	13.7	27	56.0	139	81.2	74.0	86.3	12
Cl	mg/L	8.00	4940	281	143	259	141	78.0	975	598	641	730	27	2850	4490	4030	4210	4340	12
SO4	mg/L	1.00	57.0	7.36	6.00	6.00	61	3.00	168	19.0	6.00	13.3	20	2.00	56.0	18.0	15.5	24.5	12
B	mg/L	0.26	5.37	1.00	0.87	1.04	103	0.40	0.59	0.46	0.43	0.47	7	3.66	10.5	5.62	4.82	6.34	8
F	mg/L	0.40	8.10	2.44	2.10	2.90	141	1.10	3.40	2.07	1.90	2.55	27	1.40	4.20	2.58	2.45	2.53	12

2.3 STANDARD DEFINITIONS

The following standardised set of definitions and acronyms have been used within the AWMP (see below):

- Amended Desalinated Water for irrigation purposes – Desalinated Water amended to modify SAR to a level acceptable for irrigation purposes.
- Amended Desalinated Water for water supply purposes – Desalinated Water amended to modify corrosivity to a level acceptable for water supply purposes.
- Amended Water – associated water amended to modify SAR and pH/Residual Alkalinity to an acceptable level for irrigation purposes.
- ANZECC - Australian and New Zealand Environment and Conservation Council.
- APPEA – Australian Petroleum Production and Exploration Association.
- AWAF - Associated Water Amendment Facility – located adjacent to the HCS, where required to amend AW for irrigation purposes.
- AW - Associated Water - water produced from CSG field dewatering, also known as produced formation water or CSG water.
- AWMP – Associated Water Management Plan.
- BATNEEC – Best Available Technology Not Entailing Excess Cost.
- Beneficial Use – any use to which AW or its derivatives can be put to provide benefit of some kind to Santos, the community, the environment or other stakeholders in GLNG.
- Brine – water saturated or nearly saturated with a salt – concentrate produced as a by-product of RO process. Also known as RO concentrate.
- Brine Containment Ponds – brine containment pond located downstream of the ROP.
- CSG - Coal Seam Gas - a form of natural gas extracted from coal seams.
- DERM – Department of Environment and Resource Management recently created through a merger of the NRW and EPA.
- DEEDI - The Department of Employment, Economic Development and Innovation, which includes the former DME.

- Desalinated Water – water that has been treated through the process of removing soluble salts from water, such as RO. Desalinated water is also known as permeate.
- Desalinated Water (for Irrigation Purposes) Amendment Plant – located downstream of a ROP, where required to amend desalinated water for irrigations purposes.
- Desalinated Water (for water supply purposes) Amendment Plant – located downstream of a ROP, where required to amend desalinated water for water supply purposes.
- Desalinated Water Balance Ponds – desalinated water pond located downstream of the ROP.
- Desalination - process of removing soluble salts from water to render it suitable for drinking, irrigation, or industrial uses. The principal methods used for desalination include distillation (or evaporation), electro-dialysis, freezing, ion exchange, and RO.
- DIP – Department of Infrastructure and Planning.
- DME – former Department of Mines and Energy, now DEEDI.
- EA – Environmental Authority.
- EC – Electrical Conductivity - The conductivity of a solution of water is highly dependent on its concentration of dissolved salts and sometimes other chemical species which tend to ionize in the solution. EC of water samples is used as an indicator of how salt-free, ion-free, or impurity-free the sample is; the purer the water, the lower the conductivity.
- EHSMS – Santos' Environment, Health and Safety Management System.
- EIS – Environmental Impact Statement.
- EMP – Environmental Management Plan.
- EPA – former Environmental Protection Agency recently combined with NRW to create DERM.
- ESP - Exchangeable Sodium Percentages.
- GAB – Great Artesian Basin
- Gathering network – all infrastructures required to transfer AW from CSG producing wells to the nodal ponds and treatment plant inflow balance ponds.
- GLNG – Gladstone Liquefied Natural Gas.

- HCS – Hub Compressor Station.
- Irrigation Balance Ponds – located downstream of the ROP, containing desalinated water blended with AW.
- LNG Facility – Liquefied Natural Gas Facility.
- LSI – Langelier Saturation Index is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate.
- MAR – Managed Aquifer Recharge.
- NCS – Nodal Compressor Station.
- NHMRC - National Health and Medical Research Council.
- Nodal Ponds - intermediate AW storage pond (located adjacent to the NCS).
- NRW – former Department of Natural Resources and Water recently combined with EPA to create DERM.
- P&G Act – Petroleum and Gas (Production and Safety) Act 2004.
- RO - Reverse Osmosis – water filtration/desalination method that employs a high pressure differential across a membrane to selectively remove contaminants in the AW. As the water is forced across the membrane all molecules larger than water are excluded leaving behind a concentrated waste stream (brine). RO is in widespread use for applications such as desalinisation of seawater, treatment of municipal water supplies and purification of industrial cooling water.
- ROP – Reverse Osmosis Plant – Water treatment plant employing treatment using the RO process (located adjacent to HCS, where required).
- RUP – Resource Utilisation Plan.
- SAR – Sodium Adsorption Ratio the ratio of sodium to calcium and magnesium. For most irrigation schemes a SAR of between 10 and 20 is required to avoid the sodicity of the water degrading the physical structure of the soils.
- Spine pipelines - transfer AW from nodal ponds to treatment plant inflow balance ponds.

- TDS – Total Dissolved Solids, is an expression for the combined content of all inorganic and organic substances contained in a liquid.
- Treatment Plant Inflow Balance Ponds – AW pond located adjacent to HCS and balance AW prior to treatment.

3 OVERVIEW OF ASSOCIATED WATER MANAGEMENT PLAN

The basis to the development of the AWMP has been to adopt strategies initially which:

i. Are scalable relative to actual AW production;

ii. Are based on demonstrated technologies; and

iii. Are achievable within a timeframe compatible with the GLNG project milestones.

An important component of the plan is the need for continuous improvement, to take account of evolving field development plans, advances in technology, the outcomes from ongoing studies, and improved confidence in AW volumes and qualities.

The potential impacts of the strategies/options proposed as part of this AWMP has been assessed as part of the Groundwater and Associated Water Impact Study (Golder, October 2009). Refer to Attachment D2 of the Supplementary EIS.

The following sections describe the AW management approach that has been developed for GLNG as a whole, under the following headings:

- Gathering Systems - how the AW will be collected to treatment facilities, prior to delivery to beneficial uses;
- Treatment – methods of treating AW to the required standard for beneficial uses;
- Beneficial Uses – options and priorities for use of AW; and
- Brine Management – options for brine management (waste product from ROP).

3.1 GATHERING SYSTEMS

3.1.1 ROMA AND ARCADIA GATHERING SYSTEMS

Figure 3-1 shows the schematic layout of the AW management gathering system for the Roma and Arcadia CSG fields and is described as follows:

- One or more unit areas consisting of a number of CSG wells which report to a nodal pond. Nodal ponds are co-located with NCS;
- A spine (trunk) pipeline provides transfer of AW from nodal ponds to an AW management pond (co-located with HCS). Typically between 6 – 15 nodal ponds will report to an AW management pond;
- The AW management pond reports to a ROP, co-located with HCS;
- Treatment by the ROP results in separate desalinated water and brine streams, which report respectively to a desalinated water pond and the brine containment pond; and

- Associated Water Amendment Facility (AWAF) – located downstream of the ROP, where required to amend associated or desalinated water for irrigation purposes.

3.1.2 Fairview Gathering System

Figure 3-2 shows the schematic layout of the AW management gathering system for Fairview CSG field and is described as follows:

- One or more unit areas consisting of a number of CSG wells which report to a nodal pond. Nodal ponds are co-located with NCS;
- A spine (trunk) pipeline provides transfer of AW from nodal ponds to an AW management pond (co-located with HCS). Typically between 6 – 15 nodal ponds will report to an AW management pond;
- Where source AW is < 2,500 mg/L (TDS), the AW management pond report to a AWAF, co-located with HCS;
- Where source AW is > 2,500 mg/L (TDS), the AW management pond reports to a ROP, and then an AWAF (downstream of the ROP) to amend desalinated water for irrigation purposes, both co-located with HCS; and
- Treatment by the ROP results in separate desalinated water and brine streams, which report respectively to a desalinated water pond and the brine containment pond.

3.1.3 Preliminary Gathering System Specifications

Preliminary specifications for the gathering systems for all three fields are presented in Table 3-1.

Table 3-1 Summary of Gathering System

COMPONENT	DESCRIPTION	DETAIL – SIZING, CONSTRUCTION
Nodal Pond	Nodal pond capacities for AW transferred from the wells	20ML or 50ML
AW Management Pond	Standard size of the AW management ponds	250ML
Brine Containment Pond	Main brine containment pond located at each HCS	Units of 1000 ML, total capacity of up to 3000 ML
Pond Design	Nodal, interim brine ponds and brine containment pond design	Ponds are to be constructed in accordance with the performance standards set by DERM.
Spine Capacities	Estimated pipeline capacities predicted to be necessary for the spine pipes transferring AW from Nodal Compressor Stations (NCS) to the HCS.	Based on statistical analysis of simulation flows.
Heat Exchange	Use of waste heat from compressor stations to enhance evaporation of brine	

ROP Capacity	ROP requirements associated with the HCS for Roma and Arcadia (Fairview yet to be determined)	Units of nominally 2.5 ML/d

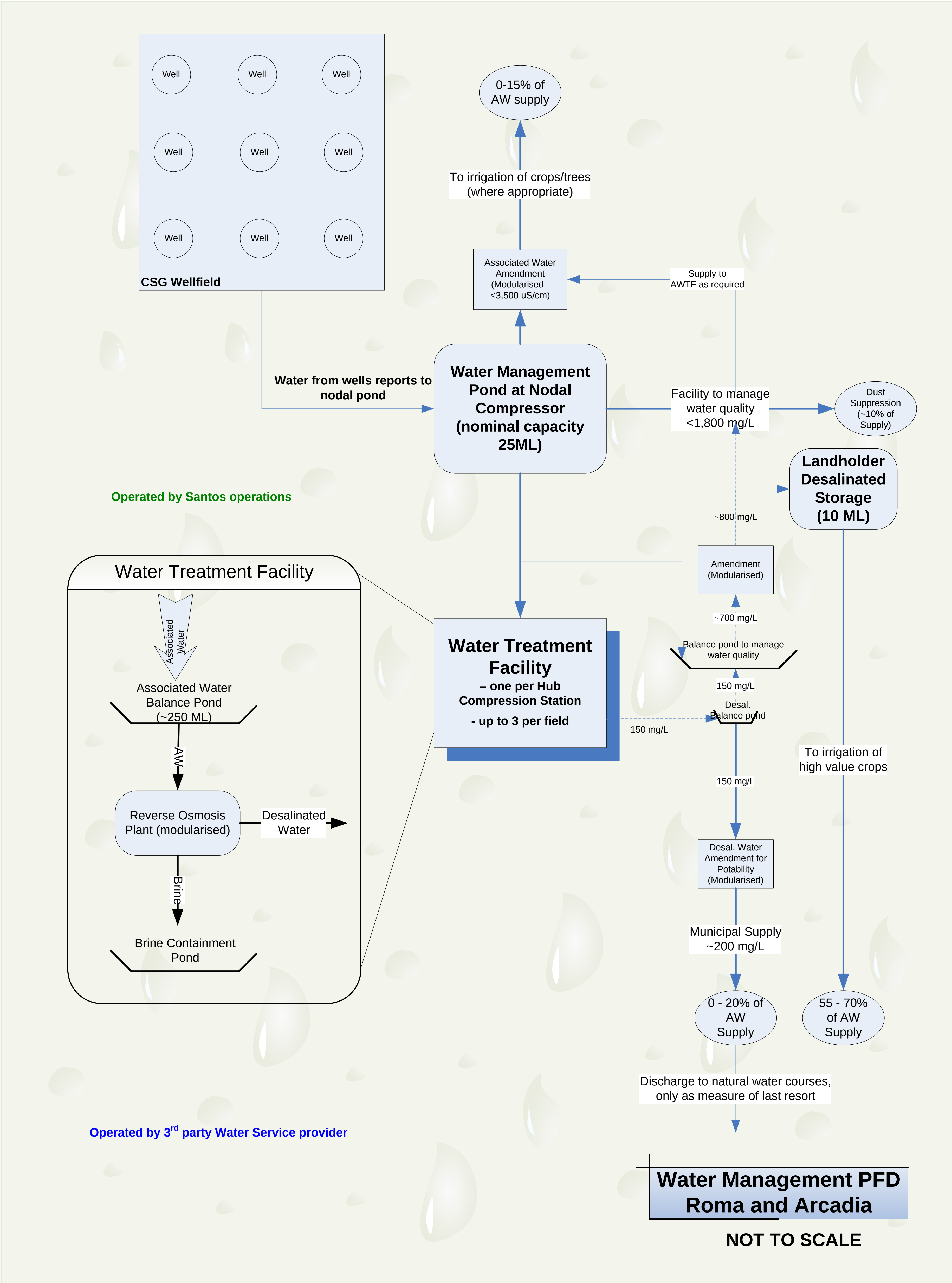
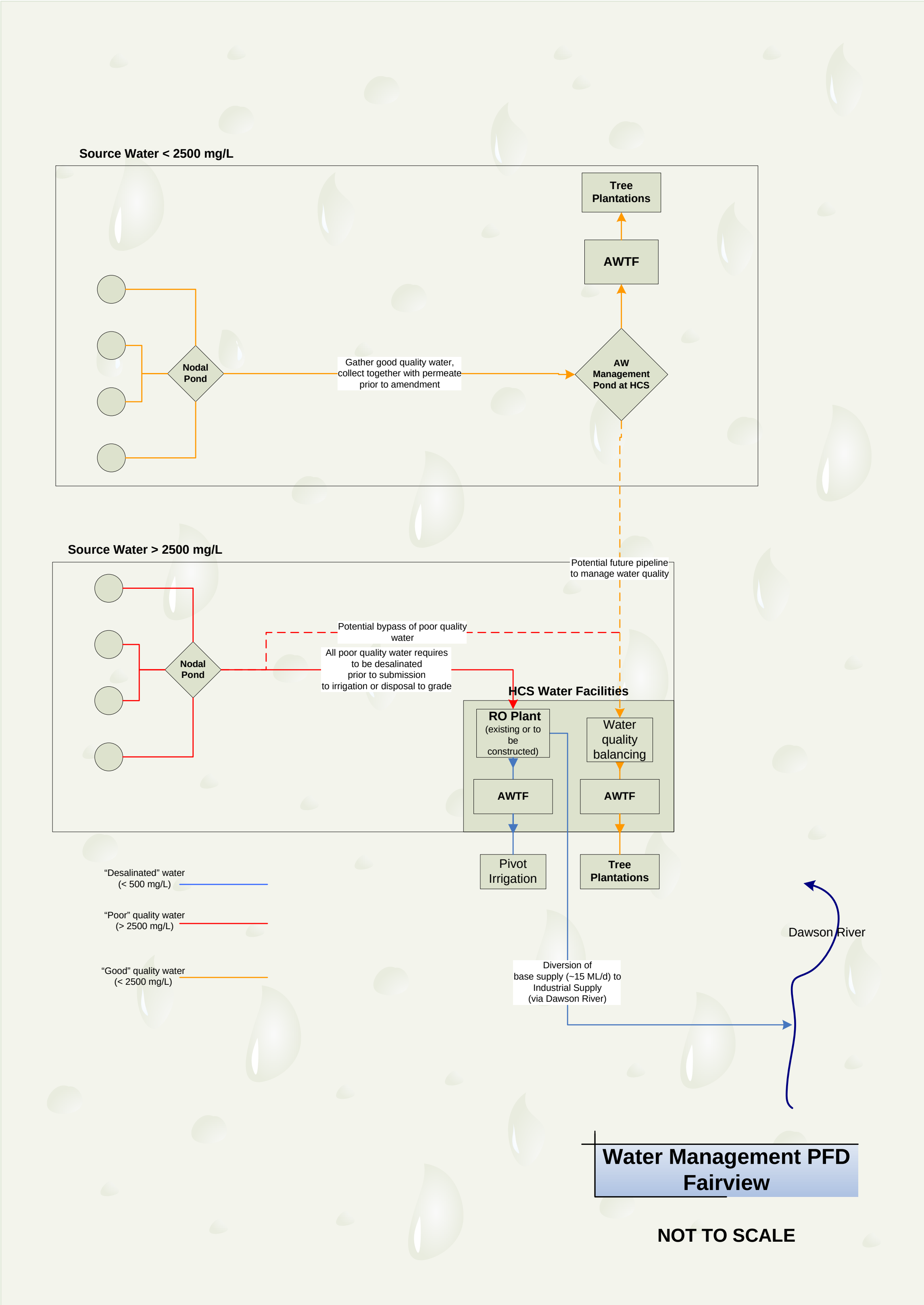


Figure 3-1 Schematic Water Management Layout – Roma and Arcadia



Source Water < 2500 mg/L
Tree Plantations
AWTF
Nodal Pond
Gather good quality water, collect together with permeate prior to amendment
AW Management Pond at HCS
Source Water > 2500 mg/L
Potential future pipeline to manage water quality
Potential bypass of poor quality water
Nodal Pond
All poor quality water requires to be desalinated prior to submission to irrigation or disposal to grade
HCS Water Facilities
RO Plant (existing or to be constructed)
Water quality balancing
AWTF
AWTF
Pivot Irrigation
Tree Plantations
"Desalinated" water (< 500 mg/L)
"Poor" quality water (> 2500 mg/L)
"Good" quality water (< 2500 mg/L)
Dawson River
Diversion of base supply (~15 ML/d) to Industrial Supply (via Dawson River)
Water Management PFD Fairview
NOT TO SCALE

Figure 3-2 Process Flow Diagram for Fairview AW Management

3.2 TREATMENT

3.2.1 AMENDMENT

Where conditions permit (including suitable soil profile, hydrogeological conditions and AW quality), AW will be amended and used for dust suppression and/or to irrigate crops including trees and establishment of Leucaena.

Amendment is defined in this context as treating the AW to lower the SAR and pH/Residual Alkalinity to acceptable levels for irrigation purposes (SAR = 10 for desalinated water & 30 for amended AW; pH = 5 - 8.5 and Residual Alkalinity <500 mg/L respectively). This process is represented in Figure 3-3 below.

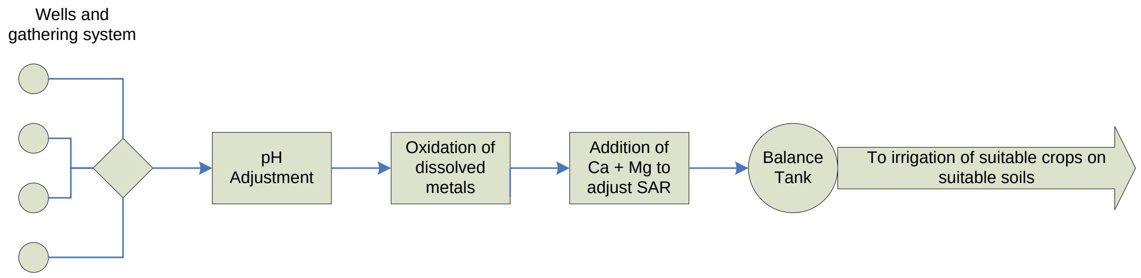


Figure 3-3 Schematic Representation of AWAF

This method of AW management is not suitable for all regions. Suitability of an area for the application of amended water without desalination will be evaluated on a case by case basis but must meet the following performance criteria:

- The potential for loss of salt from the soil profile to the local surface water and groundwater systems must be negligible with no potential to increase key attributes by more than 10% above baseline levels;
- The potential for runoff of irrigation water or lateral seepage from soils or shallow regolith to local streams must be negligible with no potential to increase key attributes by more than 10% above baseline levels;
- Irrigated soils must maintain their structural integrity and chemical fertility with monitored pH, SARs, Electrical Conductivity (EC) and Exchangeable Sodium Percentages (ESP) remaining within prescribed limits of pre-irrigation baselines;
- Demonstrated and to a sufficient level of surety, *guaranteed* demand for the amended water in this category;
- The combination of current salt levels and planned salt loads as a result of irrigation must remain below 50% of the soils capacity to take salt without loss of production;

- For soils in any monitored irrigation zone, the soil solution SAR will not exceed SAR, as for the amended water;
- Maximum weighted average rootzone salinity to 2 m (ECe) will be 5,000 µS/m for any soil monitoring zone;
- Baseline soil pHs (pH 4.5 to 9.5 as determined from 75 soil samples across 4 plateaux and 3 soil types) do not change;
- No significant deterioration on dispersibility as determined by the Emerson Aggregate test; and
- Soil ESP remain below 30% except where baseline is greater than 30%, then 20% change from baseline for relevant profile is maximum limit.

3.2.2 DESALINATION

Where AW is of high salinity, the AW is passed through a ROP which removes approximately 95% of the salts and organic compounds to produce desalinated water. The desalinated water can then be used for a number of beneficial uses, including the irrigation of a range of forage, non-forage and horticultural crops. These crops can be irrigated with desalinated water over a long term period without adverse impact on the soils.

The preferred configuration for a ROP is to install pre-fabricated RO skid-mounted modules with a design input capacity of 2.5 ML/day. The ROP will be located in close proximity to HCS.

3.2.3 APPLICATION OF DESALINATED WATER

Where conditions are not suitable for the application of non-desalinated amended AW to crops, the management solution for AW is then to gather it, desalinate it and then amend the desalinated water to render it suitable for irrigation.

Amendment of the desalinated water is required because, while the desalination process can be expected to reduce the salt load to acceptable levels for irrigation, typically the imbalance between Sodium and the combined concentration of Calcium and Magnesium persists after the desalination process, resulting in unacceptable SAR for irrigation purposes. Metal concentrations and pH of desalinated water are, however, acceptable for irrigation.

In the case where this water may be included in a municipal supply (Roma only) further amendment may also be required to reduce the corrosivity of the desalinated water, prior to inclusion in the town water supply system. This is because the desalinated water typically has too high a Langelier Saturation Index (LSI) for typical urban water reticulation systems.

Figure 3-4 below represents this process in its entirety.

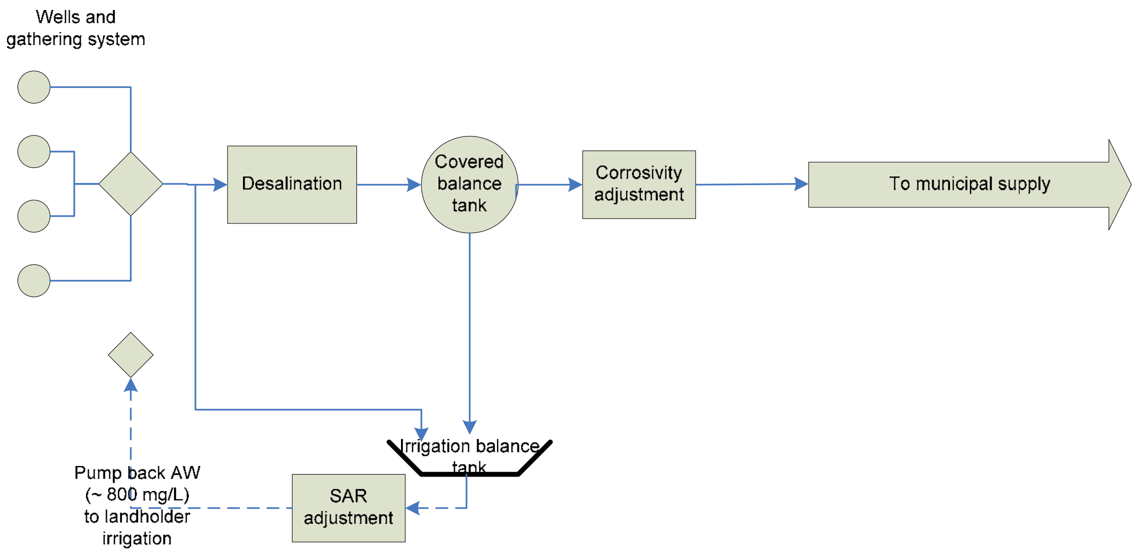


Figure 3-4 Process Flow Diagram for Gathering and Treatment - Roma

In the unlikely situation that a short term 'last resort' discharge to surface water is required, this would only be of desalinated water. Studies performed in relation to the EIS have identified the regional range of in-stream salinity (TDS) is between 215 and 350 mg/L dependent on location and distance downstream from the first perennial occurrence of the stream or river. The target discharge total salinity (TDS) for emergency release to surface water is therefore aimed at 200 mg/L.

As can be seen from the above diagram, after desalination, there will almost certainly be the further application of water treatment chemicals resulting in a rise in salinity of the desalinated, then amended, water. Accordingly, to establish a "one-design" ROP that could be placed at any location in the project and, in the event it was required, allow the discharge to be released to surface water, a target for effluent TDS of 150 mg/L (maximum of 180 mg/L) is set for ROPs for GLNG. This will allow post-desalination amendment to occur without generating desalinated and amended water that exceeds target salinity (TDS) of 200 mg/L.

3.2.4 WATER QUALITY OBJECTIVES

The following water quality objectives have been set for water treatment that will be applied by Santos.

Table 3-2 Water Quality Objectives

WATER TYPE/WATER QUALITY INDICATOR	MIN	TARGET	MAX	REFERENCE
Associated water for dust suppression				
pH	6	-	9	Environmental Protection Agency (2009). Environmental Authority (petroleum activities) - Fairview Environmental Authority (PEN100178208), Roma PLA 250 Environmental Authority (PEN100200208) and Roma PL 5 (PEN100266908).
BOD (mg/l)	-	-	20	
Total Suspended Solids (mg/l)	-	-	30	
Total Dissolved Solids (mg/l)	-	1,500	2,000	
TPH (mg/l)	-	-	10	
Total Nitrogen (mg/l)	-	-	25	
Total Phosphorus (mg/l)	-	-	10	
Amended water for irrigation				
Electrical Conductivity (µS/cm)	-	3,000	4,000	Environmental Protection Agency (2009). Notice of Decision to Approve a Resource for Beneficial Use.
Total Dissolved Solids (mg/l)	-	2,000	2,650	
pH	5.0	-	8.6	
Bicarbonate Alkalinity as $CaCO_3$ (mg/l)	-	-	500	
Carbonate Alkalinity as $CaCO_3$ (mg/l)	-	-	70	
Chloride (mg/l)	-	-	500	
Fluoride (mg/l)	-	-	3.0	
Sodium (mg/l)	-	-	800	
Boron (mg/l)	-	-	15	
SAR	10	20	30	
Desalinated Water				
TDS (mg/l)	-	150	180	GHD (2008). Specification for Roma Associated Water Desalination – General Technical Specification, April 2008.
pH	6.5	-	8.5	
SAR		<10	-	
Langelier Saturation Index (LSI)	-0.5	-	0.5	
Amended Desalinated Water for irrigation purposes				
As above (Desalinated water) and…				
pH	5.0	-	8.6	Environmental Protection Agency (2009). Notice of Decision to Approve a Resource for Beneficial Use.
Bicarbonate Alkalinity as $CaCO_3$ (mg/l)	-	-	150	
Carbonate Alkalinity as $CaCO_3$ (mg/l)	-	-	2	
Chloride (mg/l)	-	-	150	
Fluoride (mg/l)	-	-	3.0	
Sodium (mg/l)	-	-	140	
Boron (mg/l)	-	-	15	
SAR	10	20	30	
Amended Desalinated Water for water supply purposes				
As above (Desalinated water and Amended Desalinated Water for irrigation purposes)				
Sewage Effluent Discharge				
Thermotolerant Coliforms *E. coli* (colony forming units/100ml)	-	-	1,000	Environmental Protection Agency (2009). Environmental Authority (petroleum activities) - Fairview Environmental Authority (PEN100178208), Roma PLA 250 Environmental Authority (PEN100200208) and Roma PL 5 (PEN100266908).
$BODs_5$ (mg/l)	-	-	20	
pH	6	-	8.5	
Electrical Conductivity (µS/cm)	-	-	1,600	
Total Phosphorus (mg/l)	-	-	10	
Total Nitrogen (mg/l)	-	-	35	
Total Suspended Solids (TSS) (mg/l)	-	-	30	
Total Dissolved Solids (mg/l)	-	-	1,000	
Dissolved Oxygen (mg/l)	2	-	-	
Hydrostatic Test Water and Low Point Drain Water				
pH	6.5	-	8.5	Environmental Protection Agency (2009). Environmental Authority (petroleum
Arsenic (mg/l)	-	-	2.0	
Cadmium (mg/l)	-	-	0.05	
Chromium (mg/l)	-	-	1	

Copper (mg/l)	-	-	5	activities) - Fairview Environmental Authority (PEN100178208), Roma PLA 250 Environmental Authority (PEN100200208) and Roma PL 5 (PEN100266908).
Iron (mg/l)	-	-	10	
Lead (mg/l)	-	-	5	
Manganese (mg/l)	-	-	10	
Zinc (mg/l)	-	-	5	
Nitrogen (mg/l)	-	-	25	
Phosphorus (mg/l)	-	-	0.08	
Electrical Conductivity (µS/cm)	-	-	2,000	

3.3 Beneficial Uses

This section describes the beneficial uses that will be applied for the CSG fields. They include:

- Dust suppression;
- Irrigation – Amended and/ or Desalinated;
- Landholder supplies; and
- Municipal and Industrial supply.

Established beneficial uses for each GLNG field are also listed in Sections 4.1 – 4.3. As increased certainty in geological and/or planning information becomes available there is opportunity for the AWMP to evolve and adapt. A number of opportunities for beneficial use of the AW may arise in the future and although these may not be listed below and foreseen at present, can be investigated to confirm their incorporation into the plan.

An assessment has been made of the potential environmental impacts of these beneficial uses. This part of the document summarises the outcomes of those evaluations and the mitigation measures that Santos will utilise.

Figure 3-5 below compares the expected demand for AW (amended and desalinated) against peak production of AW for each CSG field, and demonstrates that significant demand exists (in excess of the peak supply of AW).

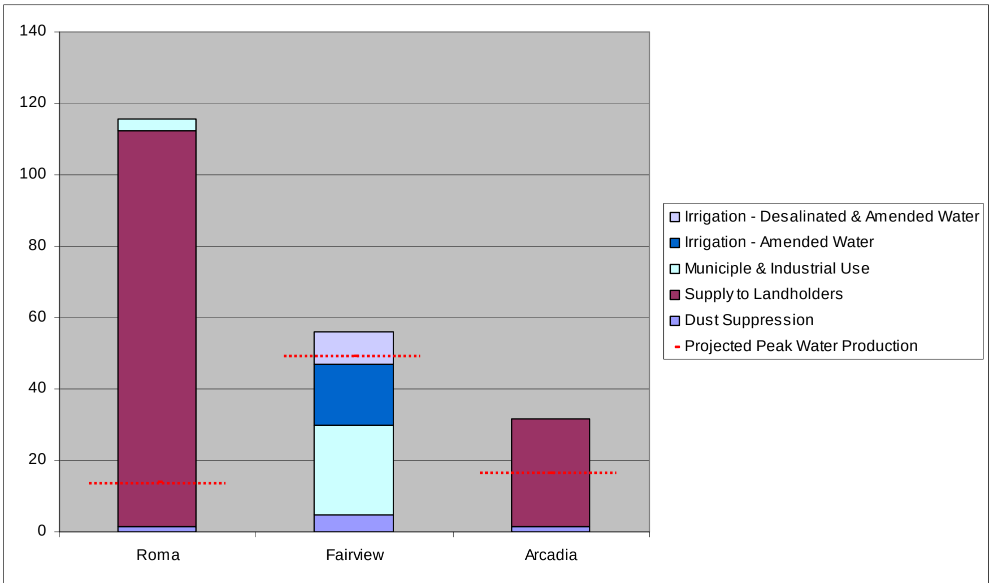


Figure 3-5 AW Production versus expected AW Demand

3.3.1 DUST SUPPRESSION

AW may require treatment to required water quality objectives prior to being used within the Fairview, Roma and Arcadia CSG fields for dust suppression of unsealed roads, road maintenance, construction activities and rig shifts. This direct use of AW is a preferred management option, as outlined in the 2007 Environmental Protection Agency (EPA) policy on *Management of water produced in association with petroleum activities (associated water) (2007).*

Dust suppression provides a beneficial use of AW, whilst being a mitigation measure for the generation of dust, which could potentially be an environmental and health and safety concern.

The application of AW to unsealed roads, road maintenance, construction activities and rig shifts, has the potential to:

- Accumulate salt on the unsealed road surface and potential for salt to impact the surrounding environment via runoff or dust;
- Change the physical properties of the unsealed road surface, with potential for roads to become slippery when wet; and
- Increase dust generation, if AW significantly alters soil particle sizes on the unsealed road surface.

A Dust Management Strategy is currently being developed. Preliminary results of the Dust Management Strategy study, indicates that:

- Very little runoff occurs during normal dust suppression or road maintenance/construction operations; and
- There is no significant difference between salinity or other chemical constituents of road verge surface soils in areas with AW applied compared with areas little or no AW has been applied. There is no evidence that the surface soil salinity in historically watered areas is different from background.

The Dust Management Strategy is expected to comprise of one or a combination of the following dust management approaches depending on the local conditions:

- Road sealing;
- Construction of all-weather but unsealed roads;
- Apply dust suppression using one of the following water sources:
  - AW;
  - Amended AW;
  - Desalinated then Amended AW; and
  - AW with proprietary dust control additives.
- Construction of new roads through soil types less likely to generate dust; and

- Dust suppression application rates developed for dust suppression purposes rather than to maximise the use of AW. This will also reduce the likelihood of AW runoff being created by dust suppression.

As part of the GLNG Water Monitoring Plan, the effects of long term application of AW will be monitored at various locations throughout the fields.

3.3.2 SANTOS IRRIGATION AND SUPPLY TO LANDHOLDERS

3.3.2.1 Amended Water Irrigation

Amended AW will be used in Fairview to irrigate approximately 2,000 ha of *Eucalyptus argophloia* (Chinchilla White Gum) plantation at an estimated average rate of 2.4 ML/ha/yr over an expected 10 year irrigation time frame.

Santos has the potential to expand amended AW irrigation on Santos owned land in the Fairview field area.

In the Roma and Arcadia areas moderate salinity amended AW will be made available to local landholders for the 1-2 year establishment irrigation of salinity-tolerant forage crops (predominantly leucaena) or forest species or for longer term irrigation depending on environmental approvals (separate to EIS process).

A proportion of landholders at Fairview, Roma and Arcadia are likely to invest in forestry or agro-forestry options e.g. wide-spaced forest tree rows with leucaena inter-rows strips. It is not expected that the supply of amended water to landholders for irrigation purposes will extend beyond the area the subject of Santos' petroleum leases.

Santos proposes to provide interested local landholders with amended AW of suitable quality and quantity for drip irrigation of nominally 50 ha blocks of dryland leucaena or similar salt tolerant crops. This water will be pumped to the edge of a suitable irrigation block on the landholders property at a sufficient delivery pressure to operate irrigation systems for a 1-2 year period. Landholders will be responsible for connecting an irrigation reticulation system to this source. A dryland crop such as leucaena is preferred, as the established crop will continue to provide fodder after irrigation ceases.

Prior to irrigating with amended AW, a detailed soil survey will be undertaken to establish the soil chemical and physical characteristics of properties and to identify soil types/land units which are suited for irrigation with moderate to high rates of low salinity water.

Depending on the results of the soil survey, an accredited independent technical specialist / agribusiness consultant will be commissioned to use soil survey information, crop suitability and profitability information and other whole property development planning information to prepare a property specific Business Plan.

Depending on the results of the Business Plan, the following plans and applications are also required to be prepared and approved (separate to the EIS process):

- LWMP;
- RUP; and
- BUA.

Ongoing monitoring of the performance of irrigation and the effectives of environmental management controls, will also be undertaken for the duration of water supply.

For the potential impacts and mitigation measures associated with amended water irrigation, refer to the Groundwater and Associated Water Impact Study (Supplementary EIS, Attachment D3).

3.3.2.2 Desalinated Water Irrigation

Desalinated water will be used at the Fairview CSG Field to spray (pivot) irrigate leucaena and grass pasture grazing system planted on Santos owned land. The leucaena-grass pasture system will be opened for the commercial demands of the Santos Group agribusiness as well as local/regional livestock producers for grazing, greenchop and silage access.

In the Roma and Arcadia areas, Santos will supply nominally 0.5 – 1.0 ML of desalinated water per day to a 10 ML pond situated adjacent to NCS located on participating landholder properties for a minimum 10 year period. It is not expected that the supply of amended water to landholders for irrigation purposes will extend beyond Santos' petroleum leases.

This water will be of sufficient quality to irrigate a range of forage and non-forage crops and potentially high value horticultural and vegetable crops (nominally TDS less than or equal to 800 mg/L). Landholders would be responsible for some minor costs associated with delivering the treated water to the holding pond and also for pumping the treated water from the pond to the land to be irrigated and will cover all irrigation and crop development costs. It is proposed that the 10 ML holding ponds would be located within 1 km of NCS sites.

Prior to irrigating with desalinated water, a detailed soil survey will be undertaken to establish the soil chemical and physical characteristics of properties and to identify soil types/land units which are suited for irrigation with desalinated water.

Depending on the results of the soil survey, an accredited independent technical specialist / agribusiness consultants will be commissioned to use soil survey information, crop suitability and profitability information and other whole property development planning information to prepare a property specific Business Plan.

Depending on the results of the Business Plan, the following plans and applications are also required to be prepared and approved (separate to the EIS process):

- LWMP;
- RUP; and
- BUA.

Ongoing monitoring of the performance of irrigation and the effectives of environmental management controls, will also be undertaken for the duration of water supply.

For the potential impacts and mitigation measures associated with desalinated water irrigation, refer to the Groundwater and Associated Water Impact Study (Supplementary EIS, Attachment D2).

3.3.2.3 Stock Water

Where water quality is suitable, Santos will provide interested landholders with treated AW for stock watering. The water will be pumped to the landholders property to a small storage tank. Landholders will be responsible for connecting and pumping water from the storage tank to their troughs and water points throughout their property.

For the potential impacts and mitigation measures associated with stock water supply, refer to the Groundwater and Associated Water Impact Study (Supplementary EIS, Attachment D3).

3.3.3 MUNICIPAL AND INDUSTRIAL SUPPLY

Municipal and Industrial supply is a potential option for Roma and for the Fairview CSG Fields. Only desalinated water would be applied to this use.

The important factors pertaining to potential use of AW for municipal and industrial use are described below:

- AW will only be available for the duration of the GLNG project, beyond which traditional (or other alternate) supplies will have to be re-established;
- Treatment of AW for potable water supply has Health and Safety Issues, and thus must meet the *Australian/New Zealand Guidelines for Fresh and Marine Water Quality (2000)* and the *Australian Drinking Water Guidelines (2004);* and
- Availability of AW for potable, municipal and industrial uses will reduce reliance on surface and ground water sources and could also lead to improvements in recreational amenity. The availability of treated AW will provide improved security of supply for the duration of the project and potentially beyond.

Sections below provide further detail on the specifics of the planned delivery of water to municipal and/or industrial use for the Roma and Fairview CSG Fields.

3.3.3.1 Roma Municipal & Industrial Supply

At Roma, municipal supply is to be provided via Managed Aquifer Recharge (MAR) to the Gubberamunda Aquifer, which forms a major part of the town water supply (TWS). Santos has investigated the viability of this alternative and the potential impacts. Industrial supply, if provided, could be developed from the Roma TWS reticulation system, or a purpose built pipeline to the industrial water intake for the Roma Industrial precinct. Figure 3-6 below presents this option schematically:

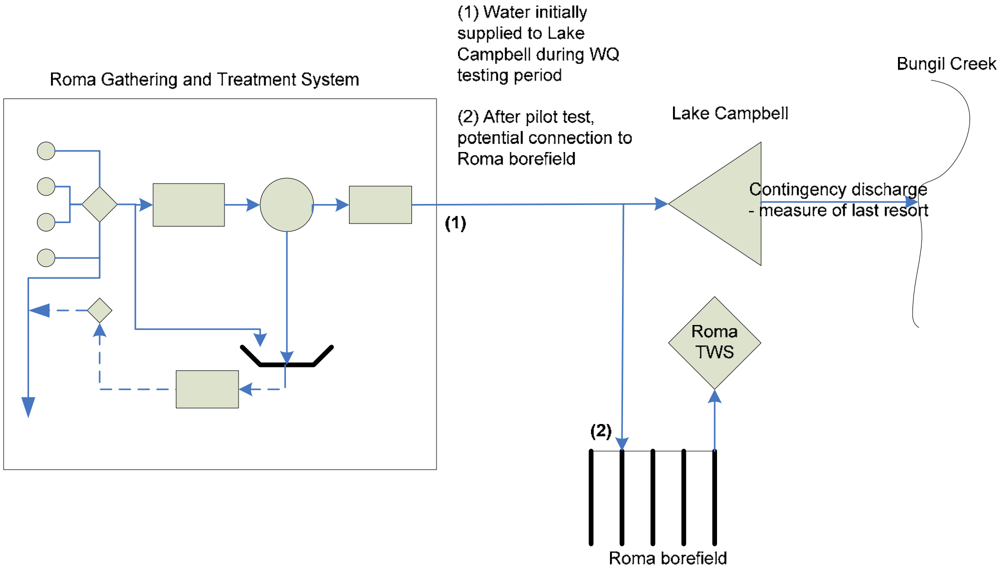


Figure 3-6 Process Flow Diagram for Supply to Roma municipal demands

There are a number of criteria that have to be met, when considering MAR. These include:

- The degree of hydraulic isolation of the target unit;
- The aquifer hydraulic characteristics of the target units, specifically storage capacity and transmissivity;
- The impact that the injected desalinated water may have on the natural waters in the formation (beneficial uses, pressures); and
- The conflicts with other potential uses of the aquifer, including possible future water supply and gas storage.

Hydraulic modelling was undertaken to evaluate how injection of fluids would affect groundwater levels and pressures within various strata, using the analytical Winflow modelling software.

Representative aquifer hydraulic properties (hydraulic conductivity and storativity) were used as model inputs. Injection rates were based on likely disposal requirements for desalinated water.

For the Roma CSG field the Gubberamunda Sandstone was evaluated.

Predicted incremental changes in heads (i.e. increased groundwater pressures) after 10 years of injection at a radial distance of 10 km from the modelled injection bore were simulated and the results are presented in Table 3-3. These predicted incremental changes would counteract, to some extent, the head decline in the Gubberamunda Sandstone aquifer that has been observed at Roma in the last 100 years (pressures have declined by more than 80m).

Table 3-3 Predicted Heads after 10 years of Injection

Predicted head at 10km from injection bore (m)			
Injection Rate Stratum	500 m3/day	1,000 m3/day	1,500 m3/day
Gubberamunda Sandstone	10	20	30

The hydraulic modelling indicates that recharge of 5 ML/day of desalinated water into the Gubberamunda Sandstone for a period of 10 years is technically possible and could result in an effective disposal of 18 GL of AW from the Roma CSG field.

No impacts to the environment are expected from such a proposal, however, since the desalinated water only will be injected into the Gubberamunda Sandstone aquifer. Santos will perform detailed injection well design studies in conjunction with pilot project testing.

3.3.3.2 Fairview Industrial Supply

There exists the need *and* the potential to supply between 10 and 25 ML/d of AW to industrial customers using the Dawson River downstream from the Fairview CSG Field. Figure 3-2 presents this option schematically.

The scheme will likely operate as follows:

- AW will be gathered to a ROP in the vicinity of Dawson's Bend on the Dawson River;
- Desalinated water intended for transfer to industrial users downstream on the Dawson River (or for local irrigation opportunities) will be stored in a desalinated water balance pond. The capacity of this pond is unlikely to be greater than 50 ML;
- Desalinated water for industrial users downstream on the Dawson River would be released on a relatively constant rate to the Dawson River at a discharge location downstream of Yebna Crossing;
- Water would be transferred down the Dawson River to the Glebe Weir;

- The Water Service Provider would take the entire supply discharged upstream, after an allocation for "distribution losses", to industrial purposes, commencing with a major extraction at Glebe Weir itself; and
- The Water Service Provider, would operate the pipeline from the ROP to Dawson River, be responsible for all reporting and environmental management of that discharge operation; and manage the river discharge scheme, including all permitting, Resource Operations Plan obligations and environmental management.

Work is being undertaken to develop the proposal for regulatory approval.

Dawson River Impacts

Using the Dawson River to transfer desalinated water to downstream industrial users, has the following potential impacts:

- That the salinity of desalinated water may not be consistent with relevant water quality guidelines and minimum target values.
- That there is the potential for the degradation of streambed soils if Sodium Adsorption Ratios are not similar to that proposed for irrigation.
- That there is potential for artificial signalling of instream species behaviours and shift in species composition (e.g. to algae) if the temperature of the water discharged is not as similar as possible to ambient water temperatures.
- If dissolved oxygen levels of the desalinated water are not at least as high as those measured in stream (>5 mg/L) there may be a reduction in instream water quality.
- There is potential for erosion at the discharge location.

Using the Dawson River to transfer desalinated water to downstream industrial users was investigated to evaluate the volume of water that could be discharged and the potential environmental impacts arising from discharge. A key focus was whether the carrying capacity of the Dawson River increases with distance downstream. Based on hydraulic modelling and aerial photography of channel type and dimensions it is not considered that there is any significant increase in channel carrying capacity between Yebna Crossing and the Injune-Condamine Connection Road.

The discharge location, downstream of Yebna Crossing, captures most (or all) of the upstream groundwater discharges into the bed of the river ensuring this site has permanent flows. The site is also well concealed to minimise visual impact; and avoids issues associated with the major road crossing as the stream gradient increases sharply as water moves into the downstream gorge country. The site is also beyond the known limit of springs.

Vegetation lies above pool water levels by at least 1 m up to 3 m in this area. This is well outside the range of interaction with any increased discharges.

Sites further downstream are in a gorge and would involve significant access issues as well as additional pump and pipeline requirements.

Aquatic ecosystems associated with Dawson River may be affected through discharge to surface water operations, although the results of ongoing river health assessments of the Dawson River in the Fairview Field suggest that increases in median river salinity values downstream from discharge to grade locations are mitigated by spring discharge further downstream.

3.3.4 Contingency Discharge to Surface Water

As can be seen from Table 2-1 and Figures 4-1 to 4-3, the discharge of desalinated water to surface water is considered the least preferred (last resort) option for disposal of associated water.

The discharge of some desalinated water to surface water is, however, considered a potentially necessary contingency for the overall AWMP because:

- At Roma CSG field, and possibly Arcadia CSG field, there is a small possibility of periods where the supply of AW suitable for irrigation and to municipal supply (desalinated and amended) exceeds the irrigation demand.
- At Roma and Arcadia CSG fields and to a lesser extent at the Fairview CSG field, seasonal demand may have a significant impact on the amount of AW that will be taken up by irrigation practices (and in the case of Roma, municipal requirements), even allowing for reaching target demand for irrigation water.
- There still remains uncertainty in the likely AW production from all three CSG fields, and even allowing for the scalable nature of this plan, "safety release" discharge pathways may need to be provided for the appropriate disposal of desalinated water should local demands not meet supply.

It is to be expected that a discharge line to a suitable discharge location on the local creek or river might be required as a last resort option at one or more of the CSG fields.

An assessment has been made of the potential environmental impacts of these contingency plans. This part of the document summarises the outcomes of those evaluations and the mitigation measures that Santos will utilise if these emergency options were implemented.

3.3.4.1 Roma CSG Field Contingency Discharge to Surface Water

A study was undertaken into the potential impacts of contingency discharge of desalinated water to streams in the Roma CSG field. The focus of the study was to understand the reach scale effects of contingency discharge and this included the assessment of reach scale storage and hydraulics; and interactions between habitat (as a surrogate for ecological impact) and flow. The commentary in this part summarises the findings of the study.

Nationally recognised protocols were used to identify representative sites for survey. Field validation of these sites was immediately followed by detailed survey for riparian vegetation, habitat types and topography/hydraulics. To supplement this detailed reach analysis, sweep net samples were taken of macro invertebrates and fish, and some spot physical water quality readings were taken.

Sites targeted for this level of analysis were located on Bungil Creek downstream of Roma and on Wallumbilla Creek near the Wallumbilla Hub. These sites, while being representative of the broad scale geomorphology and vegetation of the region are also close to proposed ROP sites or desalinated water storages.

Bungil Creek and Wallumbilla Creek are similar streams that maintain some large pools instream even during dry season. These pools act as refugia for fish, yabbies and other species. There is evidence of significant pondage arising from road building and the cutting of vehicle access points across the stream. Furthermore, stock move through the streams regularly, disturbing sediments and adding nutrients.

Based on observations of flow moving down Bungil Creek during the survey period, it is likely that water quality will improve with the introduction of desalinated water to the creek system. In particular, turbidity is likely to be reduced, and dissolved oxygen may improve.

However contingency discharge of desalinated water to Bungil Creek or Wallumbilla Creek, has the following potential impacts:

- That the salinity of desalinated water may not be consistent with relevant water quality guidelines and minimum target values.
- That there is the potential for the degradation of streambed soils if Sodium Adsorption Ratios are not similar to that proposed for irrigation.
- That there is potential for artificial signalling of instream species behaviours and shift in species composition (e.g. to algae) if the temperature of the water discharged is not as similar as possible to ambient water temperatures.

- If dissolved oxygen levels of the desalinated water are not at least as high as those measured in stream (>5 mg/L) there may be a reduction in instream water quality.
- There is potential for erosion at the discharge location.

Available habitat within the streams consists of dispersed pools, tree roots and fallen woody debris. Wallumbilla Creek contains significantly less woody debris than Bungil Creek. Adding desalinated water will gradually fill pools one by one then spill to downstream pools. This will gradually increase the amount of habitat available instream, and modelling suggests that the main habitats increased will be pools and woody debris. Some tree root habitat will also increase, but most trees are outside the main channels.

Average velocities in stream will be small; circa 0.01 ms^{-1} for ponds with faster flowing sections at the downstream edge of pools. Inundation is only likely to occur within the first 10 – 30 cm of the height of pools, managed by the amount of desalinated water being discharged. Channels are approximately 4 - 6 m deep and intermittently carry flow many orders of magnitude greater than those proposed from desalinated water discharges.

The proposed discharges could affect cattle or vehicle access across the stream, though the modelled depths of water should be passable.

Survey and modelling results indicate that the connectivity between pools will be increased. A continuous discharge would result in flow throughout the creek(s) to at least the Surat Weir pool. Intermittent discharges, provided they are short term, may not result in continuous flow through the system, but would affect various lengths of channel.

For Bungil Creek, it is estimated that there is approximately 2.2 ML/km storage available in the system. Assuming a distance of 100 km to the Surat Weir pool from Roma the total storage available is approximately 220 ML. This is equivalent to around one week of storage under peak production releases or up to 3 weeks of storage at 10 ML/day discharge.

For Wallumbilla Creek, 1.6 ML/km storage is estimated instream, thus up to 160 ML could be discharged before continuous flow arises given that the distance to the Surat Weir pool is similar. This is equivalent to five days discharge under peak production, or around two weeks at 10 ML/day discharge.

These assumed discharges are very conservative. True discharges could be substantially less and could therefore have even less impact. The total storage volume of pools within the creek systems (220 ML for Bungil and 160 ML for Wallumbilla) provide a coarse indicator of whether or not streams would flow or simply pond.

While pools will be connected, and the connectivity of the system will increase substantially under flows, the ecological implications of this increase in connectivity are unlikely to be significant since the average velocities in the pools are very low, and the flow depths between pools are small. Flow events do occur naturally during the dry season and wet season. These events will be significantly larger than any desalinated water discharges and will continue to be the major trigger for dispersal of species within the system.

Provided water quality (and particularly temperature) is maintained at or near ambient conditions, the flow rates associated with desalinated water discharge are unlikely to be major drivers for spawning or movement in the creek system.

The main impact from adding desalinated water to the creek systems is to increase the available wetted habitat. Shifts in species composition are unlikely, perhaps with the exception of diatoms in dry pool areas. These are subject to removal and dispersal by episodic flood events under the current flow regime.

There is unlikely to be a significant shift in riparian zones in either Bungil Creek or Wallumbilla Creek since the discharges contemplated will lead to only small rises in water level above existing ponded areas and plimsoll lines.

Provided water quality is managed appropriately, the main impacts of discharging desalinated water to the Bungil and/or Wallumbilla Creek systems would be an effective increase in available instream habitat.

Intermittent discharges for a few days may be appropriate on an emergency basis. One and three weeks discharge may be able to be accommodated dependent on the stream and size of discharge planned.

If discharges are used for one creek, Santos would not utilise the other creek in order to minimise the footprint of activities.

To prevent potential impacts, Santos will ensure that desalinated water is of appropriate quality for discharge. This will include:

- Making sure that the salinity is consistent with relevant water quality guidelines and minimum target values (i.e. 325 µS/cm);
- Dosing the water to ensure that the Sodium Adsorption Ratio is similar to that proposed for irrigation;
- Managing the temperature to as close to ambient water temperature as possible;

- Ensuring dissolved oxygen levels are at least as high as those measured in stream (i.e. >5 mg/L); and
- Providing suitable erosion protection works at any proposed discharge point.

3.3.4.2 Arcadia CSG Field Contingency Discharge to Surface Water

A study was undertaken into the potential impacts of contingency discharge of desalinated water to Lake Nuga Nuga, downstream of the Arcadia CSG field. The commentary in this part summarises the findings of the study.

Review of cadastral information and exhaustive discussions with personnel from a range of Queensland Government departments shows that Lake Nuga Nuga is not part of the Nuga Nuga National Park. The ownership of the land under the lake is indeterminate. However, it is clear that the lake encroaches on both private land and the Nuga Nuga National Park when it is at high lake levels.

Lake Nuga Nuga was identified by Brown, an early explorer, as a much smaller lake than is currently observed. The current lake was formed circa 1880 by a ‘cloud burst’ over the Moolayember Creek catchment that lead to the avulsion of that creek and the formation of a levee bank at the outlet of the Brown River between Moolayember Creek and Mt Warranilla. A clear crevasse splay is evident from Moolayember Creek into the Lake Nuga Nuga storage area.

Lake Nuga Nuga is continuing to grow in size as Moolayember Creek adds new loads of sediment to its levees. Downstream discharge from the lake only occurs once the water level approaches the maximum height of the levees and this is approximately equivalent to the invert of the Brown River which runs around the side of Mt Warranilla at the northeast end of the lake.

Littoral vegetation was found to have a clear succession with distance away from the lake water surface. The vegetation was indicative of specific lake levels and inundation regimes. Common vegetation types were found around the lake. No threatened species were identified.

The primary species identified within the range of lake levels are (in order of succession towards the lake):

- Sesbania cannabina – An erect, spindly annual herb or shrub, 0.5 – 3 m high that prefers sandy, clay & loamy soils. Widely spread common species found in creek & river beds, and other areas subjected to seasonal water-logging.
- Glinus lotoides – a widespread prostrate to ascending annual or perennial herb species, 0.01–0.2 m high found in clay loam and alluvium. It commonly inhabits edges of billabongs, watercourses & other wetlands.
- Various herb species – n/a.
- Nyphaea sp. (water lilly) – A floating-leaved, aquatic rhizomatous, perennial, herb, with emergent flower. Widely spread and found in ephemeral billabongs or creeks.

- Triglochin sp. (ribbon weed) – A widely distributed, cosmopolitan family of perennial submersed/floating plants with a compact stem attached to submerged substrate.

Algae was observed attached to macrophytes and free floating.

A wide range of bird species were identified including:

- Spoon bills;
- Magpie geese;
- Little pied cormorant;
- Black cormorant;
- Black swan;
- Great egret;
- White faced heron;
- Pelican;
- Marked lapwing;
- Kites;
- Sulphur Crested Cockatoo;
- Ducks unknown spp; and
- White necked heron.

Nesting of cormorants was observed.

Small common fish species were found to be numerous particularly in macrophyte beds in the lake.

The lake was found to be clear, alkaline (pH ~8.2), well mixed and with elevated salinity (~430 µS/cm) compared with streams in the general region. Dissolved oxygen concentrations were found to be good (>5 mg/L), though depressed in areas with shallow sediments. Review of DERM records showed a single water quality sample that suggests the lake contains elevated nitrate and total phosphorus levels almost 4 times greater than guidelines for Central Queensland. This suggests the lake is a mesotrophic to eutrophic environment with cycles of macrophyte and algae growth.

A conceptual model of the lake was derived, as follows:

- Lake Nuga Nuga is a terminal lake system for the Arcadia Creek and Brown River under many flow conditions. It regularly experiences wet and dry periods and the local ecosystem and littoral and submerged vegetation has adapted to this variation in water levels. The littoral zone exhibits the typical "bath ring" effect of shallow littoral benthic production.

- Currently, it is only when the lake level is higher than ~262.51m that discharge occurs downstream. The system is only connected with downstream reaches for short periods of time.

- Since the lake is a clear water lake with beds of submerged aquatic plants and medium to high levels of nutrients it is thought to be mesotrophic to eutrophic with boom and bust cycles of macrophytes and algae associated with the intermittent delivery of water and nutrients from upstream. Most nutrients will be trapped within the lake system rather than flowing through to the Brown and Comet rivers downstream.

- Episodic cycles of retention and evaporation of water, perhaps exacerbated by local geology, has lead to increased salinity in the lake with electrical conductivity circa 430 µS/cm compared with local creeks where the typical electrical conductivity is in the range 180 - 210 µS/cm.

- Inflows to the lake are predominantly acidic to circum neutral, however, the local geology contributes significant carbonates and the lake water is alkaline with a pH circa 8.2.

- The lake is an important system for waterbirds and supports both feeding and nesting.

- Populations of fish in the lake utilise extensive beds of ribbon weed for nursery and protective habitat.

- The lake regularly dries to small separate ponds and possibly has no water from time to time.

Based on the conceptual model and water balance modelling, a range of wetland stressors were considered in the context of contingency discharges of desalinated water to Lake Nuga Nuga. The hazards associated with each stressor were identified, likelihood of occurrence assessed and mitigation measures proposed as necessary.

Table 3-4 Risk Assessment and Management – Contingency discharge of desalinated water to Lake Nuga Nuga

Stressor	Hazard	Likelihood	Mitigation Measure
Aquatic sediments	Change in light environment. Changes in primary production	Very low	Nil
Bacteria/pathogens	Impact on lake users and/or instream environment	Low	Management of biofouling at ROP Temperature management to ambient conditions.
Biota removal/disturbance	N/A	N/A	Nil
Conductivity	Mortality Altered community structure	Low	Target desalination at background EC (430 µS/cm) Dose to ensure adequate ionic balance
Connectivity	Loss of change of connectivity may lead to shift in wetland species	Low	Nil. Modelling shows no significant effect on timing, magnitude or durations
Habitat removal	Loss of habitat or seasonal habitat may lead to shift in wetland species	Low	Nil. Modelling shows no significant effect on timing, magnitude or durations
Hydrology	Change in seasonality, range, durations of lake levels and discharges	Low	Nil. Modelling shows no significant effect on timing, magnitude or durations
Litter (rubbish)	N/A	N/A	Nil
Nutrients	Change in nutrient cycling with lake	Very low	Nil. Desalinated water is low in nutrients
Organic matter	N/A	N/A	Nil
Pests (animal, plant)	N/A	N/A	Nil
pH	N/A	N/A	Nil
Toxicants	Species deaths, extinctions	Low	Manage all chemicals including biofouling chemicals in ROP to environmental tolerances.

Contingency discharges of desalinated water to Lake Nuga Nuga have been evaluated and key points are summarised as follows:

- Changes in the hydrology of the lake are likely to be minimal with no shift in seasonality, discharge frequency or inundation of critical littoral zones at the edges of the lake.
- A permanent pool circa 0.1m deep and 0.7 km2 surface area would arise from desalinated water discharge. This pool would act as refugia for fish and other species in drought periods. The pool would not encroach on private land.

- Provided suitable measures are taken to control temperature, salinity and microbial activity discharge of desalinated water to Lake Nuga Nuga would result in a small environmental gain.
- Recreational use of the lake will be unaffected.
- There will be minimal change to lake inundation levels and/or frequency.

3.4 Brine Management

3.4.1 General

All options involving desalination will produce a concentrated brine stream, which will require careful management, and increase the potential for environmental harm. Brine containment ponds will need to be utilised for "containment then disposal" as the base case for brine management. These will be:

- Located adjacent to HCS or power stations to take advantage of waste heat to enhance evaporation; and
- Developed in cells, rather than "life of project capacity".

3.4.2 Short term brine management

Initially brine containment ponds will be constructed to temporarily store brine prior to development and approval of the agreed approach for brine disposal. Where any ponds built and operated over the life of the project trigger regulated dam criteria, the regulated dam decommissioning guidelines will be implemented upon closure of the pond.

3.4.3 Final Containment Strategy Overview

A definitive final containment option has not been selected for brine management. A series of final containment options currently include:

1. Inject brine into suitable underlying (basement) formations or preferably depleted coal seams, where technically, environmentally and economically the best option; otherwise
2. Brine evaporation (or crystallisation) using the storage ponds, and encapsulated or transferred to a registered landfill site.

The final containment options will be consistent with industry best practice guidelines, policies and procedures referred to in the CSG Fields EMP, EA conditions and long term monitoring requirements.

3.4.4 POTENTIAL BRINE INJECTION IMPACTS

There are a number of criteria that have to be met, when considering recharge disposal options. These include:

- The degree of hydraulic isolation of the target unit;
- The aquifer hydraulic characteristics of the target units, specifically storage capacity and transmissivity;
- The impact that the injected brine may have on the natural waters in the formation (beneficial uses, pressures); and
- The conflicts with other potential uses of the aquifer, including possible future water supply and gas storage.

3.4.4.1 Hydrogeochemical Modelling

The groundwater from aquifers in the Roma, Fairview and Arcadia CSG fields have been geochemically assessed in order to determine suitability as potential target aquifers for injection of brine. The aquifers were assessed by means of speciation using equilibrium modelling to determine potential issues and processes that may affect the efficiency of injection into the aquifers.

The results of the speciation analysis were reviewed to determine the dominant species in solution and the potential processes which may affect injections into the aquifer (e.g. potential mineral precipitation).

The brine was also modelled using a fluid evaporation model to determine which minerals may precipitate and be able to be recovered during evaporation, prior to injection.

Within the Roma CSG field the modelling predicts that alumino-silicate clay precipitation is possible within the Mooga Sandstone, under existing conditions.

Within the Fairview CSG field, the model predicts that carbonate precipitation is likely to occur in the Timbury Hills Formation. The brine contains strontium, which is likely to catalyse precipitation of carbonate minerals (e.g. calcite, aragonite and dolomite) should brine be injected into this aquifer. Precipitation minerals may reduce groundwater flow within the aquifer and inhibit mixing and injection efficiency.

The brine was also modelled using a fluid evaporation model to determine which minerals may precipitate during evaporation. The model predicts that several minerals will remain supersaturated in the brine solution throughout the evaporation process. These minerals include carbonate minerals of calcite and dolomite. The carbonates that precipitate are likely to contain strontium, and this process should effectively remove most of the strontium from the brine solution. The mineral delafossite ($CuFeO_2$) is also likely to precipitate through most of the evaporation process, until approximately 75% of water has been evaporated.

3.4.4.2 Hydraulic Modelling of Groundwater Injection

Hydraulic modelling was undertaken to evaluate how injection of fluids would affect groundwater levels and pressures within various strata, using the analytical Winflow modelling software.

Representative aquifer hydraulic properties (hydraulic conductivity and storativity) were used as model inputs. Injection rates were based on likely disposal requirements for brine.

For the Roma CSG field the depleted Walloon coal measures were evaluated.

For the Fairview/Arcadia Valley fields the following strata were evaluated:

- Depleted Bandanna Formation; and
- Timbury Hills Formation.

The Fairview disposal trial design injection rate ranges between approximately 300 m^3/day to 1 600 m^3/day. To reflect injection over a similar range, three injection scenarios of 500 m^3/day, 1 000 m^3/day, and 1 500 m^3/day into a single well were simulated for each stratum.

Predicted incremental changes in heads (i.e. increased groundwater pressures) after 10 years of injection at a radial distance of 10 km from the modelled injection bore were simulated and the results are presented in Table 3 5. These predicted incremental changes would counteract, to some extent, the head decline in the aquifer that has been observed at Roma.

Table 3-5 Predicted Heads after 10 years of Injection

Predicted head at 10km from injection bore (m)			
Roma Field			
Injection Rate Stratum	500 m3/day	1,000 m3/day	1,500 m3/day
Depleted Walloon Coal Measures	10	10	10
Fairview/Arcadia Valley Field			
Depleted Bandanna Formation	10	20	30
Timbury Hills Formation	14	28	42

3.4.4.3 Summary

In all of the CSG fields, deep well injection can be used to dispose of brine derived from the RO process of after concentration in an evaporation basin, provided aquifer hydraulics are amenable, chemistry is compatible and well construction is carried out to a high standard to prevent corrosion and leakage into adjacent strata (refer Supplementary EIS Attachment D2, Section 8.10.1).

No impacts to the environment are expected from such a proposal, however, since the brine will only be injected to aquifers that are demonstrated to be isolated from aquifers of beneficial use to the community or connected in any way to the shallow groundwater and surface water system. Santos will perform detailed injection well design studies in conjunction with pilot project testing to avoid any well design issues.

3.5 MANAGEMENT OF WATER PRODUCTION UNCERTAINTY

It is clear that given the uncertainty over the expected AW quantities and the limited knowledge of AW quality from each field area, the AWMP needs to be adaptive relative to actual production rates and qualities. The two biggest drivers in the uncertainty of AW production of the various fields are:

- Geological Uncertainty – uncertain knowledge of permeability and quantity of AW. This may result in a change of magnitude of the AW production curves or in a change of timing.
- Planning Uncertainty – dewatering rates and locations can change due to a variety of factors many times over the life of the project. This may impact the timing of the AW production curve.

These are shown on example AW production curve in Figure 3-7 below.

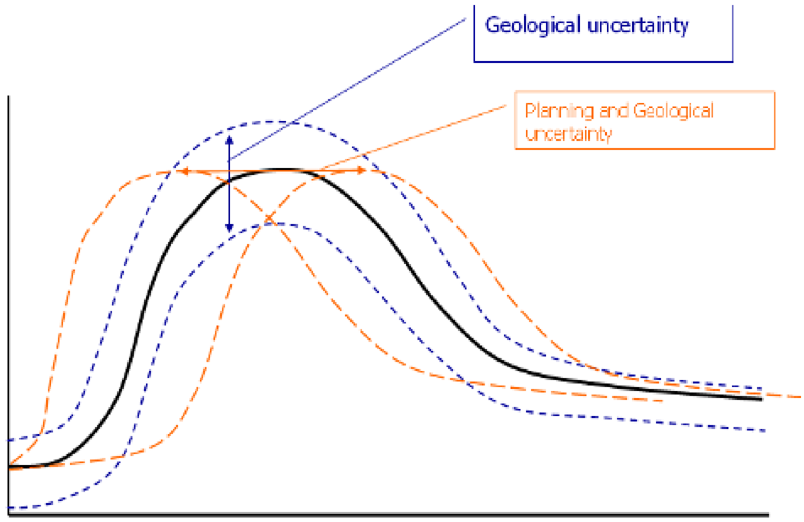


Figure 3-7 Impact Examples of Uncertainty on AW Production Curves

Planning for this uncertainty is central to the success of the project. Quarterly reviews comparing production against the predicted forecast have been identified as necessary in order to foresee changes in magnitude or timing and any arising implications or actions. This review will also allow for required purchasing and scheduling of treatment technologies and machinery etc to be made available and also for contingencies to the evaluated.

Figure 3-8 below shows an example baseline profile for AW quantity and the comparison process of AW production against forecast.

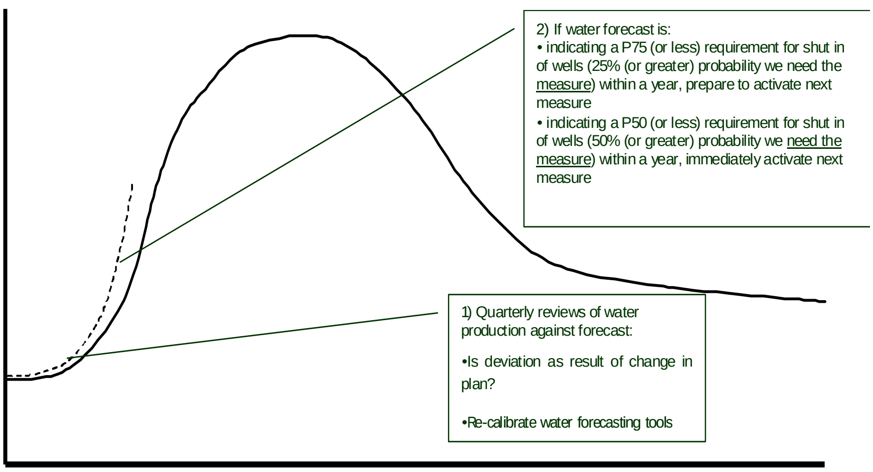


Figure 3-8 Baseline Profile reviewed with Production

Each quarterly review will examine:

- The previous calibration of AW production against plan.
- Based on an updated water balance model, what is the new forecast for AW production within the *next calendar* year – is there likely to be an incursion of pond water levels into storage reserves?
- Based on an updated water balance model, what is the new forecast for AW production *at peak production* – is there likely to be an incursion of pond water levels into storage reserves?

If the AW forecast comparison is:

- indicating a P75 (or less) requirement for shut in of wells over the acceptable level (target 95% of planned production) - meaning 25% (or greater) probability we need the supplementary measure within a year, prepare to activate next AW management measure.
- indicating a P50 (or less) requirement for shut in of wells - meaning 50% (or greater) probability we need the measure within a year, immediately activate next measure.

Figure 3-9 shows the baseline AW production curves and the production curves with planned contingency measures at 10%, 25% and 40% estimated AW production as a function of estimated peak AW in the field development plan.

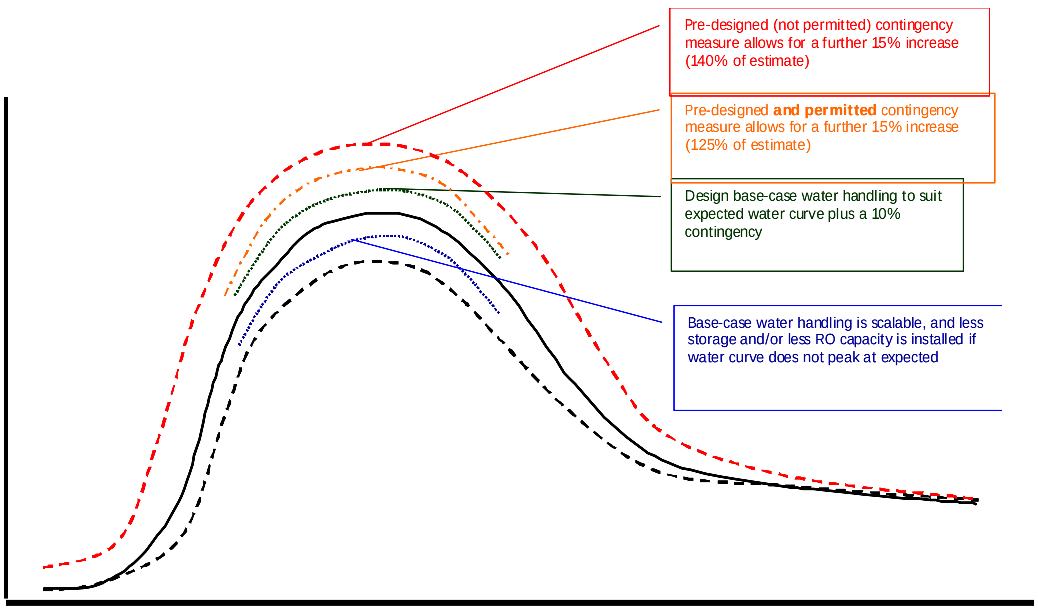


Figure 3-9 AW Management Infrastructure – Volume Risk Management

Regular reforecast of the AW production curves at each field will allow ongoing assessment of AW infrastructure capacity to adequately handle AW volumes. Should at any time an increase of significant volume identified as greater than current system capacity, a response plan will be activated. Development of the response plans is an ongoing process and forms a subset of identified risk management strategies.

If the revised peak AW forecast is:

- 10% *less* than forecasted, planned AW infrastructure will be implemented with the exception of AW treatment capacity, which could be delayed;
- 10% *greater* than forecasted, no changes to AW management are expected, because the facilities will be designed to accommodate this increase. Monitoring will be stepped up;
- 25% *greater* than forecasted, a pre-designed (tender-ready designs will have been developed in advance) and pre-permitted contingency measure will be “taken off the shelf” and implemented; or
- 40% *greater* than forecasted, a pre-designed (feasibility level designs will have been developed in advance) contingency measure will be progressed to the detailed design stage and preparations made to implement them. On going monitoring will be used to inform the decision as to whether to proceed with the measure.

4 FIELD-SPECIFIC WATER MANAGEMENT PLANS

4.1 ROMA

The AWMP for the Roma CSG field includes a variety of beneficial use opportunities as a result of the field's proximity to municipal and industrial centres (Roma and Wallumbilla). Furthermore, within the field areas there is likely to be a significant demand from local landholders for treated water to enable them to develop small-scale irrigation schemes (crops). On the basis of work undertaken during the GLNG EIS (URS, 2009) and Stage 1 of the Water Demand Study (URS, 2009), it is likely that demand will exceed supply in this area and therefore priority levels and target allocations have been assigned to each beneficial user (see Figure 4-1).

In the list of beneficial uses provided below, the target allocations and demand estimates are preliminary only and will be updated following the completion of a more detailed demand study currently being undertaken by Santos and URS (outputs are due by end of December 2009).

1) Dust suppression - use of AW (may require treatment to required water quality objectives) for dust suppression along non-paved roads/tracks within the CSG field area (refer Section 3.3.1). Nominal allocation of 10% of peak.

2) Supply to landholders – return pipelines transferring treated water (amended and/or desalinated & amended) from the ROP to 10ML ponds located adjacent to the nodal ponds for local landholder use (stock watering and small-scale irrigation schemes) (refer Section 3.3.2), Nominal allocation of 60% of peak.

3) Municipal use – provision of treated water to augment town water supplies for Roma and Wallumbilla (refer Section 3.3.3). Nominal allocation of 10% of peak.

4) Industrial supply - provision of treated water to local industry, including feedlots, saleyards, truck washdown facilities and industrial areas (refer Section 3.3.3). Nominal allocation of 10% of peak.

5) Emergency discharge (last resort) of desalinated AW to surface water (Bungil Creek) – the balance of available desalinated AW will be discharged at suitable locations (subject to an ongoing study to identify sustainable locations for discharge) (refer Section 3.3.4). Nominal allocation of 0+% of peak.

It is expected that local demand, as described above, will exceed available supply.

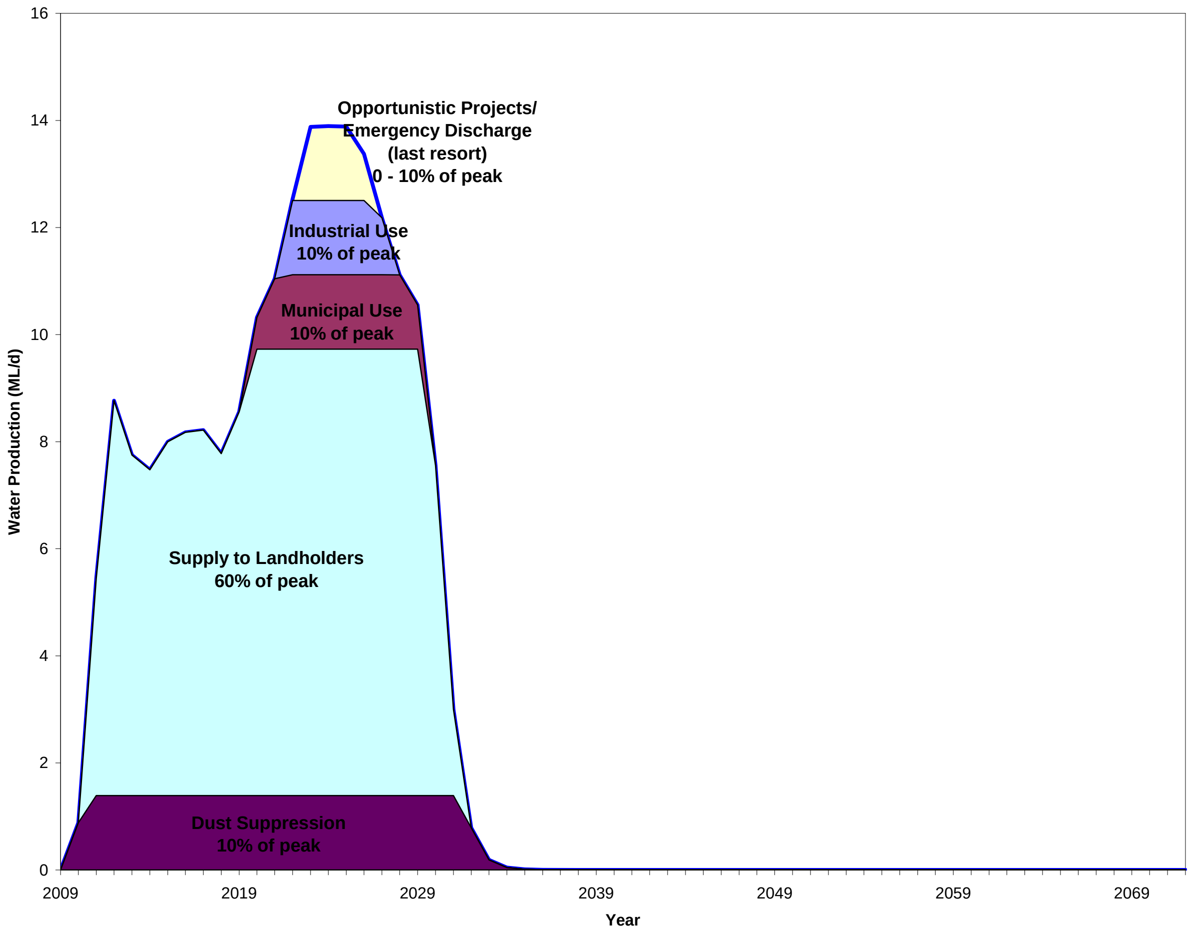


Figure 4-1 Roma Water Allocation Targets

4.2 FAIRVIEW

The main components of the Fairview CSG field's AWMP are summarised below (see Figure 4-2). Santos has an approved Resource Utilisation Plan (RUP) (Santos, Oct 2008) for the irrigation of approximately 2,000 ha of plantation eucalypt forest and 234 ha of Leucaena - pasture/grass-fodder crop over the next 10 years. Further AW will be sent to dust suppression and potentially discharged into the Dawson River to supply downstream users.

Figure 4-2 presents the recommended priority allocation of AW to water management options available at Fairview, which are described below.

1) Dust suppression – continued and extended use of AW (may require treatment to required water quality objectives) for dust suppression along 60-70km of Santos owned non-paved tracks within the CSG field area (refer Section 3.3.1). Nominal allocation of 10% of peak.

2) Industrial Supply – discharge of desalinated water to a suitable location (i.e. perennial and posing minimal risk ecological communities) along the Dawson River, for supply to downstream industrial

users. This option would involve a 3rd party Water Service Provider (WSP) (refer Section 3.3.3). Nominal allocation of up to 45% of peak.

3) Irrigation using amended water – extended irrigation (beyond current RUP) of 3,440 ha of Eucalyptus Argophloia (Chinchilla white gum) on Santos owned plateau land. This would include an Adaptive Irrigation and Groundwater Management Plan, supported by rigorous risk-based groundwater and surface water monitoring (refer Section 3.3.2). Nominal allocation of 35% of peak potentially extending to 100% of peak.

4) Irrigation using amended desalinated water – continued irrigation of 234 ha of Leucaena dominant forage system, using desalinated water from the existing Pony Hills ROP (refer Section 3.3.2). Nominal allocation of 10% of peak.

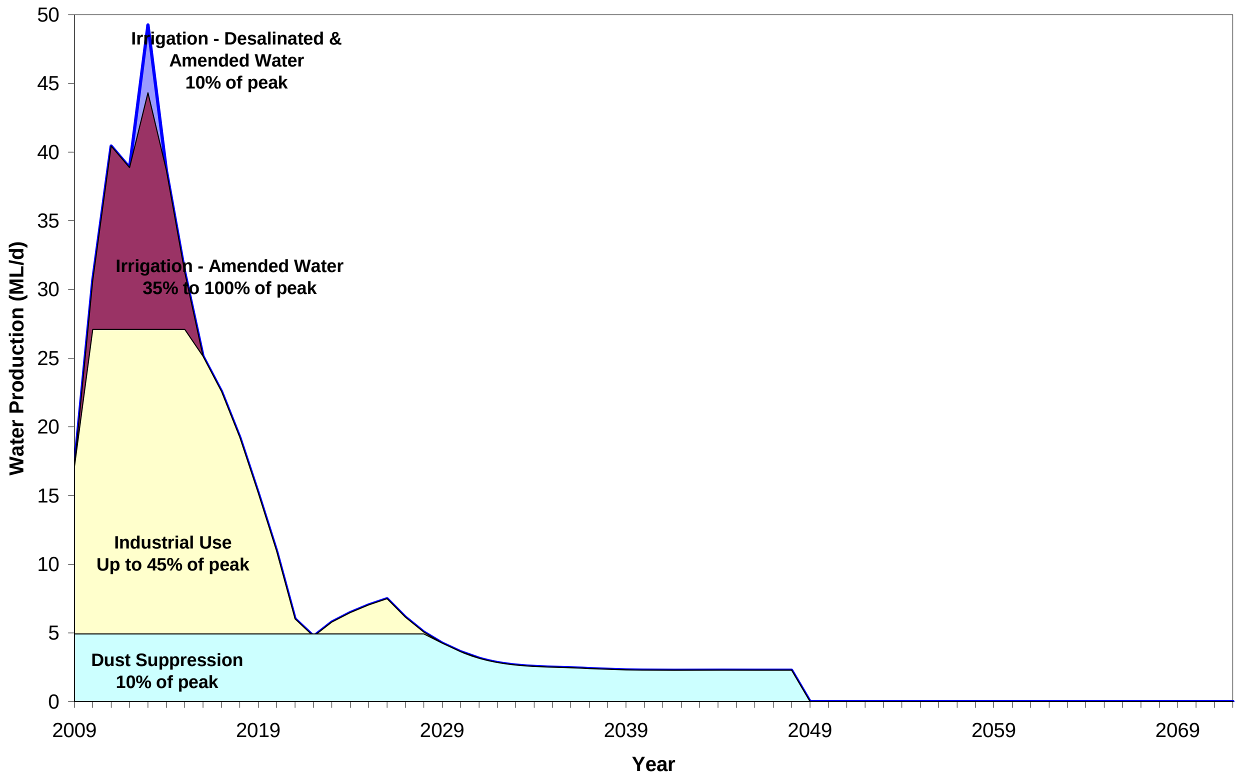


Figure 4-2 Fairview Water Allocation Targets

4.3 ARCADIA VALLEY

Within the Arcadia Valley, as with Roma, demand is also expected to exceed supply and therefore a similar approach to prioritisation has been carried out. Figure 4-3 below outlines the priority levels and target allocations that have been assigned to each beneficial user.

1) Dust Suppression - use of AW (may require treatment to required water quality objectives) for dust suppression along Santos owned non-paved roads/tracks within the CSG field area (refer Section 3.3.1). Nominal allocation of 10% of peak.

2) Supply to landholders – return pipelines transferring treated water (desalinated and amended) from the ROP to 10ML ponds located adjacent to the nodal ponds for local landholder use (stock watering and small-scale irrigation schemes) (refer Section 3.3.2). Nominal Allocation of 60% of peak.

3) Supply to opportunistic projects. No opportunistic projects have been identified at this time. In the event that an opportunistic project is identified the potential impacts and mitigation measures will be investigated fully at that time. Nominal allocation of 20% of peak.

4) Emergency discharge (last resort) of desalinated AW to Lake Nuga Nuga – the balance of available desalinated AW will be discharged at suitable locations (subject to an ongoing study to identify sustainable locations for discharge) (Refer Section 3.3.4). Nominal allocation of <5% of peak.

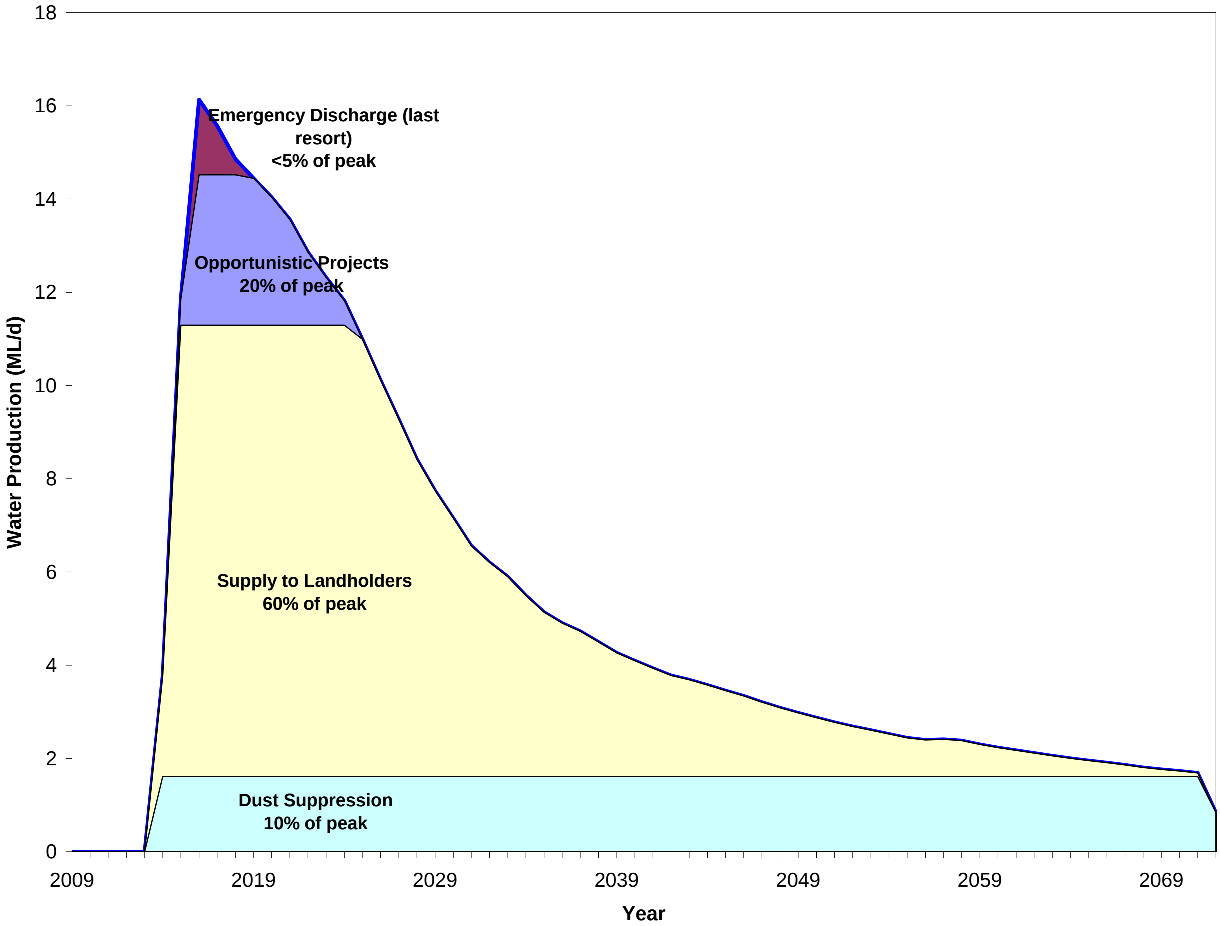


Figure 4-3 Arcadia Water Allocation Targets

5 WATER RESOURCES MANAGEMENT

Santos is committed to the protection of surface water and groundwater resources within and downstream of the project. As part of the AWMP, the following will be undertaken to manage water resources:

- Baseline and background characterisation, to develop a comprehensive understanding of the existing water resources;
- Ongoing water resource monitoring, to enable evaluation of changes to water quality and quantity; and
- Establishment of monitoring trigger levels to facilitate early detection and management of potential changes in water quality and/or quantity.

5.1 MONITORING AND REPORTING

The Upstream GLNG Water Monitoring Plan is to be developed as part of the CSG field EMP referred to in the EIS and will enable baseline characterisation and evaluation of changes to surface and groundwater quality and quantity in the vicinity of the GLNG CSG operations and receiving water resources. Whilst monitoring will not mitigate against potential impacts to water resources, it will allow for early identification of the potential impacts, and enable effective mitigation measures and contingencies to be designed and implemented.

The monitoring requirements have been developed to meet the specifications of the following sources/processes:

- Regulatory requirements specified either through the EA, Beneficial Use approval, permits or relevant general legislation;
- A risk-based monitoring approach developed by Santos to address CSG activities or infrastructure not specifically regulated elsewhere;
- CSG field EMP referred to in the EIS; and
- Industry codes of practice and guidelines.

At each identified location, specific monitoring will be undertaken as per Table 5-1, below. It should be noted that the information presented in this table is to be used as a guide and is subject to constant review of the applicability of the monitoring frequency and suites. For a list of analytical parameters for each specified suite, refer to Appendix A.

Table 5-1 Monitoring Summary Table of Facilities and Environmental Assets

Facility/Location	Sampling Point	Monitoring Suite	Frequency	Monitoring Driver
Regulated Dam	Water's Edge	WL/F	M	L
		SS	Q	
		BSW		
		FS		
		VI	A	
		CSGI	ET	
		HCS		
Hub and Nodal Compressor Stations	Inflow/outlet pipes	FS	As required or per operational specification	O,R,L
		BSW		
		SS		
		CSGI		
		HCS		
Non-Regulated Dam or Associated Water Collection Ponds	Water's Edge	WL/F	M	O,R,L
		BSW	Q	
		FS		
		CSGI	ET	
		HCS		
		VI	A	
Water Treatment Facilities	Inflow/outlet pipes	FS	As required or per operational specification	O,R,L
		BSW		
		CSGC		
		HCS		
		PW		
Irrigation Facility	Inflow/outlet pipes, water's edge of any dams, paddock	VI	M	EHSMS, EA, EMP
		WL/F	C	
		SM		
		GWP		
		FS		
		SS	Q	
		SC		
		BSW	M	
		CSGI	ET	
		HCS		
Low Point Drains	Outlet	HS	ET	EHSMS, EA, EMP
Sewage Treatment Plants	Outlet	STP	M	EHSMS, EA, EMP
		SC	A	
Landholder Supply (intended to sample water supplied to a landholder	Inflow/outlet pipes, water's	VS	M or as required for a specific	EHSMS, EA, EMP
		BSW		
		FS		

Facility/Location	Sampling Point	Monitoring Suite	Frequency	Monitoring Driver
for a beneficial use)	edge of any dams, paddock	WL/F	suite	
		SM	Q or as required for a specific suite	
		SS		
		SC		
		CSGI		
		HCS		
Environmental Asset	**Sampling Point**	**Monitoring Suite**	**Frequency**	**Monitoring Driver**
Springs	Spring	BSW	A	EHSMS, EA, EMP
		WL/F	C	
		FS	C	
Rivers/Creeks/ Perennial/ Ephemeral Streams	River monitoring location	FS	C	EHSMS, EA, EMP
		VI	A/ET	
		BSW	M	
		CSGI	ET	
		WL/F	C	
Groundwater	Bore/well	FS,WP	BA/C	EHSMS, EA, EMP
		BSW	A	
		GW	BA	
Irrigation Area and Soils	Plantation areas (Trees, forage crops) and facilities	SM	C	EHSMS, EA, EMP,O
		SS	M	
		SC	A	

Table 5-2 Notes for Summary Table

Monitoring Suite Notes	Frequency Notes	Driver Notes
FS - Field Suite	A – Annual	L- Legal
BSW - Base line Surface water (Surface Water Suite)	M – Monthly	R- Risk
GW - Groundwater suite	ET - Event Triggered	O - Operational
WP - Water Pressure	Q - Quarterly	EHSMS – Environmental Health and Safety Management system
HS - Hydrostatic Test	BA - Biannually	EA- Environmental Authority

STP - Sewage Treatment Plant	C - Continuous	EMP – Environmental Management Plan
WL/F - Water level Flow		
CSGI - CSG Indicator suite		
VI - Visual Inspection		OP - Optimisation
SC - Soil Core		
SS - Soil Solute		
SM - Soil Moisture		

The Water Monitoring Plan has separated various monitoring requirements into a series of purpose-specific monitoring suites for ease of reference and application. Different suites of analytes for monitoring have been developed to target chemical and physical parameters according to the potential source, the level of the potential contaminant/risk of concern and the impact area. Monitoring suites will be reviewed and updated if necessary to ensure accurate monitoring is achieved at all times.

The frequency and spatial variation of the monitoring will take into account the rating at which water risks have been assessed and the monitoring that is stipulated has not been stated by the regulation.

Audits of the Plan shall[3] be conducted annually by Santos. DERM may also audit any aspect of the Plan.

An organised internal approach to data management and monitoring documentation is currently being developed to facilitate the identification of potential issues of concern in a timely manner, such that appropriate contingency actions can be implemented if warranted. Through full utilisation of Envirosys ™ prescribed trigger levels or thresholds values will be added to the data set. Setting of these values in Envirosys ™ will allow for early detection of upward or downward trends with the pre-emptive notification to mobile phones or emails. All data will be managed in accordance with the GLNG Environmental Data Management Plan and stored in the Envirosys™ database.

As required by the Petroleum and Gas (Production and Safety) Act 2004, an annual monitoring report will be prepared, including a factual summary of all monitoring activities and results performed over the year, and interpretation of the results relative to the assessment criteria and extended monitoring triggers. In the event of a specific contamination event, a summary report providing details of the event and mitigation measures undertaken will be provided as soon as practicable following the event.

[3] As mandated by the Petroleum and Gas (Production and Safety) Act 2004

5.2 WATER SUPPLY PROTECTION

Under the Petroleum and Gas (Production and Safety) Act 2004, Santos is obligated to protect the water supplies of neighbouring users and surrounding ecosystems.

A combination of the GLNG Water Monitoring Plan and the development of triggers (as required under the Act) for water levels and water quality, have been established with the aim of protecting groundwater and surface water supplies. Should the water resources supply be adversely impacted, Santos is required to 'make good' in accordance with the requirements of the *Petroleum & Gas (Production and Safety) Act 2004.*

Refer to Supplementary EIS, Attachment D2 for further details.

6 REFERENCES

1 Associated Water Management Strategy -Technical Appendix Q of the GLNG EIS (January 2009). URS.

2 Associated Water Injection Study (October 2009). URS.

3 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).

4 Australian Drinking Water Guidelines (2004).

5 Australian Drinking Water Guidelines (NHMRC and ARMCANZ 1996).

6 Desalinated Water Discharge to Grade – Roma Field (October 2009). URS.

7 Investigation of Potential Discharge Locations – Arcadia and Dawson River (October 2009). URS.

8 Scoping Study on the Potential for Desalinated Water Discharges to Lake Nuga Nuga (October 2009). URS.

APPENDIX A – WATER AND SOIL MONITORING PARAMETERS

Water Monitoring Parameters

Parameter	Field Suite	Surface Water Suite	Ground water Suite	CSG Characterisation Suite	Hydrocarbon Suite
Additional Dissolved Metals: Cadmium (Cd) and Mercury (Hg)				x	
Ammonia (NH_4^+)		x	x	x	
Blue Green Algae: (Mycrocystis)		x		x	
BOD_5		x			
Calcium (Ca^{2+})		x	x	x	
Carbon 14 (one off sample)			x		
Chloride (Cl^-)		x	x	x	
Chlorine 36 (one off sample)			x		
Cyanide				x	
Dissolved Oxygen (DO) (event triggered) (field test)	x	x	x	x	
E. coli (coliform forming units/100mL)		x			
Electrical Conductivity (µS/cm @ 25°C) (field test)	x	x	x	x	
Electrical Conductivity (µS/cm @ 25°C)		x	x	x	
Fluoride (F^-)		x	x	x	
Langelier Index (calculated)		x			
Magnesium (Mg^{2+})		x	x	x	
Major Cations and Anions Bicarbonate/carbonate (HCO_3^-/Co_3^{2-})		x	x	x	
Metals (dissolved): Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Vanadium (V), Zinc (Zn)			x	x	
Metals (total): Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Vanadium (V), Zinc (Zn)		x			

Parameter	Field Suite	Surface Water Suite	Ground water Suite	CSG Characterisation Suite	Hydrocarbon Suite
Nitrate (NO_3^-)		x	x	x	
Nitrite (NO_2^-)		x	x	x	
PAH including naphthalene and benzo(a)pyrene, TPH, BTEX			x	x	x
PCBs 1242/1254 9 (one off sample)			x		
pH		x	x	x	
pH (field test)	x	x	x	x	
Potassium (K^+)		x	x	x	
Redox Potential (Eh) (field test)	x	x	x	x	
Sodium (Na^+)		x	x	x	
Sodium Adsorption Ratio (SAR)* (calculated)		x			
Strontium (Sr^{2+})		x	x	x	
Sulphate (SO_4^{2-})		x	x	x	
Temperature (°C) (field test)	x	x	x	x	
Total Alkalinity		x	x	x	
Total and Dissolved Organic Carbon (TOC/DOC)		x	x	x	x
Total Dissolved Solids		x	x	x	
Total Phosphorus (PO_4^{3-})		x	x	x	
Total Suspended Solids		x			
Turbidity (NTU) (field test)	x	x	x	x	
Water Level	x	x	x	x	

Hydro Static Test

Hydrostatic Test Water and Low Point Drain Water	pH	6.5	-	8.5
	Arsenic (mg/l)	-	-	2
	Cadmium (mg/l)	-	-	0.05
	Chromium (mg/l)	-	-	1
	Copper (mg/l)	-	-	5
	Iron (mg/l)	-	-	10
	Lead (mg/l)	-	-	5
	Manganese (mg/l)	-	-	10
	Zinc (mg/l)	-	-	5
	Nitrogen (mg/l)	-	-	25
	Phosphorus (mg/l)	-	-	0.08
	Electrical Conductivity (µS/cm)	-	-	2,000

Sewage Treatment STP

Sewage Effluent Discharge	Thermotolerant Coliforms *E. coli* (colony forming units/100ml)	-	-	1,000
	BOD_5 (mg/l)	-	-	20
	pH	6	-	8.5
	Electrical Conductivity (µS/cm)	-	-	1,600
	Total Phosphorus (mg/l)	-	-	10
	Total Nitrogen (mg/l)	-	-	35
	Total Suspended Solids (TSS) (mg/l)	-	-	30
	Total Dissolved Solids (mg/l)	-	-	1,000
	Dissolved Oxygen (mg/l)	2	-	-

Soil Monitoring Parameters

Parameter	Soil Moisture Suite	Soil Solute Suite	Soil Core Suite
Plant Available Water (calculated)	x		
Salinity 1:5 soil solution	x	x	x
Total Dissolved Solids		x	
pH		x	x
Calcium		x	
Magnesium		x	
Sodium		x	
Sodium Adsorption Ration (SAR) (calculated)		x	
Chloride		x	x
Total Alkalinity as $CaCO_3$		x	
Bicarbonate alkalinity as $CaCO_3$		x	
Carbonate alkalinity as $CaCO_3$		x	
Hydroxide alkalinity as $CaCO_3$		x	
Langelier Index (calculated)		x	
Field Texture			x
Clay Content			x
Porosity			x
Dispersibility			x
Clod Density			x
Exchangeable Calcium			x
Exchangeable Magnesium			x
Exchangeable Potassium			x
Exchangeable Sodium			x
Base Saturation			x
Cation Exchange capacity			x
Exchangeable Sodium Percentage (ESP)			x
Ca:Mg Ratio			x
CEC: Clay ration (CCR)			x
Total Carbonate			x

Parameter	Soil Moisture Suite	Soil Solute Suite	Soil Core Suite
Available Phosphorus			x
Ammonia (1:5 extract)			x
Nitrite + Nitrate (1:5 extract)			x
Nitrite (1:5 extract)			x
Nitrate (calculation)			x
Total Kej Nitrogen (calculation)			x
Total Nitrogen			x
Total Sulphur			x
Organic Matter			x
Boron			x
Zinc			x
Iron			x
Copper			x
Manganese			x
Water at saturation			x
Field Capacity			x
Wilting Point			x
Moisture Content			x
PAWC (Plant Available Water Capacity)			x