

Santos

GLNG Project

Santos GLNG

Coal Seam Water Monitoring and Management Annual Report 2013



GLNG is a Santos PETRONAS Total KOGAS venture.

Santos



Executive Summary

Purpose

This is the Coal Seam Water Monitoring and Management Annual Report 2013 for the Santos GLNG Project, as required by the Commonwealth Department of the Environment (DOTE). This Annual Report:

- Has been prepared in response to Conditions 49 i) and 53 c)ix) of the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) (EPBC Act) Approval (2008/4059) (EPBC Approval);
- Provides progress against commitments made in the Santos GLNG Stage 2 CSG Water Management and Monitoring Plan (Revision 2) (Stage 2 CWMMP Rev 2); and
- Covers the period from the submission of the Stage 2 CWMMP Rev 2 in October 2013 to December 2013.

Approval Context

In October 2010, the Minister for the former Department of Sustainability, Environment, Water, Population and Communities (now DOTE) granted the EPBC Approval under the EPBC Act, with various conditions. Conditions included the submission of a Stage 1 and Stage 2 Coal Seam Gas Water Monitoring and Management Plan (CWMMP) in which Santos GLNG made commitments for addressing the EPBC Act Approval conditions. The Stage 1 CWMMP and Stage 2 CWMMP Rev 2 were approved by the Minister for the Environment on 29 November 2013.

Features of this Annual Report

Santos GLNG is progressing as planned against the commitments in the Stage 2 CWMMP Rev 2. The Santos GLNG project continues to be developed and operated in a sustainable manner, with the appropriate mitigation measures implemented. Potential impacts to Matters of National Environmental Significance (MNES) remain low. Key achievements since the submission of the Stage 2 CWMMP Rev 2 in October 2013 include:

- Further expansion of the groundwater monitoring network (4 new dedicated groundwater monitoring wells drilled) to meet Queensland Water Act 2000 commitments;
- Ongoing surface water flow and water quality sampling;
- Groundwater baseline data acquisition continued with 32 samples taken;
- Preparation of an Injection Management Plan for a basement injection trial (approved by Department of Environment and Heritage Protection (DEHP)) and Managed Aquifer Recharge (MAR) within the Roma CSG field;
- Final reporting and data submission for the regional bore baseline assessment program (833 landholder bores visited);
- Completion of the 100 km EPBC springs survey;
- Submission of EPBC springs hydrogeological conceptual models to the DOTE;
- Completion of the first round of springs baseline surveys required by DOTE;
- Completion and commissioning of Associated Water Amendment Facility (AWAF) 3 within the Fairview CSG field; and
- First water produced from CSG wells in the Fairview and Roma CSG fields that will feed the first LNG train.

Table A provides a summary of Santos GLNG's commitments made for the period covered in the Stage 2 CWMMP Rev 2 and provides a status update of progress up to the end of December 2013.

Table A Stage 2 CWMMP Rev 2 Commitments & Progress Update

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49a, 49d,53c.vi	Groundwater Drawdown			
	Drawdown limits are now defined for the source aquifer at selected locations. These limits are subject to periodic updates.	Completed	●	Section 2
	Installation of Early Warning Spring (EWS) monitoring network	End 2016	►	Section 2
	Ground truthing of a selection of springs to assess the presence of EPBC listed species and EPBC communities	Completed – to be reported April 2015	●	Section 2
	Santos GLNG will assume responsibility of mitigation (if required) for on-tenement springs and those off-tenement springs as will be assigned by the Surat Underground Water Impact Report (UWIR)/DOTE.	Ongoing	◆	Section 2
	Comparison of drawdown to UWIR predictions will occur on a quarterly basis. This methodology has evolved since the Stage 2 CWMMP – once groundwater level reference values are defined, Santos is assessing the feasibility of programing a system of alerts in the database. Until then, three monthly data checks will be completed.	Quarterly once groundwater baseline is completed and reference value is defined.	►	Section 2

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49b, 53b, 53d(i)4	Aquifer Connectivity			
	Santos GLNG commits to provide further characterisation on the level of connectivity between the formations, including undertaking the following upcoming and ongoing hydraulic connectivity programs. Note that the results will be presented in future updates to the CWMMP.			
	Multi-level monitoring bores	Further installation in 2014, ongoing data collection	►	Section 3
	Contact Zone Program	In progress. Significant review due to geology update. Program delay due to establishing land access agreements for new monitoring locations (Section 3.4).	►	Section 3
	Wallumbilla Fault Program	In progress. Significant review due to geology update. Program delay due to establishing land access agreements for new monitoring locations (Section 3.4).	►	Section 3
	Aquifer Response	In progress. Several studies underway.	►	Section 3
	Isotope and geochemical signature	Aquifer geochemical signature to be updated in 2014	►	Section 3
	Pumping response observations and assessments	Annually from 2014	◆	Section 3
	The outcomes of the conventional oil and gas well and water bore risk assessment will be presented in the next revision of the CWMMP.	2014	►	Section 3

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49c, 53a, 53d)ii	Aquifer Re-injection			
	Santos GLNG has developed a Managed Aquifer Recharge (MAR) piloting program and schedule for CSG field piloting of aquifer reinjection:			
	Fairview CSG Field Stage 1– Desktop Study	Completed March 2012	●	Section 4
	Roma CSG Field Stage 1– Desktop Study	Completed in January 2011	●	Section 4
	Roma CSG Field Stage 2 – Investigations and Assessment	Completed in January 2011	●	Section 4
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning	Completed in Q1/Q2 2012	●	Section 4
	Roma CSG Field pilot trial (Hermitage) Stage 4 – Operation	Completed Q4 2012	●	Section 4
	Roma CSG Field (The Bend) Stage 3 – Construction and Commissioning	Due for completion Q3 2014	►	Section 4
	Roma CSG Field (The Bend) Stage 4 – Operation	Due to commence Q3/Q4 2014	►	Section 4
	Arcadia CSG Field Stage 1 – Desktop Study	Completed in September 2013	●	Section 4
	All approved Injection Management Plans will be provided in the next revision of the CWMMP.	Ongoing	◆	Section 4

● Commitment Complete; ► Commitment In Progress; ◆ Continuous Commitment

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49e	Hydraulic Fracturing As part of respective Annual Report requirements to both the State and Federal Governments, Santos GLNG will provide a projection of the anticipated number of wells to be hydraulically stimulated during each year (up to and including 2015) as well as the number of hydraulic stimulations completed in the preceding year. Additional details to be reported will also include location information and the depth of each respective hydraulic stimulation.	Annually, submitted within the first quarter of each year (i.e. the 2013 annual report will be submitted to the DOTE in Q1 2014), together with updated plan of future hydraulic fracturing.	◆	Section 5
49f	Santos GLNG has agreed with the DOTE to undertake additional Direct Toxicity Assessment that will include: <ul style="list-style-type: none"> • an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with fracking chemicals, and (iii) fracking chemicals in freshwater; • assessing the toxicity of individual fracking chemicals of concern; and • assessing contribution of fracking chemicals to toxicity of fracking fluids and flowback waters (mixture toxicity). Santos is committed to undertaking these assessments, as part of the joint industry Ecotoxicity Work Program; the result of which will be provided to the DOTE upon completion.	December 2013 – Assessments in progress	►	Section 5

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49.g.iv)	Surface Water Baseline			
	Ongoing collection of surface water baseline data	End of 2013. Completed for Fairview and Roma. Arcadia to be complete by mid 2015.	►	Section 6
	EPBC spring hydrogeological conceptual model	Existing models submitted November 2013. Remaining models to be submitted by April 2015 following completion of Spring baseline	►	Section 2
	Atmospheric pressure monitoring – 1 installation (barrologger or other) at each EPBC spring complex or cluster of spring complexes	Completed for on-tenement springs, by end 2014 for Elgin 2	►	Section 2
49.g.vi)	Surface Water Threshold Values			
	Collection and reviewing 2 years of baseline data and development of upper and lower confidence levels (Threshold values) for key parameters (relevant to MNES). These threshold values will be provided in the next revision of the CWMMP.	End of 2014	►	Section 6
49.g.x)	Brine Management Plans			
	Provision of Brine Management Plans developed for Arcadia Valley, Roma and Fairview CSG Fields as a State Government requirement within the respective CSG field's Environmental Authorities. These will be provided in the next revision of the CWMMP.	December 2014	►	Section 7

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49i, 53c)ix)	Reporting			
	A Coal Seam Water Monitoring and Management Annual Report will be developed for each calendar year and submitted to the DOTE within the first quarter of the following year.	31 March 2014 and Annually thereafter.	◆	Section 10
	Digital data can be provided to the DOTE on request	Ongoing	◆	Section 10
	Santos GLNG will publish the following reports on the internet (via the Santos Water Portal): <ul style="list-style-type: none"> ▪ Coal Seam Water Monitoring and Management Annual Report ▪ Link to the latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) 	31 March 2014	●	Section 10
	Santos GLNG will regularly publish data from all aspects of the water monitoring network on the Santos Water Portal	Ongoing (last updated November 2013. Q4 2013 update in progress)	◆	Section 10
55	The next revision of the CWMMP is currently planned to be submitted to the DOTE 3 months prior to first LNG cargo	3 months prior to first LNG cargo in 2015.	►	Section 10

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
53.c)iv)	Groundwater Baseline			
	Groundwater baseline data collection completion	End of 2014	►	Section 8
	Santos GLNG, in collaboration with the other Proponents (APLNG and QGC), will by the end of 2013 develop a statistical methodology to enable definition of significant exceedences from the baseline water pressure and water quality levels. The establishment of this methodology can only reasonably be commenced once the three Projects all have sufficient confirmation of their EPBC conditions being met by the respective CWMMPs.	Completed. The JIP provides a statistical methodology for groundwater level trend analysis.	●	Section 2
53.d.i.III	Subsidence			
	The Subsidence Management Plan provides a response plan into any exceedance of the defined subsidence trigger. The Subsidence Management Plan describes the monitoring undertaken to establish variation of ground level over time.	Completed	●	Section 9
	Subsidence baseline	Completed	●	Section 9
	Monitoring through satellite measurements	Ongoing	◆	Section 9

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Appendix A: Summary of Stage 2 CWMMP Rev 2 Commitments and Progress Update

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Chapter 1

Introduction



1.0 Introduction

1.1 Scope of the Annual Report

The Santos Gladstone Liquefied Natural Gas (GLNG) Coal Seam Water Monitoring and Management Annual Report 2013 (Annual Report) has been prepared in response to Condition 49 i) and 53 c)ix) of the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act) Approval 2008/4059 (EPBC Approval). This Annual Report provides progress against commitments made in the Santos GLNG Stage 2 Coal Seam Gas Water Management and Monitoring Plan (Revision 2) (Stage 2 CWMMP Rev 2) for the period between the submission of the Stage 2 CWMMP Rev 2 (October 2013) and December 2013.

Annual Reports will be submitted to the Department of the Environment (DOTE) by 31 March of each calendar year. Each Annual Report will cover the progress for the previous calendar year (January to December) against commitments made in the Stage 2 CWMMP Rev 2. The focus of this annual report is to:

- Document the progress against each commitment summarised in Table-A (Appendix A) from October 2013 to December 2013;
- Provide commentary on findings from completed work; and
- Document the forward work plan for completion of committed actions.

The report has been structured to present progress on commitments under the following subject areas:

- EPBC Springs;
- Aquifer Connectivity;
- Managed Aquifer Recharge;
- Hydraulic Fracturing;
- Surface Water Monitoring;
- Brine Management;
- Groundwater Monitoring;
- Subsidence; and
- Reporting.

1.2 Project Context

The Santos GLNG project will convert coal seam gas (CSG) to liquefied natural gas (LNG) for export to global markets. The GLNG project area is shown in Figure 1-1.

In May 2010, the Queensland Coordinator-General approved the project under the State Development and Public Works Organisation Act 1971. In October 2010, the Minister for the former Department of Sustainability, Environment, Water, Population and Communities (now DOTE) granted approval under the EPBC Act, with various conditions including:

- Condition 49 requires the submission and approval of a Stage 1 Coal Seam Gas Water Monitoring and Management Plan (CWMMP) within 6 months of project approval; and
- Condition 52 and 53, which requires the submission and approval of a Stage 2 CWMMP within 18 months of project approval.

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as Matters of National Environmental Significance (MNES). Accordingly, the CWMMP is primarily concerned with the protection and management of MNES in relation to coal seam water management.

Santos GLNG prepared both Stage 1 and Stage 2 CWMMPs within the specified timeframes to meet the requirements of these conditions. The Stage 1 CWMMP and Stage 2 CWMMP Rev 2 were approved by the Minister for the Environment on 29 November 2013. The Stage 2 CWMMP Rev 2 fulfils the requirements of Conditions 49, 52 and 53.

The Stage 2 CWMMP Rev 2 covers the proposed management activities from 2013 to the first LNG cargo scheduled for 2015.

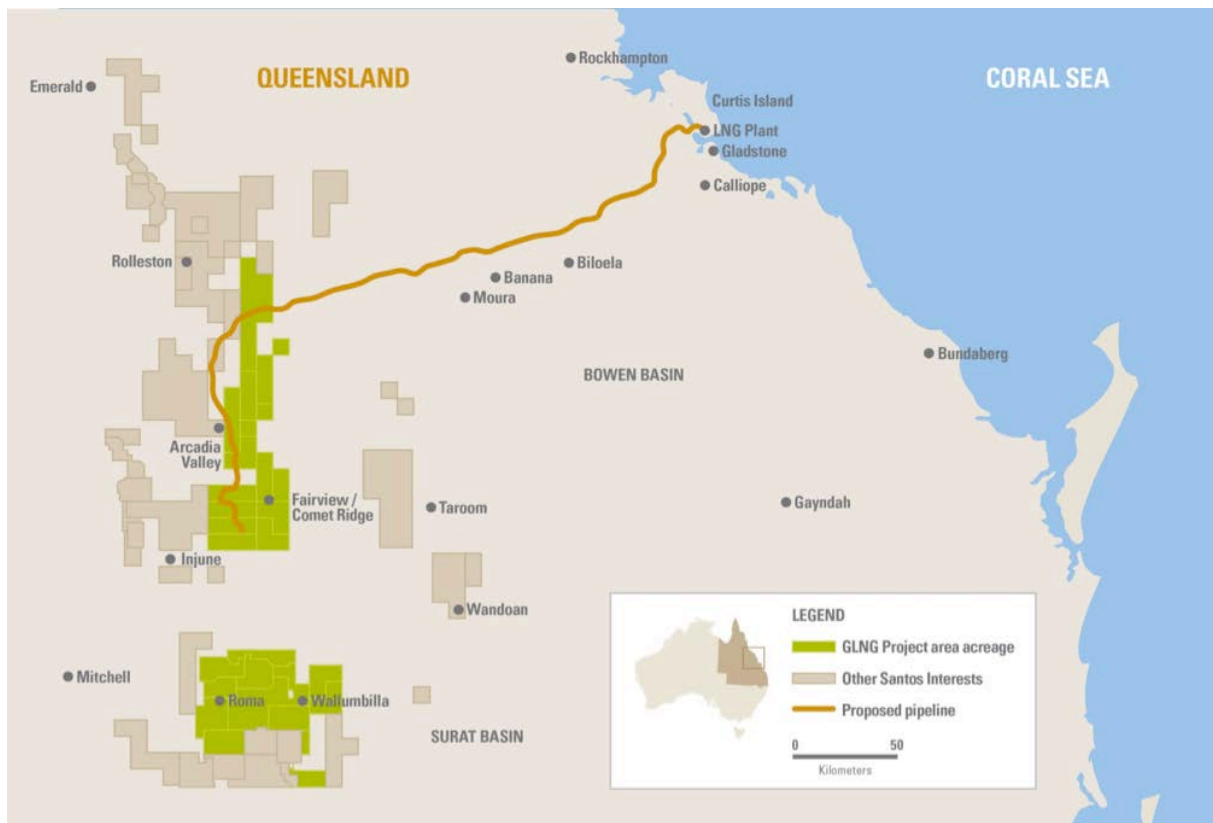


Figure 1-1: Santos GLNG Project

Chapter 2

EPBC Springs



2.0 EPBC Springs

2.1 Overview

Groundwater drawdown propagating from production CSG fields has the potential to impact springs hosting ecological communities that are listed as MNES under the EPBC Act or springs that are sourced from the Great Artesian Basin (GAB). These are known as “EPBC Springs”.

The CSG operators in the southern Bowen and Surat Basins (Santos GLNG, Origin Energy and Origin Energy on behalf of APLNG and the Queensland Gas Company (QGC)) have developed a Joint Industry Plan (JIP) for a groundwater monitoring and management system to ensure EPBC Springs are not impacted by groundwater drawdown associated with CSG production.

The methodology for monitoring and management of EPBC Springs is defined in the JIP, which was approved by the Minister for the Environment in November 2013 and provided as an appendix to the Santos GLNG Stage 2 CWMMP Rev 2.

Progress and completion of a number of tasks and commitments took place in 2013.

2.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 2-1 provides an outline of Santos GLNG’s commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (EPBC Springs) and progress against each commitment.

Table 2-1: Stage 2 CWMMP Rev 2 Commitments – EPBC Springs

Condition	Commitment	Target Completion Date Specified in the Stage 2 CWMMP Rev 2	Status
49a, 49d, 53c.vi	Drawdown limits are now defined for the source aquifer at selected locations. These limits are subject to periodic updates.	Completed	Completed
	Installation of Early Warning Spring (EWS) monitoring network	End 2016	Ongoing
	Ground truthing of a selection of springs to assess the presence of EPBC listed species and EPBC communities	On and off tenement spring baseline initiated as part of the Joint Industry program, to be reported in April 2015 (refer Appendix I)	Completed
	Santos GLNG will assume responsibility of mitigation (if required) for on-tenement springs and those off-tenement springs as will be assigned by the Surat Underground Water Impact Report (UWIR)/DOTE.	Ongoing	Ongoing

Condition	Commitment	Target Completion Date Specified in the Stage 2 CWMMP Rev 2	Status
	Comparison of drawdown to UWIR predictions will occur on a quarterly basis - Graphic comparisons will be provided in the Santos GLNG Annual Report for Early Warning System bores that Santos GLNG is responsible for.	Quarterly	The methodology has evolved – once groundwater level reference values are defined, Santos GLNG is assessing the feasibility of programing a system of alerts in the database. Until then three monthly data checks will be completed.
49.g.iv)	EPBC spring hydrogeological conceptual model	Existing conceptual models to be provided in November 2013. All conceptual models will be provided at completion of spring baseline assessment (April 2015)	Submitted November 2013. Updated hydrogeological conceptual models to be provided in 2015.
	Atmospheric pressure monitoring – 1 installation (barrologger or other) at each EPBC Spring complex or cluster of spring complexes	Completed	Completed for on-tenement springs, by end 2014 for Elgin 2
53.c)iv)	Santos GLNG, in collaboration with the other Proponents (APLNG and QGC), will by the end of 2013 develop a statistical methodology to enable definition of significant exceedences from the baseline water pressure and water quality levels. The establishment of this methodology can only reasonably be commenced once the three Projects all have sufficient confirmation of their EPBC conditions being met by the respective CWMMPs.	Completed	Completed. The JIP provides a statistical methodology for groundwater level trend analysis.

2.4 Progress Report 2013 (Oct-Dec)

Details of activities undertaken during 2013 are summarised in the following subsections.

100 km EPBC Springs Survey

Santos GLNG, on behalf of the CSG Industry, carried out the identification and survey of springs within 100 km of the maximum predicted drawdown area. A number of potential springs were identified using remote sensing technologies. The presence of potential EPBC Springs was confirmed through helicopter survey. For each of the potential EPBC Springs confirmed by the helicopter survey, Santos GLNG engaged a consultant and the Queensland Herbarium to undertake the field surveys. The study was completed in October 2013 and all reports were submitted to the DOTE in October 2013.

Although the study identified a number of springs, all were found to be water table discharge springs and no EPBC listed species were identified during the ground survey.

EPBC Springs Hydrogeological Conceptual Models

The CSG Industry committed in the JIP to provide the DOTE with spring hydrogeological conceptual models for the springs closest to the areas of CSG production (namely Lucky Last, Yebna2, Abyss and Scotts Creek) and provide existing hydrogeological cross sections for all other EPBC Springs. This report was submitted to the DOTE in November 2013.

As committed in the JIP, the spring conceptual models will be further developed after completion of the spring baseline and submitted to the DOTE by April 2015.

Progress on the EPBC Springs Early Warning System Implementation

Potential impact on EPBC Springs is and will continue to be monitored through a network of groundwater monitoring bores providing early warning of potential impact propagating from the production CSG fields towards the EPBC Spring in the source aquifer. The JIP defines the responsibilities for the implementation and monitoring of the groundwater monitoring bores.

There are 11 groundwater level monitoring installations which fall under Santos GLNG responsibility within the JIP, of which four are operational and the remaining seven are scheduled for completion in 2014. A summary status is provided in Table 2-2 and shown geographically on Figure 2-1.

Table 2-2: Progress on EPBC Springs Early Warning System Monitoring Implementation

Bore	Latitude (WGS84)	Longitude (WGS84)	Aquifer	EPBC Spring	Status
Contact Zone	-25.8098	148.8276	Precipice Sandstone	Abyss, Lucky Last	Planned 2014
Mt Hutton – Hutton (QWC129)	-25.8250	148.7916	Hutton Sandstone	Abyss	Planned 2014
Mt Hutton – Precipice (QWC129)	-25.8250	148.7916	Precipice Sandstone	Lucky Last	In place & equipped
MW0905	-25.7309	148.8456	Precipice Sandstone	Abyss, Lucky Last	Planned 2014
Scotia OBS#1 =AVLOP01	-25.9419	150.0742	Precipice Sandstone	Cockatoo Creek	Bore in place, groundwater level monitoring sensor to be installed
RN23147 = AVLGWH	-25.9141	150.0736	Hutton Sandstone	Cockatoo Creek	In place & equipped
AVLVWP	-25.9379	150.0739	Hutton Sandstone , Precipice Sandstone	Cockatoo Creek	In place & equipped
EWMI7	-24.6074	149.0761	Clematis Sandstone	Elgin 2	Planned 2015
QWC104	-25.8263	149.0370	Hutton Sandstone	Yebna 2	Planned 2014
QWC104	-25.8263	149.0370	Precipice Sandstone	Yebna 2	Planned 2014
MW0902	-25.7347	149.0829	Precipice Sandstone	Yebna 2	In place & equipped

The location for the “Contact Zone” monitoring bore, as provided in the above table, was not installed in 2013 as planned, as access to the property has not been granted. Santos GLNG has initiated processes to relocate the bore and has commenced land access negotiations.

Atmospheric Pressure Monitoring

In the JIP, a commitment was made to install barometric pressure sensors in close proximity to EPBC Springs. Pressure monitoring location AW2 is located 6 kilometres south west of Yebna 2. For the Lucky Last and Abyss EPBC Springs, a barometric pressure sensor has been installed at the Mount Hutton groundwater monitoring bore location located approximately 3.5 km to the south east of the EPBC Springs.

Spring Baseline Acquisition

The CSG Industry has engaged a consultant to perform quarterly spring baseline surveys within a one year period. The first round of survey occurred in October 2013, the second round of baseline survey is scheduled for late February 2014.

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2.5 Definition of a Reference Value and Assessment of Trends for Analysis of Groundwater Data

Reference values for water level and water quality are to be defined for each groundwater bore of the Early Warning System (EWS) network, within six months of completion of groundwater level baseline at the bore, i.e. within 6 months of acquiring 12 months of water level data at the bore. For groundwater levels, a minimum one year of data is required whilst a minimum of seven six-monthly sampling events are required for groundwater quality.

Santos GLNG is currently reviewing the available data and will be defining reference values in 2014 for MW0902, AVLGWH and AVLWVP. It is anticipated that by 2016 there will be a representative dataset adequate for defining most groundwater level reference values. There is currently not enough groundwater quality data to define groundwater quality reference values.

The JIP contains the methodology developed by QGC for groundwater level and trend analysis. This methodology represents the first phase of developing a process and tools to effectively detect any groundwater level changes due to CSG production. Santos GLNG is building on this methodology and developing further by incorporating the removal of non-CSG regional groundwater variations.

2.6 Forward Work Plan

The Santos GLNG forward work program for EPBC Springs is primarily focussed on the delivery of the monitoring bores which form part of the EWS network and baseline at the EPBC Springs. Additional studies to refine spring conceptual models are also underway.

The forward work program related to EPBC Springs includes:

- Quarterly spring baseline monitoring;
- Six-monthly groundwater monitoring and ongoing logging of water levels of existing and equipped EWS bores;
- Drilling and equipment of five monitoring bores for the EWS;
- Field studies to refine the geological and hydrogeological conceptual model at the Lucky Last spring complex, including shallow geophysical survey, shallow monitoring bores installation at the spring and geological mapping;
- Definition of groundwater level reference value for MW0902, AVLGWH and AVLWVP; and
- Further development of the trend analysis methodology for removal of non-CSG effects on groundwater levels.

2.7 Risks

One potential risk that has been identified to this program is land access approval which is yet to be confirmed for the installation and/or equipment of the following groundwater monitoring bores:

- “Contact Zone” location, now planned for installation in 2014; and
- EWM17 location near Elgin 2 spring complex. This installation is planned for 2015, however land access processes will start in 2014. This site is located off-tenement, however Santos GLNG has no regulatory support for off-tenements activities.

Negotiations are underway and mitigation measures such as relocation of monitoring bores are being considered.

Chapter 3

Aquifer Connectivity



3.0 Aquifer Connectivity

3.1 Overview

The requirement for hydraulic connectivity (movement of water between geological layers) characterisation stipulated by the DOTE is intrinsically linked to the existence and potential impact on EPBC Springs. The primary source aquifers for EPBC Springs of the Surat Basin and southern Bowen Basin are the Hutton Sandstone and Precipice Sandstone. Santos GLNG aquifer connectivity studies therefore *primarily* extend to:

- the characterisation of aquifer connectivity between the CSG bearing formations and the Hutton and Precipice Sandstone aquifers;
- the characterisation of these formation's hydraulic characteristics, including potential groundwater flows; and
- the hydraulic connectivity of these formations at significant geological features (such as subcrop or fault lineament).

These studies will be carried out through both regional and local scale investigations, including installation of monitoring bores, multi-level water level and pressure monitoring, geochemical fingerprinting, pumping tests and down-hole geophysics.

The purpose of Santos GLNG's studies is to provide information towards characterising the risk of impact propagation to MNES. The collected data will also be provided to the Office of Groundwater Impact Assessment (OGIA) for inclusion into the update of the Surat Cumulative Management Area groundwater model.

Santos GLNG activities and results to October 2013 were reported in the Stage 2 CWMMP Rev 2. No major additional results have been collected since the submission of the Stage 2 CWMMP Rev 2, however the forward work program is outlined in the following sections.

3.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 3-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (aquifer connectivity) and progress against each commitment.

Table 3-1: Stage 2 CWMMP Rev 2 Commitments – Aquifer Connectivity

Condition	Commitment	Target Completion Date Specified in the Stage 2 CWMMP Rev 2	Status
49b, 53b, 53d(i)4)	Santos GLNG commits to provide further characterisation on the level of connectivity between the formations, including undertaking the following upcoming and ongoing hydraulic connectivity programs. Note that the results will be presented in future updates to the CWMMP.		
	Multi-level monitoring bores	Ongoing monitoring and data assessment.	Further installation of monitoring bores in 2014, ongoing data collection
	Contact Zone Program	Ongoing after installation	Significant review due to geology update – Installation planned for 2014

Condition	Commitment	Target Completion Date Specified in the Stage 2 CWMMP Rev 2	Status
	Wallumbilla Fault Program	Installation, planned for 2014, scope currently under development	Significant review due to geology update – a work program has been defined for 2014
	Aquifer Response to CSG depressurisation	Ongoing	Several studies, in progress
	Isotope and geochemical signature	Ongoing	Aquifer geochemical signature to be updated in 2014
	Pumping response observations and assessments	Annually from 2014	Initiated
	The outcomes of the conventional oil and gas well and water bore risk assessment will be presented in the next revision of the CWMMP.	2014	2014

3.3 Progress Report 2013 (Oct-Dec)

No hydraulic connectivity study results in addition to the Stage 2 CWMMP Rev 2 are available for the October 2013 – December 2013 period.

3.4 Forward Work Plan

The following work programs were initiated in 2013 (or earlier) and will be continued:

- Installation of multi-level monitoring bores;
- Assessment of aquifer response through assessment of private bores water level associated with pumping and short pumping test during bore redevelopment; and
- Risk assessment of conventional oil and gas wells with respect to CSG activities.

Work programs planned to commence in 2014 include:

- Roma Wallumbilla Fault Program;
- Contact Zone Program; and
- Aquifer geochemical characterisation updates (isotope and geochemical signature).

Geological knowledge acquired throughout 2013 is resulting in the necessary review of the Roma Wallumbilla Fault Program and Contact Zone Program.

3.5 Risks

The main risk affecting progress against commitments and plans is gaining land access to drill and monitor groundwater bores. Land access agreements have not yet been obtained for the Contact Zone Program and the Wallumbilla Fault program, which may delay the completion of these programs.

Chapter 4

Managed Aquifer Recharge



4.0 Managed Aquifer Recharge

4.1 Overview

Managed aquifer recharge (MAR) is the purposeful recharge (or injection) of water to aquifers for subsequent recovery or environmental benefit. In the case of the Santos GLNG MAR schemes, the injected water comprises treated coal seam water. In this way, reinjection of treated coal seam water into underground aquifers via MAR schemes represents a water management strategy that can be both socially and environmentally beneficial.

This section provides an update on the water monitoring and management strategies that Santos GLNG proposes to implement for MAR. This reiterates the work that has been completed to date, and provides an update to the development schedule that was outlined in the Stage 2 CWMMP Rev 2.

4.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 4-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (MAR) and progress against each commitment.

Table 4-1: Stage 2 CWMMP Rev 2 Commitments - MAR

Condition	Commitment	Target Completion Date Specified in the Stage 2 CWMMP Rev 2	Status
49c, 53a, 53d)ii	Santos GLNG has developed a MAR piloting program and schedule for CSG field piloting of aquifer reinjection:		
	Fairview CSG Field Stage 1– Desktop Study	Completed March 2012	Completed March 2012
	Roma CSG Field Stage 1– Desktop Study	Completed in January 2011	Completed in January 2011
	Roma CSG Field Stage 2 – Investigations and Assessment	Completed in January 2011	Completed in January 2011
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning	Completed in Q1/Q2 2012	Completed in Q1/Q2 2012
	Roma CSG Field pilot trial (Hermitage) Stage 4 – Operation	Completed Q4 2012	Completed Q4 2012
	Roma CSG Field (The Bend) Stage 3 – Construction and Commissioning	Due for completion Q3 2014	Due for completion Q3 2014
	Roma CSG Field (The Bend) Stage 4 – Operation	Due to commence Q3/Q4 2014	Due to commence Q3/Q4 2014
	Arcadia CSG Field Stage 1 – Desktop Study	Completed in September 2013	Completed in September 2013
	All approved Injection Management Plans will be provided in the next revision of the CWMMP.	Ongoing	Ongoing

4.3 Progress Report 2013 (Oct-Dec)

Santos GLNG proposes to implement a MAR scheme based in its Roma CSG field at the location of water treatment and gas compressor station at Roma Hub Compressor Station 2 (HCS-02).

The Roma MAR scheme will comprise injection of treated water into a number of injection wells. As few as four and as many as 12 injection wells may be used. The number of wells will depend upon the total volume of water produced by Santos GLNG activities less the demands for coal seam water from the portfolio of alternative beneficial re-use strategies such as use in construction, dust suppression and irrigation.

An application to the Queensland Government seeks to amend Environmental Authority (EA) conditions to permit the operation of MAR in the Roma CSG field. Santos GLNG has prepared and submitted an Injection Management Plan (IMP) in support of this application. The purpose of the IMP is to support Santos GLNG's application to amend EA conditions and allow for the injection of up to 24 ML/d of treated coal seam gas water into the Gubberamunda Sandstone aquifer for up to 20 years in accordance with the those conditions.

The IMP adopts a risk management framework consistent with the "National Water Quality Management Strategy, Australian Guidelines for Water Recycling Managing Health and Environmental Risks (Phase 2), Managed Aquifer Recharge". The finalised IMP that was submitted to the Department of Environment and Heritage Protection (DEHP) on 15 January 2014 is provided in Appendix B.

There are no new findings regarding MAR feasibility and operation to those presented in the Stage 2 CWMMP Rev 2.

4.4 Forward Work Plan

The mechanical completion and operational commissioning of the necessary water treatment and delivery facilities for the Roma MAR scheme are due to be completed as early as Q3 2014, but may be delayed until Q2 2015 depending upon ongoing rationalisation and balancing of coal seam water treatment and re-use demand. It should be noted that the completion date of Q3 2013 was mistyped in the Stage 2 CWMMP Rev 2 commitments table and should read Q3 2014.

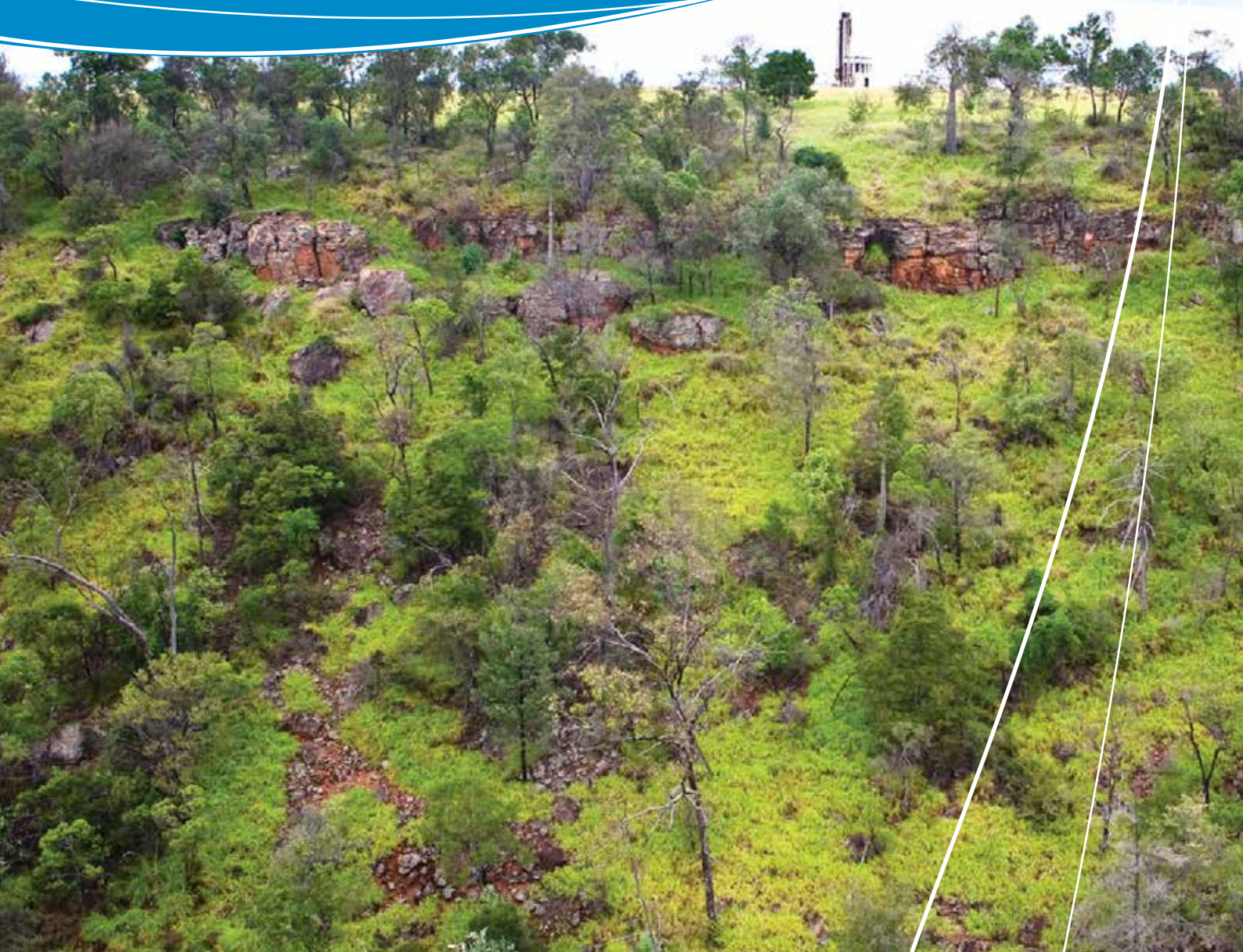
4.5 Risks

Santos GLNG is committed to implementing an operational MAR scheme in its Roma CSG field. The timing of that implementation however is subject to a number of constraints and opportunities including:

- The ongoing negotiation and agreement with DEHP regarding the specific conditions that are required to be met as negotiated for inclusion in the relevant EA to undertake each specific MAR activity;
- The timing of successful completion and commissioning of all necessary water treatment and reticulation facilities that are required to operate MAR in accordance with operational requirements; and
- The rate and volume of coal seam water made available for MAR, including the rationalisation of coal seam water production profiles and the balancing of alternative coal seam water re-use options (e.g. construction water, dust suppression and irrigation).

Chapter 5

Hydraulic Fracturing



5.0 Hydraulic Fracturing

5.1 Overview

Hydraulic fracturing is employed in the oil and gas industry to improve the production efficiency of oil and gas appraisal and production wells (i.e. more efficient and more economical extraction of gas from the coal seams). Hydraulic fracturing is not carried out on all CSG wells as the process is only necessary at locations with low permeability.

Hydraulic fracturing is carried out as one of the last activities in the construction of a CSG appraisal and/or production well and prior to bringing the well into service. It is typically performed on newly drilled and constructed appraisal and production wells after the final well casing pipe has been inserted and the bore annulus cemented and after the casing has been perforated (i.e. the well is opened to access specific coal seams).

Hydraulic fracturing uses a mix of water, sand and minor concentrations of other fluids mixed on the surface and then injected down into the well and then through the perforations into the coal seam. The water and sand are typically around 99% of the volumes of the hydraulic fracturing fluids, the remainder being the added chemical used to enhance the process.

The hydraulic fracturing process occurs under varying positive high hydraulic pressures (ranging from approximately 7,000 to 34,500 KPa) in order to open existing fractures in the coal matrix. The hydraulic fracturing fluids are injected through the perforations in the steel well casing pipe via wellhead works on the surface and coil-tube pipe down to a device which isolates the coal seam to be fractured.

After completion of the stimulation, the volumes of fluids inserted are pumped out of the well. This flow-back largely comprises the water used in the hydraulic fracturing fluid mixture, degraded additives as well as coal seam water and other geo-genic constituents sourced from the target formation. There will be a small amount of fluid liquid lost in far reaching fractures which may never be recovered during the flow-back pumping; however most of the remaining fluid left after "flow back" will be recovered during the long term production development.

5.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 5-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (hydraulic fracturing) and progress against conditions.

Table 5-1: Stage 2 CWMMP Rev 2 Commitments – Hydraulic Fracturing

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49e	As part of respective Annual Report requirements to both the State and Federal Governments, Santos GLNG will provide a projection of the anticipated number of wells to be hydraulically stimulated during each year (up to and including 2015) as well as the number of hydraulic stimulations completed in the preceding year. Additional details to be reported will also include location information and the depth of each respective hydraulic stimulation.	Annually, submitted within the first quarter of each year (i.e. the 2013 annual report will be submitted to the Department of the Environment in Q1 2014), together with updated plan of future hydraulic fracturing.	Ongoing. Provided in Figure 5-1, Figure 5-2 and Table 5-2 of this Annual Report.

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49f	<p>Santos GLNG has agreed with the Department of the Environment to undertake additional Direct Toxicity Assessment that will include:</p> <ul style="list-style-type: none"> • an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with fracking chemicals, and (iii) fracking chemicals in freshwater; • assessing the toxicity of individual fracking chemicals of concern; and • assessing contribution of fracking chemicals to toxicity of fracking fluids and flow-back waters (mixture toxicity). <p>Santos GLNG is committed to undertaking these assessments, as part of the joint industry Ecotoxicity Work Program; the result of which will be provided to the Department of the Environment upon completion.</p>	<p>Commitment made by December 2013. Target completion 2015.</p>	<p>Assessments being undertaken as per commitment are ongoing.</p>

5.3 Progress Report 2013 (Oct-Dec)

5.3.1 Hydraulic Fracturing in 2013

As of December 2013, 147 wells within the Santos GLNG CSG fields had been hydraulically fractured. Fifty-five (55) hydraulic fracturing events/stages were completed within nineteen (19) wells in 2013.

The location and depth of the 55 hydraulic fracturing stages completed in the 19 wells in 2013 are presented in Table 5-2.

The spatial distribution of wells that have been hydraulically fractured to the end of 2013 within the Santos GLNG CSG fields is presented in Figure 5-1.

Table 5-2: Hydraulic Fracturing Locations and Perforation Details Completed in 2013

Well Name and Stage	Latitude (decimal) [WGS84]	Longitude (decimal) [WGS84]	Top of Perforation (mbgl)	Bottom of Perforation (mbgl)
Arcadia Branch 5	-25.29152	148.92834	843.9	843.9
Arcadia Branch 5			798.5	799.7
Arcadia Branch 5			775.7	776.0
Arcadia Branch 6	-25.29151	148.92826	1256.5	1256.5
Arcadia Branch 6			1189.7	1190.5
Arcadia Branch 6			1105.8	1106.5
Pleasant Hills 41	-26.40588	149.01802	1012.7	1355.2
Pleasant Hills 42	-26.40584	149.01810	1010.5	1114.8
Pleasant Hills 43	-26.40580	149.01817	1073.0	1085.0
Fairview 258	-25.78510	149.06798	638.3	638.9
Fairview 258			664.9	665.5
Fairview 258			707.6	708.2
Fairview 277	-25.79317	149.10866	757.9	758.6
Fairview 277			775.2	775.8
Fairview 277			845.2	845.8
Fairview 286A	-25.82498	149.12050	711.1	712.3
Fairview 286A			723.8	724.4
Fairview 286A			754.0	754.6
FV17-19-1	-25.78862	149.05546	668.7	668.9
FV17-19-1			676.1	676.2
FV17-19-1			708.8	709.0
FV17-19-2	-25.78857	149.05552	628.2	628.5
FV17-19-2			670.2	670.4
FV17-19-2			717.2	717.5
FV17-31-1	-25.82428	149.02268	658.0	658.6
FV17-31-1			683.6	684.2
FV17-31-1			703.7	704.3
FV17-31-1	-25.82748	149.07244	726.8	727.4
FV17-34-1			622.2	622.8
FV17-34-1			645.6	646.2
FV17-34-1	-25.82743	149.07249	659.3	659.9
FV17-34-2			635.8	636.0
FV17-34-2			649.5	649.6
FV17-34-2			656.0	656.0
FV17-34-2	-25.77969	149.08216	674.0	674.0
FV18-06-1			691.1	691.2
FV18-06-1			755.0	755.1
FV18-06-1			764.3	764.5

Well Name and Stage	Latitude (decimal) [WGS84]	Longitude (decimal) [WGS84]	Top of Perforation (mbgl)	Bottom of Perforation (mbgl)
FV18-06-2	-25.77963	149.08219	654.9	655.0
FV18-06-2			667.2	667.3
FV18-06-2			705.8	705.8
FV18-06-2			754.0	754.3
FV18-06-3	-25.77956	149.08223	688.9	689.0
FV18-06-3			701.1	701.2
FV18-06-3			740.5	740.6
FV18-06-3			793.9	794.2
Springwater 13	-25.71463	148.97508	1304.0	1310.2
Springwater 13			1315.4	1317.9
Springwater 13			1321.3	1325.6
Springwater 2	-25.76744	149.08934	1343.0	1344.5
Springwater 2			1393.4	1397.9
Springwater 2			1526.6	1528.7
Yebna South 1	-25.77179	149.11933	1425.4	1426.9
Yebna South 1			1560.5	1562.0
Yebna South 1			1780.7	1782.2

mbgl – metres below ground level

5.3.2 Direct Toxicity Assessment

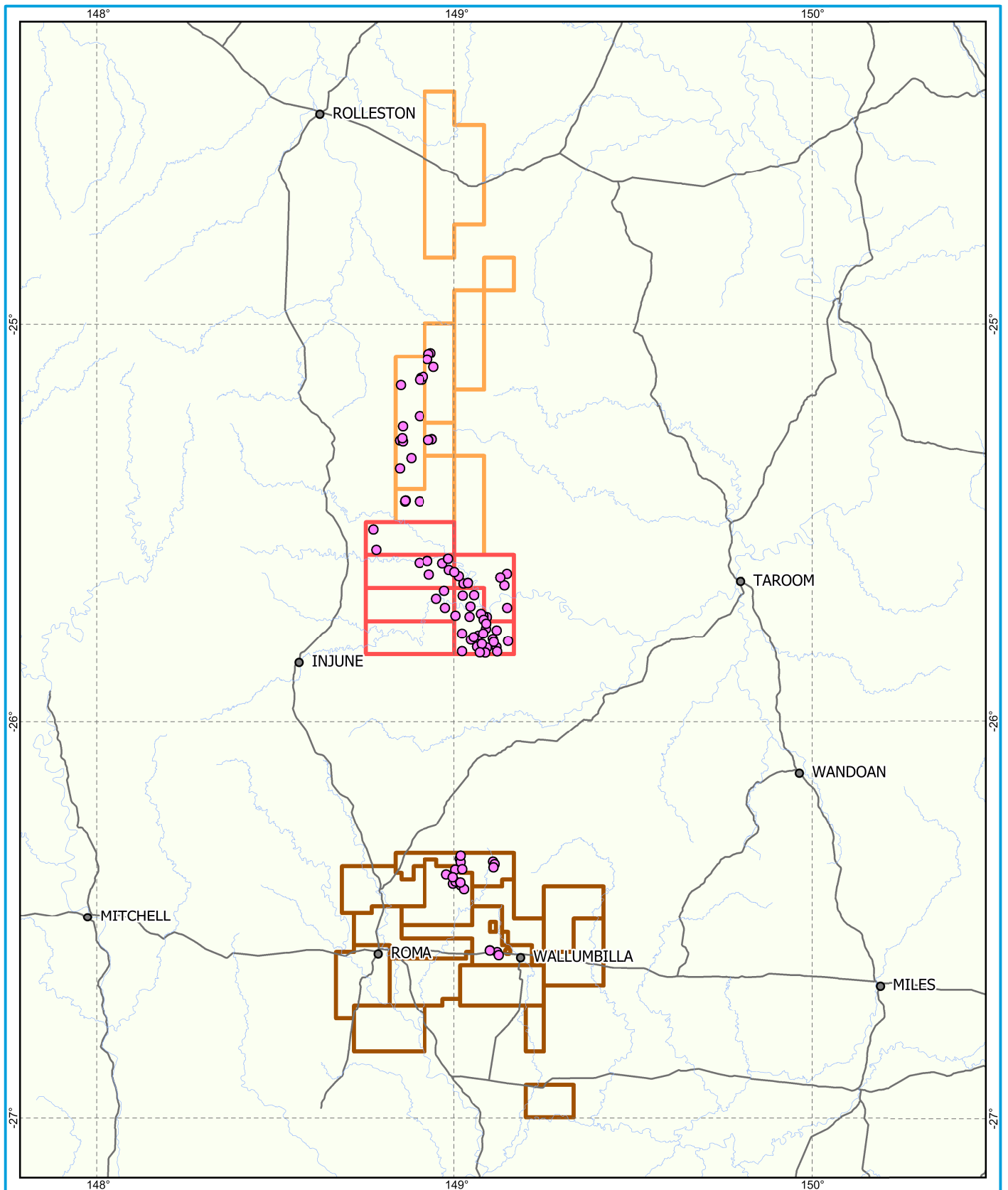
As detailed in the Stage 2 CWMMP Rev 2, Santos GLNG committed to undertake additional Direct Toxicity Assessments as part of the joint Industry Working Group (IWG) CSG Fracing Fluid Ecotoxicology Work Plan (Hydrobiology, June 2013). The Ecotoxicology Work Plan, prepared by Hydrobiology and approved by the former Department of Sustainability, Environment, Water, Population and Communities (now DOTE) and the Expert Panel for major coal seam gas projects, was developed to assess the incremental toxicity of fracing fluids in the context of the natural ecotoxicity of coal seam gas water to surface water organisms.

5.4 Forward Work Plan

Up to 170 wells within Santos GLNG CSG fields are scheduled to undergo hydraulic fracturing throughout 2014 and 2015, as presented in Figure 5-2.

Whilst this number is not expected to be exceeded, the need for hydraulic fracturing is subject to change and is affected by the progress of drilling and well completion activities, the availability of resources and the geology and permeability characteristics across the CSG fields and as such more wells may require hydraulic fracturing over this period.

The Ecotoxicology Work Plan is currently advancing with a number of assessments for various waters and fluids, presented by other IWG partners, being completed. Direct toxicity assessment of Santos GLNG 'nominated' waters and fluids is due to commence in early 2014, pending the progress of drilling and well completion activities as well as the anticipated hydraulic fracturing events. The results of these assessments will be provided to the DOTE upon completion.



GLNG CSG WMMP ANNUAL REPORT 2013

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State Controlled Roads
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Hydrology
© Commonwealth of Australia (Geoscience Australia) 2009

HYDRAULIC FRACTURING LOCATIONS - COMPLETED



LEGEND

- Hydraulic Fracturing Location
- City / Town
- Creek / River
- State Controlled Road

- Tenements - PL / ATP
- Roma GLNG Project Area
 - Fairview GLNG Project Area
 - Arcadia Valley GLNG Project Area

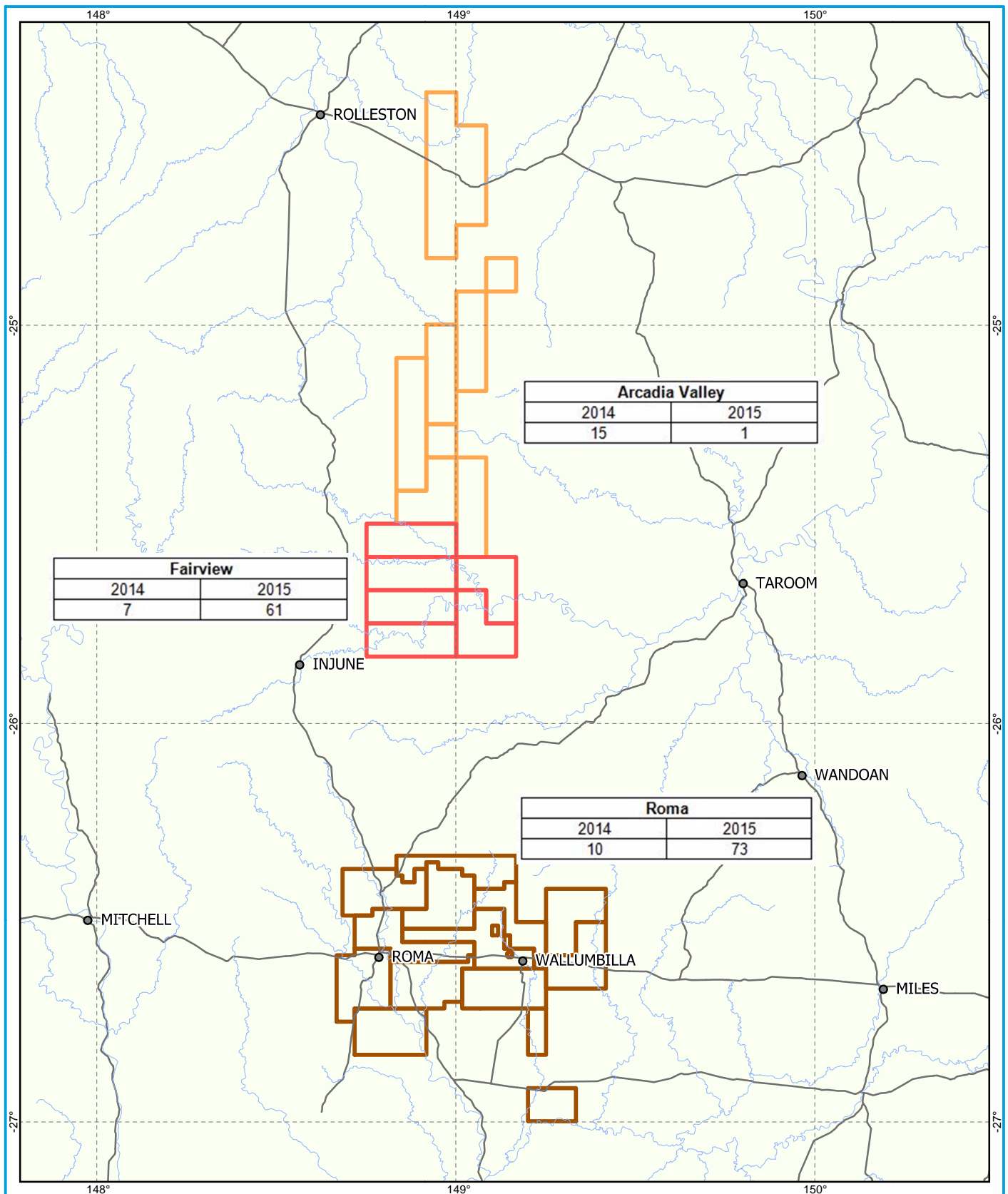
0 10 20 30 40 50 km

Date: February 2014, File No. GLNG 612a



FIGURE 5-1

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GLNG CSG WMMP ANNUAL REPORT 2013

Santos GLNG

State Controlled Roads
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Hydrology
© Commonwealth of Australia (Geoscience Australia) 2009

HYDRAULIC FRACTURING LOCATIONS - SCHEDULED



- City / Town
- Creek / River
- State Controlled Road

Tenements - PL / ATP

- Roma
GLNG Project Area
- Fairview
GLNG Project Area
- Arcadia Valley
GLNG Project Area

Roma	2015	Number of Scheduled Hydraulic Fracturing Locations
	73	

0 10 20 30 40 50 km

Date: February 2014, File No. GLNG 612b



FIGURE 5-2

Santos
GLNG Project

Chapter 6

Surface Water Monitoring



6.0 Surface Water Monitoring

6.1 Overview

The Fairview and Arcadia CSG fields are located within the Fitzroy Basin, whilst the Roma CSG field is located in the upper catchment area of the Murray Darling Basin (MDB). The main water systems within the Fairview CSG field are the Dawson River and its tributaries Baffle Creek and Hutton Creek. There are five creeks running through the Roma CSG field which drain south to the Balonne River (Condamine-Balonne River system), including Dargal Creek, Bungil Creek, Blyth Creek, Wallumbilla Creek, and Yuleba Creek and from there into the MDB. The Arcadia Valley CSG field lies within both the Comet River and Dawson River catchments, however the surface water network is largely limited to ephemeral streams.

Santos GLNG has established surface water monitoring programs for springs, treated coal seam water discharge points, ephemeral streams, and permanent watercourses within these river systems.

This chapter outlines the surface water monitoring programs that have been undertaken in response to commitments made in the Stage 2 CWMMP Rev 2.

6.2 Coal Seam Water Monitoring and Management Plan Commitments

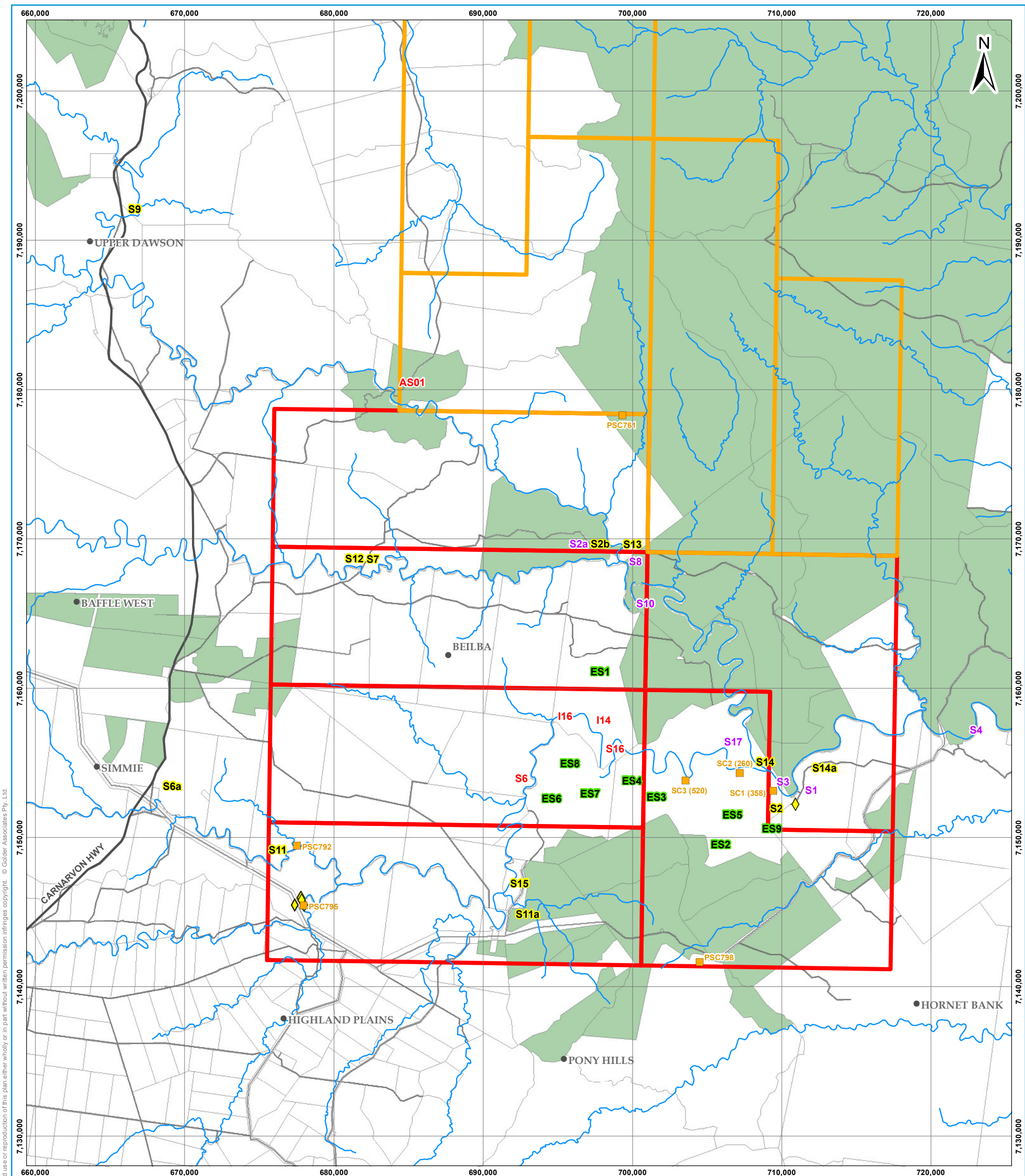
Table 6-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (surface water monitoring) and progress against each commitment.

Table 6-1: Stage 2 CWMMP Rev 2 Commitments – Surface Water Monitoring

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49.g.iv)	Surface Water Baseline		
	Ongoing collection of surface water baseline data	End of 2013	Completed for Fairview and Roma. Arcadia by mid 2015
49.g.vi)	Surface Water Threshold Values		
	Collection and reviewing 2 years of baseline data and development of upper and lower confidence levels (Threshold values) for key parameters (relevant to MNES). These threshold values will be provided in the next revision of the CWMMP.	End of 2014	In Progress

6.3 Establishment of Baseline

Monthly collection of surface water data is conducted in Roma, Fairview and Arcadia CSG fields targeting both ephemeral and perennial surface water sites shown geographically on Figure 6-1, Figure 6-2 and Figure 6-3.



GLNG CSG WMMP - STAGE 2

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SURFACE WATER MONITORING - FAIRVIEW

NOTES

- 1. Base map data copyright MapInfo Australia Pty Ltd.
- 2. ATP/PL tenure supplied by Santos, January 2009.
- 3. Springs sourced from Herbarium dataset provided by Santos.

LEGEND

- Town
- EPBC Listed Spring
- Monitoring Locations
 - Springs
 - Santos Ephemeral Surface Water Monitoring Location
- Santos Perennial Surface Water Monitoring Locations
 - Upstream
 - Midstream
 - Downstream
- Creek/River
- Highway / Main Road
- ATP/ PL Field
 - Arcadia Valley - GLNG Project area
 - Fairview - GLNG Project area

0 1 2 4 6 8 10 km

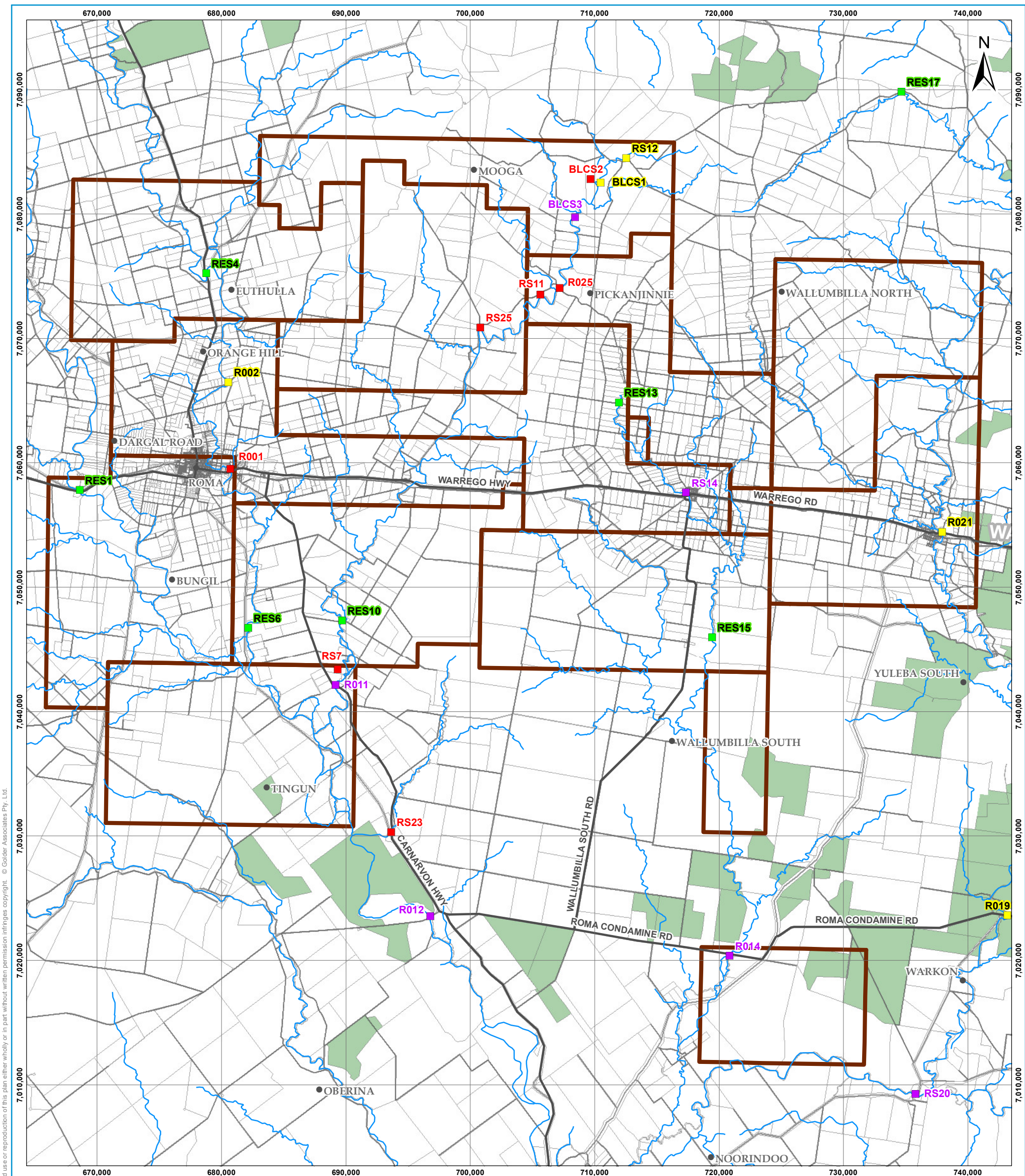
SCALE (at A3) 1:250,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117636002-3100
DATE: MARCH 2013
DRAWN: SL
CHECKED: TB

FIGURE 6-1

Santos
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GLNG CSG WMMP - STAGE 2

SANTOS

SURFACE WATER MONITORING - ROMA

NOTES

- 1. Base map data copyright MapInfo Australia Pty Ltd.
- 2. ATP/PL tenure supplied by Santos, January 2009

LEGEND

- Town
- Santos Ephemeral Surface Water Monitoring Location
- Santos Perennial Surface Water Monitoring Locations
 - Upstream
 - Midstream
 - Downstream
- Creek/River
- Highway / Main Road
- ATP/ PL Field
 - Roma - GLNG Project area

0 1 2 4 6 8 10 km

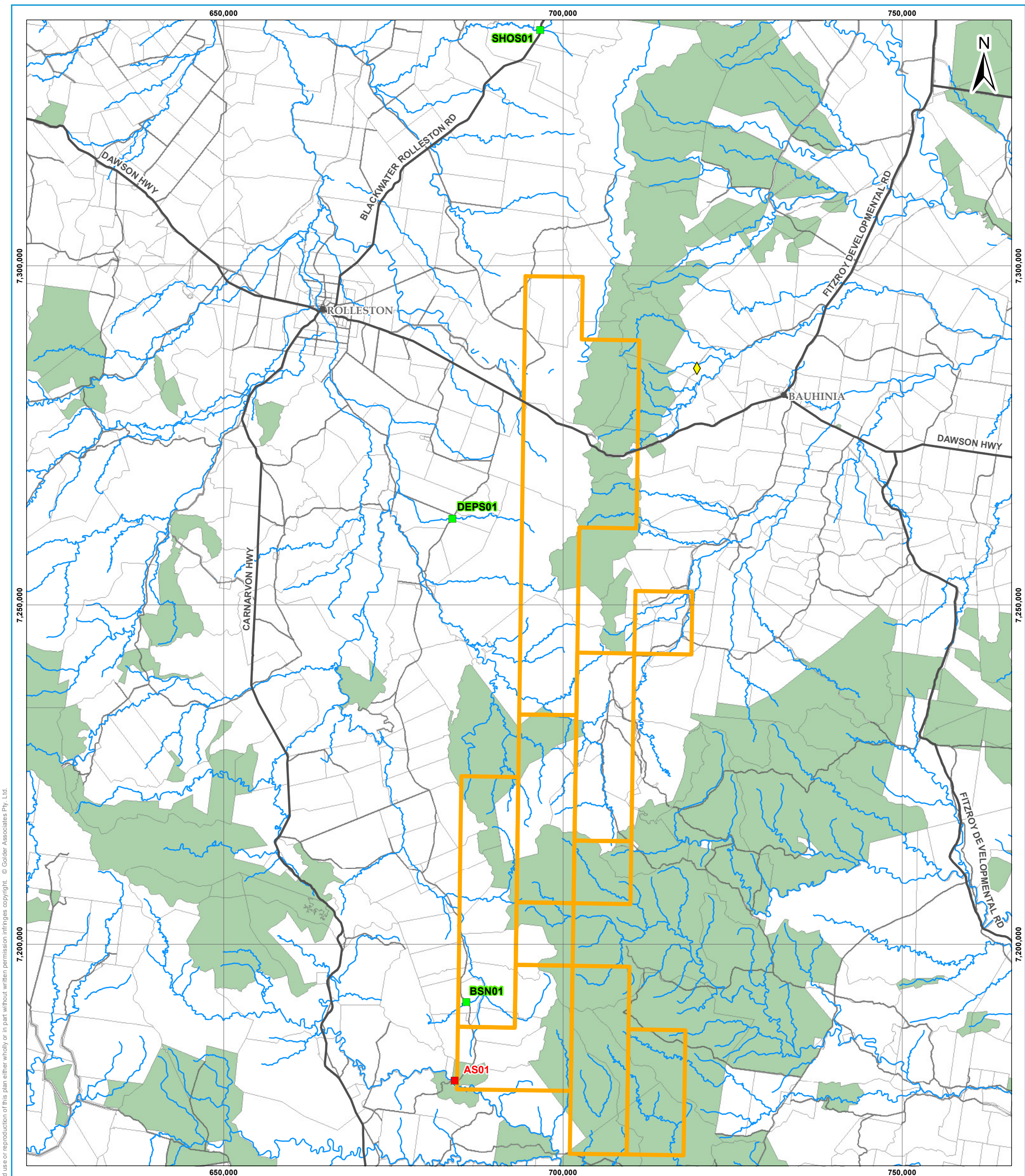
SCALE (at A3) 1:300,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117636002-3100
DATE: MARCH 2013
DRAWN: SL
CHECKED: TB

FIGURE 6-2

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GLNG CSG WMMP - STAGE 2

SANTOS

SURFACE WATER MONITORING - ARCADIA

NOTES

- 1. Base map data copyright MapInfo Australia Pty Ltd.
- 2. ATP/PL tenure supplied by Santos, January 2009.
- 3. Springs sourced from Herbarium dataset provided by Santos.

LEGEND

- Town
- EPBC Listed Spring
- Monitoring Locaiton
 - Santos Ephemeral Surface Water Monitoring Location
- Santos Perennial Surface Water Monitoring Location
 - Midstream
- Creek/River
- Highway / Main Road
- ATP/ PL Field
 - Arcadia Valley - GLNG Project area

0 5 10 15 20 25 km

SCALE (at A3) 1:550,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117636002-3100

DATE: OCTOBER 2013

DRAWN: SL

CHECKED: LB

FIGURE 6-3

Details of the environmental values to be monitored, number of monitoring locations and type of monitoring undertaken is provided in Table 6-2. Response levels for each monitored parameter are presented in the Stage 2 CWMMP Rev 2.

Table 6-2: Overview of surface water monitoring

Environmental Value	Number of monitoring points	Monitoring
Springs	Three spring clusters	Continuous electrical conductivity, pH, water level (when automated); Event based sampling (automated); Semi-annually Field Suite and Surface Water Baseline Suite
	All springs	Spring survey as per UWIR Evaluation of Prevention or Mitigation Options Report (EPMOR) requirements
Ephemeral streams	22 locations	Continuous electrical conductivity and water level (where automated); Event based sampling (where automated); Semi-annually Field Suite and Surface Water Baseline Suite
Perennial streams	44 locations including six upstream and two downstream Fairview CSG field, Two upstream and four downstream of Roma CSG field. The other locations are within the CSG fields.	Continuous electrical conductivity, pH, dissolved oxygen, and water level (where automated); Event based sampling (automated); Semi-annually Field Suite and Surface Water Baseline Suite.
Coal seam water release points	One location downstream (Yebna Crossing)	Monthly surface water baseline suite

6.4 Progress Report 2013 (Oct-Dec)

Ongoing monitoring undertaken as part of the surface water baseline program has included continuous automated flow records, manual and automated water quality sampling, continuous electrical conductivity (EC) and temperature measurement which continued between October 2013 and December 2013. Site descriptions and location references are listed in Table 6-3 and Table 6-4. The surface water data for the period of October 2013 to December 2013 can be supplied upon request.

Table 6-3: Automated surface water gauging stations and period of record

Site No.	Location	Period of record
S2	Upstream of Dawson River Discharge Scheme - Dawson Downstream of confluence with Hutton River	1/04/2009 - Present
S4	Downstream of Dawson River Discharge Scheme - Downstream Dawson River at Yebna Crossing	6/12/2011 – Present
S8	Downstream Baffle Creek U/S confluence of Dawson River	13/05/2009 - Present
S12	Upstream Baffle Creek near Waterview	2/04/2009 - Present
S13	Upstream Dawson River at north lease boundary	2/04/2009 - Present
S14	Hutton Creek Upstream of confluence of Dawson River	18/06/2009 - Present
S15	Upstream Hutton Creek at Springrock Crossing	18/06/2009 - Present
S16	Midstream Hutton Creek (IWS)	9/07/2009 - Present
S17	Downstream Hutton Creek	1/4/2009 – Present
ES1	Fairview plateau	7/3/2009 - Present
ES2	Eastern side of leucaena area, IR4	8/3/2009 - Present
ES3	Eastern side of IR5	18/2/2009 - Present
ES4	Western side of IR5	8/3/2009 - Present
ES5	West of leucaena area, IR4	8/3/2009 - Present
ES6	West of Springwater Plateau, IR6	8/3/2009 - Present
ES7	Eastern side of Springwater plateau, IR6	8/3/2009 - Present
ES8	North East of Springwater plateau, IR6	8/3/2009 - Present
ES9	East of pivot plateau	20/7/2009 - Present
BLCS1	Blyth Creek S1 - Upstream Mount Hope Irrigation	23/11/2011 – Present
BLCS3	Blyth Creek S3 - Downstream Mount Hope Irrigation	18/11/2011 – Present
ES9	East of pivot plateau	20/7/2009 - Present
BLCS1	Blyth Creek S1 - Upstream Mount Hope Irrigation	23/11/2011 – Present
BLCS3	Blyth Creek S3 - Downstream Mount Hope Irrigation	18/11/2011 – Present

Table 6-4: Surface water sampling stations and period of record

Site No.	Location	Period of records
AS01	Midstream Dawson River at Arcadia Valley Road Crossing detailing baseline for Arcadia Valley surface waters.	20/04/2010 – Present
BSNS01	Basin Creek (flows into Arcadia Creek)	01/6/2013 – Present
BMIS01	Barramundi Creek	01/6/2013 – Present
HGPS01	Highland Plains Creek	01/6/2013 – Present
DEPS01	Deep Creek	01/6/2013 – Present
SHOS01	Shotover Creek	01/6/2013 – Present
DFYS01	Drafting Yard Creek	01/6/2013 – Present
BLCS2	Blyth Creek S2 Easter Affected Mount Hope Irrigation	11/12/2011 – Present
I14	Midstream Hutton Creek	3/03/2009 – Present
I16	Midstream Hutton Creek	2/08/2007 – Present
R001	Midstream Bungil Creek at Warrego Hwy (EIS) (S&B Site 5)	17/05/2010 – Present
R002	Upstream Bungil Creek at Burtons Rd	11/04/2011 – Present
R011	Downstream Blyth Creek at Carnarvon Hwy	28/04/2011 – Present
R012	Downstream Bungil Creek at Dunkeld Road (EIS) (S&B Site 8)	18/05/2010 – Present

Site No.	Location	Period of records
R014	Downstream Wallumbilla Creek at Roma Condamine Road (EIS) (S&B Site 16)	18/05/2010 – Present
R019	Upstream Yuleba Creek at Roma Condamine Rd (EIS) (S&B Site 21)	20/05/2010 – Present
R021	Upstream Yuleba Creek at Warrego Hwy (EIS) (S&B Site 22)	20/05/2010 – Present
R025	Midstream Blyth Creek at North Pickanjinie Road	28/04/2011 – Present
RES1	Midstream Bungeworgorai Creek	20/05/2010 – Present
RES10	Downstream Blyth Creek	18/05/2010 – Present
RES13	Upstream Wallumbilla Creek	19/05/2010 – Present
RES15	Downstream Wallumbilla Creek	20/05/2010 – Present
RES17	Midstream Cattle Creek Ephemeral	19/05/2010 – Present
RES4	Upstream Bungil Creek	17/05/2010 – Present
RES6	Downstream Bungil Creek	18/05/2010 – Present
RS11	Midstream Blyth Creek	19/05/2010 – Present
RS12	Upstream Blyth at Apple Tree Creek	19/05/2010 – Present
RS14	Downstream Wallumbilla Creek	19/05/2010 – Present
RS20	Downstream Balonne River	20/05/2010 – Present
RS23	Midstream Bony Creek	18/05/2010 – Present
RS24	Upstream Balonne River (Warkon)	8/07/2010 – Present
RS25	Midstream Blyth Creek	2/11/2010 – Present
RS7	Midstream Bungil Creek	18/05/2010 – Present
S1	Downstream Dawsons Bend (S&B)	11/09/2003 – Present
S10	Dawson River Downstream of confluence with Baffle Creek (S&B)	6/10/2006 – Present
S11	Upstream Hutton Creek	5/10/2006 – Present
S11a	Upstream Hutton Creek in Kevington (S&B)	11/09/2003 – Present
S14a	Dawson River Upstream Hutton Creek outflow (S&B)	23/04/2004 – Present
S2a	Baffle Creek - 50m Downstream FV12 discharge (S&B)	9/09/2003 – Present
S2b	Baffle Creek - 5m Upstream FV12 discharge (S&B)	9/09/2003 – Present
S3	Dawson River Downstream Hutton Creek (S&B)	23/04/2004 – Present
S5	Downstream Utopia Downs (S&B)	25/05/2005 – Present
S6	Midstream Hutton Creek (FV66) (S&B)	19/04/2004 – Present
S6a	Upstream Hutton Creek (Carnarvon Development Road) (S&B)	10/09/2003 – Present
S7	Upstream Baffle Creek (S&B)	9/09/2003 – Present
S9	Upstream Dawson River road crossing #2 (S&B)	9/05/2006 – Present
SC1	Glasby Spring	3/11/2009 – Present
SC2	Grandpas Springs	3/11/2009 – Present
SC3	Junction Spring	3/11/2009 – Present

6.5 Forward Work Plan

Surface water monitoring baseline was completed in Roma and Fairview CSG fields at the end of 2013. Monthly monitoring will continue until the end of 2014 when data analysis to establish threshold values has been completed. Threshold limits are on track to be established in these fields by the end of 2014 and will be made available in the next revision of the CWMMP.

Surface water monitoring locations in Arcadia CSG field were established in 2013 and have therefore not completed the necessary 24 months monitoring to establish threshold values. Santos GLNG has a target for completion of baseline monitoring in the Arcadia CSG field in 2015 allowing for 24 months of monthly surface water monitoring to be completed.

Chapter 7

Brine Management



7.0 Brine Management

7.1 Overview

Brine is defined as the concentrated Reverse Osmosis waste stream (RO concentrate). Once RO concentrate is concentrated above 40,000 mg/L total dissolved solids (TDS), it is then defined by DEHP as 'brine'. For Santos GLNG, the estimated RO concentrate production is expected to peak in 2018 when up to 4.1 ML/day of RO concentrate will be produced across the project. A total RO concentrate volume of approximately 17 GL at an average TDS of 34,000 mg/L is expected over the lifetime of the Santos GLNG project. This volume is based on the conservative assumption that all coal seam water produced is treated using RO. A total salt volume of 570,000 tonnes is expected over the life of the Santos GLNG Project.

Santos GLNG has the following mechanisms currently in place for RO concentrate management:

- **Fairview CSG field:** Santos GLNG currently manages RO concentrate production from its existing reverse osmosis plant by injection into the deep, saline fractured basement rock of the Timbury Hills Formation, in accordance with State Government Environmental Authority (EA) Conditions. Brine containment ponds are also under construction which once completed, will buffer the system and temporarily contain all RO concentrate from the additional reverse osmosis plant currently under construction (until sufficient extra injection capacity is developed).
- **Roma CSG field:** All RO concentrate generated within the Roma CSG field will be temporarily stored in brine containment ponds prior to the commencement of future injection projects or brine crystallisation.
- **Arcadia CSG field:** No RO concentrate will be produced in Arcadia CSG field within the scope of the Santos GLNG Stage 2 CWMMP Rev 2.

As the GLNG CSG fields are further developed and expanded, additional brine management options or up-scaling of current options will be required. Santos GLNG is therefore assessing options for the long-term management of RO concentrate and/or brine.

Santos GLNG is required to develop Brine Management Plans for Fairview, Roma and Arcadia CSG field by December 2014, in accordance with State Government EA Conditions. A commitment was made in the Santos GLNG Stage 2 CWMMP Rev 2 to provide these brine management plans to the DOTE. This chapter provides a progress update on this commitment.

7.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 7-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (brine management) and progress against each commitment.

Table 7-1: Stage 2 CWMMP Rev 2 Commitments – Brine Management

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49.g.x)	Brine Management Plans		
	Provision of Brine Management Plans developed for Arcadia, Roma and Fairview CSG Fields as a State Government requirement within the respective CSG field's Environmental Authorities. These will be provided in the next revision of the CWMMP.	December 2014	In Progress

7.3 Progress Report 2013 (Oct-Dec)

To provide enough brine injection storage capacity for the life of the Fairview CSG field, the current injection scheme will be expanded, by drilling additional wells to utilise existing capacity in the Timbury Hills Formation, as required. Three additional brine injection wells into the Timbury Hills formation are currently under investigation with drilling scheduled for 2014 and online by 2015/2016. Documenting the Fairview brine management plan will commence in Q1 2014.

Two methods of long term brine management are under investigation for the Roma CSG field. The preferred brine management approach is deep well injection and exploration for the presence of a formation suitable for deep well injection is currently being undertaken. Until the feasibility of deep well injection can be proven, Santos GLNG is also investigating solar evaporation, crystallisation and residual salt storage in a purpose-built landfill monocell. Documenting the Roma brine management plan will commence in Q1 2014.

Arcadia CSG field is not estimated to start production until 2017 and therefore there will be no brine to manage during the scope of the Stage 2 CWMMP Rev 2.

7.4 Forward Work Plan

Table 7-2 below provides a summary of the forward work plan against the brine management plan commitment.

Table 7-2: Brine Management Plan Commitments Forward Work Plan

Brine Management Plan	Investigations and Feasibility Studies	Submission to State Government	Submission to DOTE
Fairview CSG field	Ongoing	December 2014	With the next revision of CWMMP (due in 2015)
Roma CSG field	Ongoing	December 2014	With the next revision of CWMMP (due in 2015)
Arcadia CSG field	Ongoing	December 2014	With the next revision of CWMMP (due in 2015)

Chapter 8

Groundwater Management



8.0 Groundwater Monitoring

8.1 Overview

Since 2008, Santos GLNG has implemented a program for regional groundwater monitoring of private bores, dedicated groundwater monitoring bores and vibrating wire piezometers (VWPs). The network extends across all Santos GLNG tenements and across MNES aquifers within Santos GLNG tenements.

Groundwater impact monitoring refers to the measurement, recording and analysis of groundwater pressures and chemistry over time at selected locations. The decline in groundwater pressures or 'potentiometric heads' over time at a point is referred to as 'drawdown'. Monitoring can be used to assess groundwater drawdown and chemistry changes potentially arising from CSG production and in turn, of the potential impacts on MNES within and in the vicinity of Santos GLNG CSG fields.

Further expansion of the Santos GLNG groundwater monitoring program to address commitments is ongoing, however a summary of the current program is provided within this section.

8.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 8-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (groundwater monitoring) and progress against each commitment.

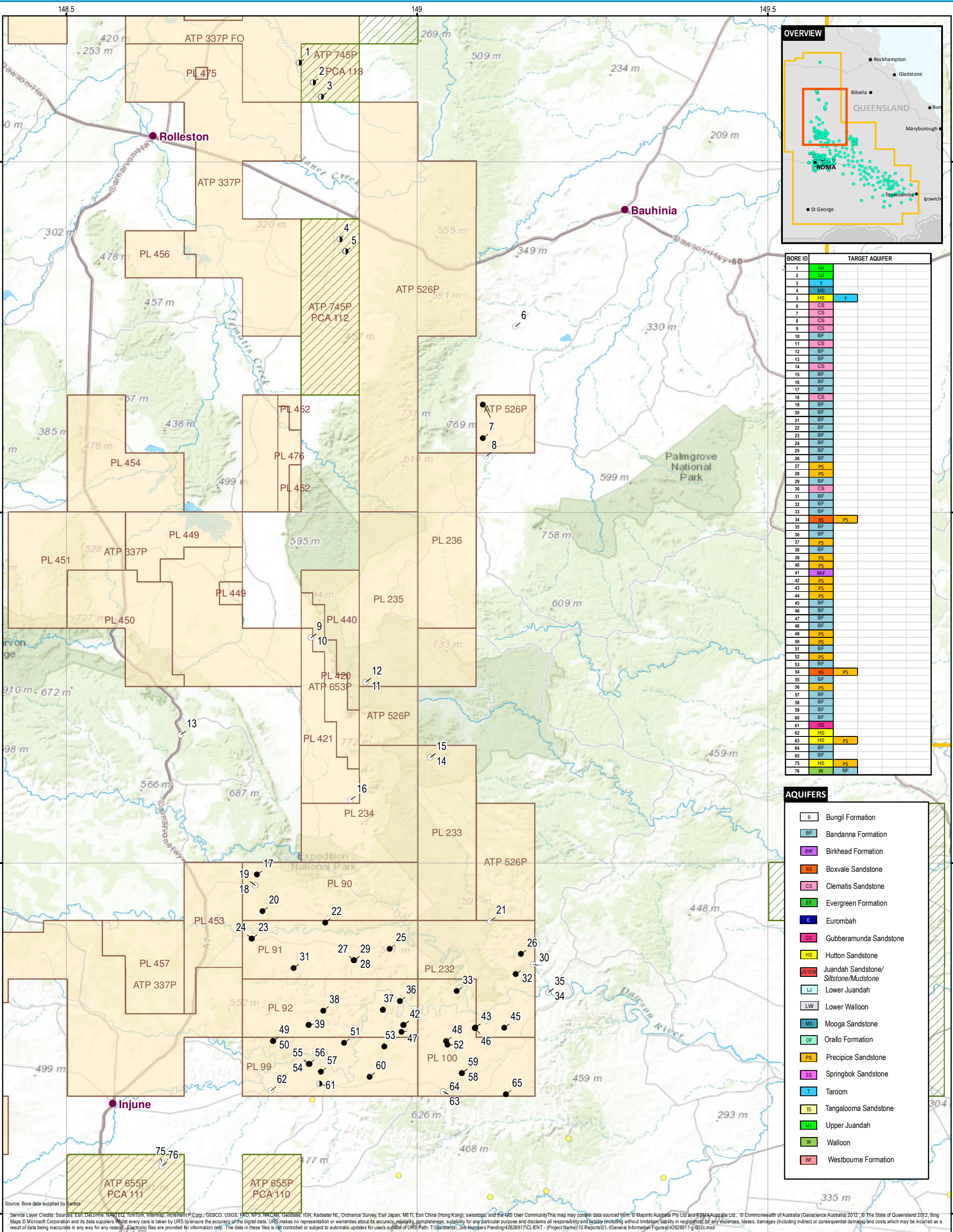
Table 8-1: Stage 2 CWMMP Rev 2 Commitments – Groundwater Monitoring

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
53.c)iv)	Groundwater Baseline		
	Groundwater baseline data collection completion	End of 2014	Ongoing

8.3 Progress Report 2013 (Oct-Dec)

The Santos GLNG groundwater monitoring program commenced in 2008 and currently entails 241 water level monitoring points as summarised in Table 8-2. Monitoring locations are shown geographically on Figure 8-1 and Figure 8-2. The program is continuously refined as new monitoring bores or VWPs are installed.

Four new dedicated groundwater monitoring wells have been drilled since October 2013 (two within the Springbok formation, one within the Gubberamunda Sandstone formation and one within the Hutton Sandstone formation).



GLNG CSG WMMP ANNUAL REPORT 2013

Santos GLNG

ARCADIA & FAIRVIEW GROUNDWATER MONITORING BORES

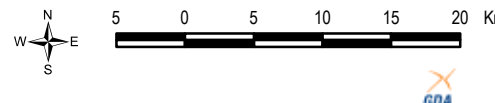
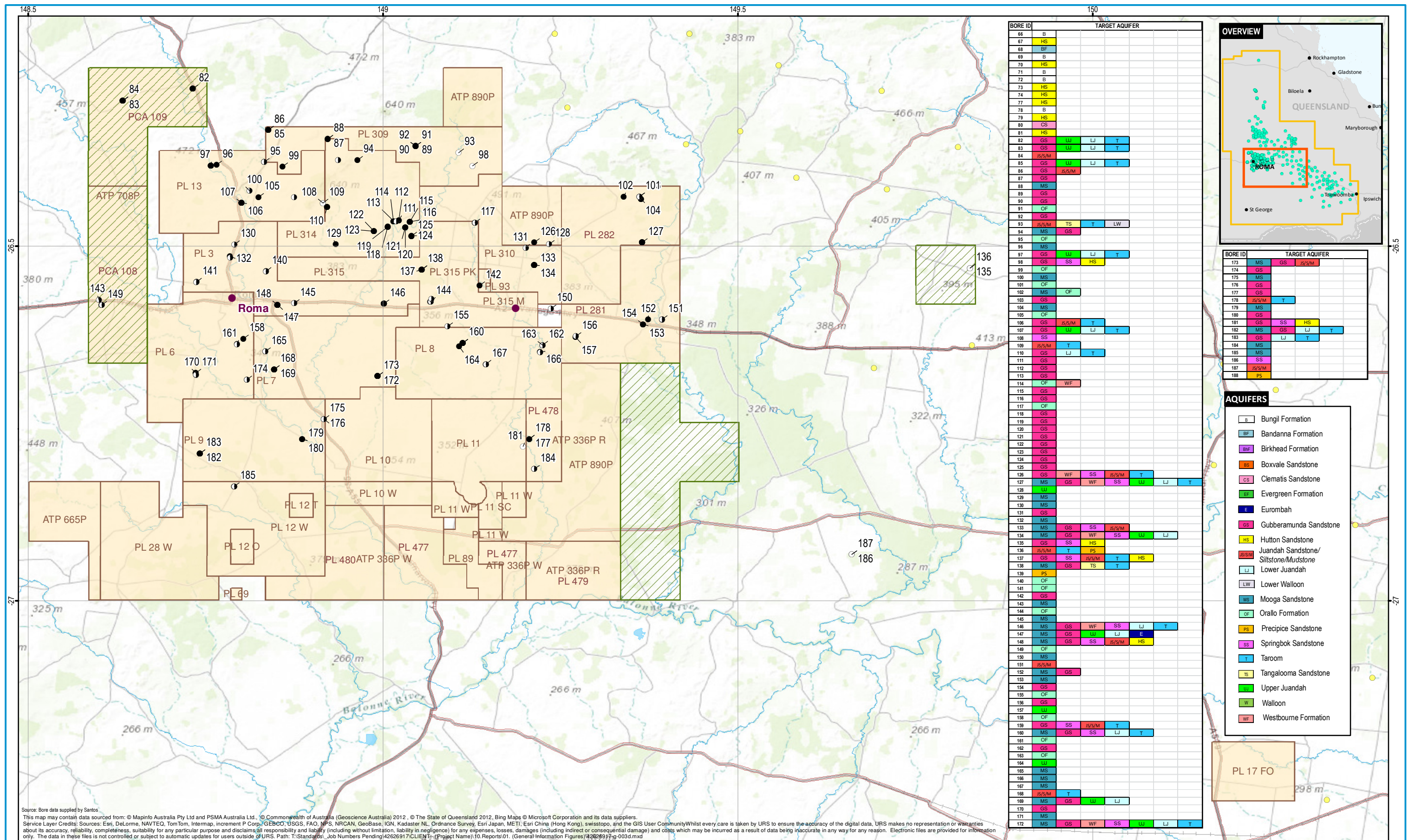


FIGURE 8-1

Santos
GLNG Project



GLNG CSG WMMP ANNUAL REPORT 2013

Santos GLNG

ROMA GROUNDWATER MONITORING BORES

LEGEND

- Towns
- Major Roads
- Waterbody
- Major Drainage
- Santos Tenements
- Santos T2 Development
- National Park
- State Forests
- Surat Cumulative Management Area
- Existing Monitoring Bore
- Proposed Monitoring Bore
- Existing Telemetry Farm Bore
- Water Monitoring Bore
- Railways

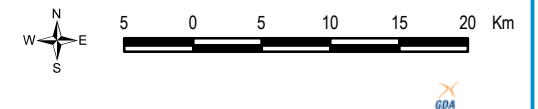


FIGURE 8-2

Santos
GLNG Project

Table 8-2: Summary of Baseline Regional Hydrogeology Monitoring Locations

Formation	Private Bores	Santos GLNG VWP	Santos GLNG GW Monitoring Bores	Total
Bungil Formation	4	-	-	4
Mooga Sandstone	25	13	7	45
Orallo Formation	13	3	8	24
Gubberamunda Sandstone	9	23	25	56
Westbourne Formation	-	10	-	5
Springbok Sandstone	-	6	2	7
Walloon Coal Measures (WCM, targeting various seams)	-	32	-	32
Hutton Sandstone	2	1	2	5
Precipice Sandstone	1	4	9	14
Unknown*	19	-	-	19
Clematis Sandstone	1	-	-	1
Bandanna Formation	-	33	-	33
TOTAL	73	125	48	241

Notes:

Data source: Santos GLNG (as of 28 February 2013)

These numbers are continuously changing as new monitoring bores or VWPs are installed.

- no bores present.

** unknown indicates that the aquifer is to be confirmed through ongoing assessment*

Since 2008, a total of 846 groundwater samples (32 additional samples between October 2013 and December 2013) have been collected in conjunction with the regional bore baseline assessment program and regional groundwater monitoring program, including:

- 619 samples from the Roma CSG field (22 additional samples between October 2013 and December 2013);
- 171 samples from the Fairview CSG field (7 additional samples between October 2013 and December 2013); and
- 56 samples from the Arcadia Valley CSG field (3 additional samples between October 2013 and December 2013).

Data analysis for the regional groundwater baseline monitoring program is due for completion in 2014 and results will be made available to the DOTE upon completion.

The regional bore baseline assessment was required as a condition of the Queensland Water Act 2000 to provide accurate, verifiable and representable groundwater information to understand current bore use(s) and groundwater conditions for each private landowner bores within the Santos GLNG CSG fields. In early 2013, field work for the baseline assessments for 833 bores within and adjacent to Santos GLNG tenements was completed. In December 2013, the final baseline assessment report was submitted to the DEHP and the final dataset was provided to OGIA.

8.4 Groundwater Impact Monitoring

Santos GLNG, in collaboration with the other CSG Proponents (APLNG and QGC), developed a statistical methodology to enable definition of exceedences from the baseline water pressure and water quality levels.

The groundwater impact monitoring methodology aims to:

- Incorporate protocols to confirm that “baseline” has been established using statistical data exploration techniques;
- Provide a method for estimation of and subsequent removal of localized and regional “non-CSG” water pressure and quality changes – such that CSG-related impacts can be clearly identified and the level of statistical certainty of identified CSG-related trends documented; and
- Ensure compliance with Australian and New Zealand Environment and Conservation Council (ANZECC) Water Quality Guidelines for Protection of Fresh and Marine Water Quality (2000) and Queensland Water Quality Guidelines (2009).

Further detail on the framework for statistical analysis of water quality and pressure is included in the Environmental Monitoring and Reporting Strategy (EMRS) provided as an appendix to the Stage 2 CWMMP Rev 2.

Santos GLNG’s schedule for groundwater impact monitoring is presented in Table 8-3.

Table 8-3: Groundwater Impact Monitoring

Environmental Value / MNES	Number of Monitoring Points	Monitoring Details
Regional groundwater	Private bore – 73 locations	Semi-annually for : <ul style="list-style-type: none"> ■ Baseline water quality suite (quarterly initially) ■ Field water quality suite ■ Water level (daily if equipped with logger)
	Dedicated groundwater monitoring bores – 51 locations	Semi-annually for : <ul style="list-style-type: none"> ■ Baseline water quality suite (quarterly initially) ■ Field water quality suite ■ Water level (daily if equipped with logger)
	Multi-levels VWP – 125 locations	Daily for: <ul style="list-style-type: none"> ■ Water level (equipped with a logger)
Hydraulic Fracturing	Wells where hydraulic fracturing is undertaken	Refer to Stimulation Impact Monitoring Program
GAB aquifer supplying EPBC springs	Approximately 16-20, per collaborative scheme	Daily for: <ul style="list-style-type: none"> ■ Water level (equipped with a logger) Quarterly (EWMI) or annually (TMP) for : <ul style="list-style-type: none"> ■ Baseline water quality suite (quarterly initially) ■ Field water quality suite
Irrigation monitoring – GAB aquifers in the proximity to irrigation program	Groundwater bores – 3 telemetered and 11 manually monitored bores	Daily for: <ul style="list-style-type: none"> ■ Flow rates (where possible) ■ Water level ■ Electrical Conductivity Semi-annually for: <ul style="list-style-type: none"> ■ Baseline water quality suite
	Groundwater monitoring bores – 3 locations	Daily for: <ul style="list-style-type: none"> ■ Water level ■ Electrical Conductivity 6 monthly for: <ul style="list-style-type: none"> ■ Baseline water quality suite

8.5 Forward Work Plan

Santos GLNG has implemented a program for the regional groundwater monitoring of private bores, dedicated groundwater monitoring bores and vibrating wire piezometers (VWPs) since 2008. This monitoring program will continue. The groundwater baseline monitoring program has a target completion date of December 2014.

Chapter 9

Subsidence



9.0 Subsidence

9.1 Overview

Pressure reductions in the subsurface due to coal seam water production have the potential to cause subsidence of the ground surface. Santos GLNG is required by EPBC Act Approval Condition 65 to undertake:

- a) baseline and ongoing geodetic monitoring programs to quantify deformation at the land surface within the proponent's tenures. This should link from the tenement scale to the wider region across which groundwater extraction activities are occurring as well as to any relevant regional program of monitoring;
- b) modelling to estimate the potential hydrological implications of the predicted surface and subsurface deformation; and
- c) methods for linking surface and sub-surface deformation arising from CSG activities.

Santos GLNG is using InSAR (interferometric synthetic aperture radar) technology to detect ground movement and deformation across the entire extent of its CSG fields.

Santos GLNG has developed a Subsidence Management Plan which defines the process for identifying a reportable subsidence occurrence. The Subsidence Management Plan was provided as an Appendix to the Santos GLNG Stage 2 CWMMP Rev 2.

9.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 9-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (subsidence) and progress against each commitment.

Table 9-1: Stage 2 CWMMP Rev 2 Commitments - Subsidence

Condition	Commitment	Target Completion Date Specified in the Stage 2 CWMMP Rev 2	Status
53.d.i.III	Subsidence		
	The Subsidence Management Plan provides a response plan into any exceedance of the defined subsidence trigger. The Subsidence Management Plan describes the monitoring undertaken to establish variation of ground level over time.	Completed	Completed
	Subsidence baseline	Completed	Completed
	Monitoring through satellite measurements	Ongoing	Ongoing

9.3 Progress Report 2013 (Oct-Dec) and Findings to Date

An Interim report on the ongoing InSAR monitoring program (monitoring through satellite measurements) was submitted to the DOTE in November 2013 as per the commitment made in the Stage 2 CWMMP Rev 2. A total of 1,493,370 measuring points were monitored over the Santos GLNG tenements. Overall the results show a stability pattern over time for the whole Santos GLNG tenements. No direct correlation between ground deformation and exact locations of the CSG activities is evident and the localised displacements measured over the Santos GLNG CSG fields (accumulated values of up to 20 mm) are likely due to superficial processes in the soil.

9.4 Forward Work Plan

The collection of InSAR images is ongoing. The next report from Altamira is due in July 2017 and will report on five years of ground motion monitoring.

Chapter 10

Reporting



10.0 Reporting

10.1 Overview

Santos GLNG is focused on achieving continual improvement in environmental performance and acknowledges that regular reporting is critical to this process. Santos GLNG has committed to the implementation of a series of reporting throughout the project.

This section will outline the reporting commitments made in the Stage 2 CWMMP Rev 2 and report on progress against each item.

10.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 10-1 provides an outline of Santos GLNG's commitments presented in the Stage 2 CWMMP Rev 2, specific to this section (reporting) and progress against each commitment.

Table 10-1: Stage 2 CWMMP Rev 2 Commitments - Reporting

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49i, 53c)(ix)	Reporting		
	A Coal Seam Water Monitoring and Management Annual Report will be developed for each calendar year and submitted to the Department of the Environment within the first quarter of the following year.	31 March 2014	Complete
	Digital data can be provided to the Department of the Environment on request	Ongoing	Ongoing
	Santos GLNG will publish the following reports on the internet (via the Santos Water Portal): <ul style="list-style-type: none"> Coal Seam Water Monitoring and Management Annual Report Link to the latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) 	31 March 2014	Complete
	Santos GLNG will regularly publish data from all aspects of the water monitoring network on the Santos Water Portal	Ongoing	Ongoing (last updated November 2013. Q4 2013 update in progress)
55	The next revision of the CWMMP is currently planned to be submitted to the DOTE 3 months prior to the first LNG cargo	3 months prior to first LNG cargo in 2015.	In progress

10.3 Progress Report 2013 (Oct-Dec)

10.3.1 CWMMP Annual Report

The first Annual Report (this document) was submitted to the DOTE by 31 March 2014. The 2013 Annual Report includes progress updates from October 2013 to December 2013 which incorporates the 2013 period since submission of Stage 2 CWMMP Rev 2. It will be made available on the Santos Water Portal as required by Condition 49 and 53.

10.3.2 Digital Data Requests

No digital data was requested by the DOTE during this reporting period.

10.3.3 Santos Water Portal

The latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) was released in November 2012 and was made available on the Santos Water Portal at that time. The Santos Water Portal will be updated with the latest revisions of each report as they become available.

Updates to water monitoring network and data were published on the Santos Water Portal and includes new groundwater baseline bores as well as updated water level and water quality results for a range of groundwater bores and surface water sites. These were most recently updated in November 2013. In 2013, the Santos Water Portal underwent enhancement to allow key climate data captured throughout the Santos GLNG project area to be available on the site. This data gives context to results available on the Santos Water Portal which can be directly affected by climatic conditions.

The Santos Water Portal can be accessed via <http://www.santoswaterportal.com.au/>.

10.3.4 Revised CWMMP

The next revision of the CWMMP is due for submission to the DOTE 3 months prior to first LNG cargo, scheduled for 2015.

10.4 Forward Work Plan

The forward work plan to meet reporting commitments is outlined below:

- Provision of digital data to the DOTE upon request;
- Updates to water monitoring network and data on the Santos Water Portal on a regular basis with Q4 2013 data being uploaded in February 2014. The next update for Q1 2014 will be uploaded in April 2014;
- Commence update to the CWMMP to incorporate water management and monitoring plans beyond first LNG cargo; and
- Commence work on the Annual Report 2014 covering January 2014 to December 2014.

Chapter 11

References



11.0 References

Altamira, October 2013, *InSAR ground displacement monitoring on the Surat Basin*.

Department of the Environment, 2013, *Letter of Approval of Stage 2 CSG Water Management and Monitoring Plan - Reference: MS13-000959*.

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Queensland Water Commission, 2012, *Underground Water Impact Report for the Surat Cumulative Management Area*.

Santos GLNG, 2013, *Joint Industry Plan for an Early Warning System for the Monitoring and Protection of EPBC Springs*.

Santos GLNG, 2013, *Stage 2 Revision 2 CSG Water Management and Monitoring Plan*.

Santos GLNG, 2013, *EPBC Spring Hydrogeological Conceptual Model, Submitted to the Department of the Environment*.

Appendix A

Summary of Commitments



Appendix A – Summary of Stage 2 CWMMP Rev 2 Commitments and Progress Update

Table A Stage 2 CWMMP Rev 2 Commitments & Progress Update

● Commitment Complete; ▶ Commitment In Progress; ◆ Continuous Commitment				
Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49a, 49d,53c.vi	Groundwater Drawdown			
	Drawdown limits are now defined for the source aquifer at selected locations. These limits are subject to periodic updates.	Completed	●	Section 2
	Installation of Early Warning Spring (EWS) monitoring network	End 2016	▶	Section 2
	Ground truthing of a selection of springs to assess the presence of EPBC listed species and EPBC communities	Completed – to be reported April 2015	●	Section 2
	Santos GLNG will assume responsibility of mitigation (if required) for on-tenement springs and those off-tenement springs as will be assigned by the Surat Underground Water Impact Report (UWIR)/DOTE.	Ongoing	◆	Section 2
	Comparison of drawdown to UWIR predictions will occur on a quarterly basis. This methodology has evolved since the Stage 2 CWMMP – once groundwater level reference values are defined, Santos is assessing the feasibility of programing a system of alerts in the database. Until then, three monthly data checks will be completed.	Quarterly once groundwater baseline is completed and reference value is defined.	▶	Section 2

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49b, 53b, 53d(i)4	Aquifer Connectivity			
	Santos GLNG commits to provide further characterisation on the level of connectivity between the formations, including undertaking the following upcoming and ongoing hydraulic connectivity programs. Note that the results will be presented in future updates to the CWMMP.			
	Multi-level monitoring bores	Further installation in 2014, ongoing data collection	►	Section 3
	Contact Zone Program	In progress. Significant review due to geology update. Program delay due to establishing land access agreements for new monitoring locations (Section 3.4).	►	Section 3
	Wallumbilla Fault Program	In progress. Significant review due to geology update. Program delay due to establishing land access agreements for new monitoring locations (Section 3.4).	►	Section 3
	Aquifer Response	In progress. Several studies underway.	►	Section 3
	Isotope and geochemical signature	Aquifer geochemical signature to be updated in 2014	►	Section 3
	Pumping response observations and assessments	Annually from 2014	◆	Section 3
	The outcomes of the conventional oil and gas well and water bore risk assessment will be presented in the next revision of the CWMMP.	2014	►	Section 3

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49c, 53a, 53d)ii	Aquifer Re-injection			
	Santos GLNG has developed a Managed Aquifer Recharge (MAR) piloting program and schedule for CSG field piloting of aquifer reinjection:			
	Fairview CSG Field Stage 1– Desktop Study	Completed March 2012	●	Section 4
	Roma CSG Field Stage 1– Desktop Study	Completed in January 2011	●	Section 4
	Roma CSG Field Stage 2 – Investigations and Assessment	Completed in January 2011	●	Section 4
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning	Completed in Q1/Q2 2012	●	Section 4
	Roma CSG Field pilot trial (Hermitage) Stage 4 – Operation	Completed Q4 2012	●	Section 4
	Roma CSG Field (The Bend) Stage 3 – Construction and Commissioning	Due for completion Q3 2014	►	Section 4
	Roma CSG Field (The Bend) Stage 4 – Operation	Due to commence Q3/Q4 2014	►	Section 4
	Arcadia CSG Field Stage 1 – Desktop Study	Completed in September 2013	●	Section 4
	All approved Injection Management Plans will be provided in the next revision of the CWMMP.	Ongoing	◆	Section 4

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49e	<p>Hydraulic Fracturing</p> <p>As part of respective Annual Report requirements to both the State and Federal Governments, Santos GLNG will provide a projection of the anticipated number of wells to be hydraulically stimulated during each year (up to and including 2015) as well as the number of hydraulic stimulations completed in the preceding year. Additional details to be reported will also include location information and the depth of each respective hydraulic stimulation.</p>	Annually, submitted within the first quarter of each year (i.e. the 2013 annual report will be submitted to the DOTE in Q1 2014), together with updated plan of future hydraulic fracturing.	◆	Section 5
49f	<p>Santos GLNG has agreed with the DOTE to undertake additional Direct Toxicity Assessment that will include:</p> <ul style="list-style-type: none"> • an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with fracking chemicals, and (iii) fracking chemicals in freshwater; • assessing the toxicity of individual fracking chemicals of concern; and • assessing contribution of fracking chemicals to toxicity of fracking fluids and flowback waters (mixture toxicity). <p>Santos is committed to undertaking these assessments, as part of the joint industry Ecotoxicity Work Program; the result of which will be provided to the DOTE upon completion.</p>	December 2013 – Assessments in progress	►	Section 5

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49.g.iv)	Surface Water Baseline			
	Ongoing collection of surface water baseline data	End of 2013. Completed for Fairview and Roma. Arcadia to be complete by mid 2015.	►	Section 6
	EPBC spring hydrogeological conceptual model	Existing models submitted November 2013. Remaining models to be submitted by April 2015 following completion of Spring baseline	►	Section 2
	Atmospheric pressure monitoring – 1 installation (barrologger or other) at each EPBC spring complex or cluster of spring complexes	Completed for on-tenement springs, by end 2014 for Elgin 2	►	Section 2
49.g.vi)	Surface Water Threshold Values			
	Collection and reviewing 2 years of baseline data and development of upper and lower confidence levels (Threshold values) for key parameters (relevant to MNES). These threshold values will be provided in the next revision of the CWMMP.	End of 2014	►	Section 6
49.g.x)	Brine Management Plans			
	Provision of Brine Management Plans developed for Arcadia Valley, Roma and Fairview CSG Fields as a State Government requirement within the respective CSG field's Environmental Authorities. These will be provided in the next revision of the CWMMP.	December 2014	►	Section 7

● **Commitment Complete;** ► **Commitment In Progress;** ◆ **Continuous Commitment**

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
49i, 53c)ix)	Reporting			
	A Coal Seam Water Monitoring and Management Annual Report will be developed for each calendar year and submitted to the DOTE within the first quarter of the following year.	31 March 2014 and Annually thereafter.	◆	Section 10
	Digital data can be provided to the DOTE on request	Ongoing	◆	Section 10
	Santos GLNG will publish the following reports on the internet (via the Santos Water Portal): <ul style="list-style-type: none"> ▪ Coal Seam Water Monitoring and Management Annual Report ▪ Link to the latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) 	31 March 2014	●	Section 10
	Santos GLNG will regularly publish data from all aspects of the water monitoring network on the Santos Water Portal	Ongoing (last updated November 2013. Q4 2013 update in progress)	◆	Section 10
55	The next revision of the CWMMP is currently planned to be submitted to the DOTE 3 months prior to first LNG cargo	3 months prior to first LNG cargo in 2015.	►	Section 10

● Commitment Complete; ► Commitment In Progress; ◆ Continuous Commitment

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status	Annual Report Reference
53.c)iv)	Groundwater Baseline			
	Groundwater baseline data collection completion	End of 2014	►	Section 8
	Santos GLNG, in collaboration with the other Proponents (APLNG and QGC), will by the end of 2013 develop a statistical methodology to enable definition of significant exceedences from the baseline water pressure and water quality levels. The establishment of this methodology can only reasonably be commenced once the three Projects all have sufficient confirmation of their EPBC conditions being met by the respective CWMMPs.	Completed. The JIP provides a statistical methodology for groundwater level trend analysis.	●	Section 2
53.d.i.III	Subsidence			
	The Subsidence Management Plan provides a response plan into any exceedance of the defined subsidence trigger. The Subsidence Management Plan describes the monitoring undertaken to establish variation of ground level over time.	Completed	●	Section 9
	Subsidence baseline	Completed	●	Section 9
	Monitoring through satellite measurements	Ongoing	◆	Section 9

Appendix B

Roma MAR Project Injection Management Plan



Roma MAR Project Injection Management Plan

Document Number 3301-GLNG-4-1.3-0042


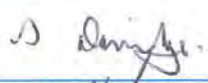
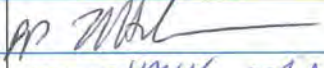
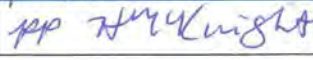
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1 Introduction

This Injection Management Plan (IMP) is intended for The Roma HCS-02 Managed Aquifer Recharge Scheme (Roma MAR Project) near Roma, Queensland.

1.1 Purpose

This IMP is submitted to Department of Environment and Heritage Protection (DEHP) in support of Santos GLNG's application to amend Environmental Authority (EA) conditions and allow for the injection of up to 24 ML/d of treated coal seam gas water into the Gubberamunda Sandstone aquifer for up to 20 years in accordance with proposed conditions.

This IMP adopts a risk management framework consistent with the National Water Quality Management Strategy, Australian Guidelines for Water Recycling Managing Health and Environmental Risks (Phase 2), Managed Aquifer Recharge (2009).

1.2 Background

1.2.1 Beneficial Use of CSG Groundwater

Santos' GLNG Project is being developed to convert coal seam natural gas (CSG) to liquefied natural gas (LNG). The GLNG Project will transfer compressed CSG from the Surat and Bowen geological basins in south-western Queensland to an LNG plant located on Curtis Island near Gladstone Harbour in Queensland.

The CSG process involves the extraction of coal seam water (referred to as "CSG water") from the formation in order to reduce the water pressure and release gas from the coal. During the life of CSG production, the GLNG project will produce significant quantities of CSG water. The CSG water that is produced must be managed in a sustainable manner and in accordance with conditions that are legislated by the relevant EA, issued by DEHP.

Amendments to the Water Supply (Safety and Reliability) Act 2008 in December 2010 established purpose-built and rigorous requirements for CSG water management. The purpose of the amendments is to protect public health where CSG water may have an impact on an urban community's drinking water supply source. In 2012, the DEHP released their Coal Seam Gas Water Management Policy (DEHP, 2012). The objective of the policy is to be achieved by managing CSG water in accordance with the following two priorities:

Priority 1 – CSG water is used for a purpose that is beneficial to one or more of the following: the environment, existing or new water users, and existing or new water-dependent industries.

Priority 2 – After feasible beneficial use options have been considered, treating and disposing of CSG water in a way that firstly avoids, and then minimises and mitigates impacts on environmental values.

Consistent with Priority 1 of the CSG Water Management Policy (DEHP, 2012) a number of potential beneficial uses have been identified for the re-use of CSG water that include:

- Dust suppression;

- Rehabilitation and environmental use;
- Supply to local landholders for irrigation and feedlots;
- Municipal and industrial use (including river transport of treated water to customers); and
- Managed Aquifer Recharge (MAR).

Additional treatment of CSG water is typically required for it to be deemed suitable for the beneficial uses identified above (URS, 2011).

1.2.2 Roma MAR Project

MAR is the purposeful recharge of water (in this case treated CSG water) to aquifers for subsequent recovery or environmental benefit. Santos is proposing to implement a MAR scheme at the location of The Roma HCS-02 site (The Roma MAR Project), located on The Bend property within the Roma CSG field of The Santos GLNG Project. A site location plan is presented Figure 1.

For the Roma MAR Project, CSG water will be treated using reverse osmosis (RO) prior to injection into the Gubberamunda Sandstone aquifer. The target aquifer is used locally for stock and domestic supplies and also as a source aquifer for the town water supply (TWS) for Roma, located approximately 28 km to the south west of The Roma MAR site.

Groundwater levels within the Gubberamunda Sandstone aquifer around the town of Roma have been steadily declining in response to sustained groundwater extraction for the TWS over the last 50 years. The Roma MAR Project has the potential to provide environmental benefit as it may partially and locally offset the long term decline in groundwater levels that have been observed more regionally in the Gubberamunda Sandstone aquifer.

Other than what may be required for periodic rehabilitation of the injection bores to maintain operational performance, no significant extraction of injected water is proposed as part of the Roma MAR Project.

In addition to supplying treated CSG for the purpose of MAR, the RO plant located at the Roma HCS-02 site will also be used to supply treated CSG water for the purpose of irrigation and dust suppression. The details of the operation of the irrigation scheme are beyond the scope of this document.

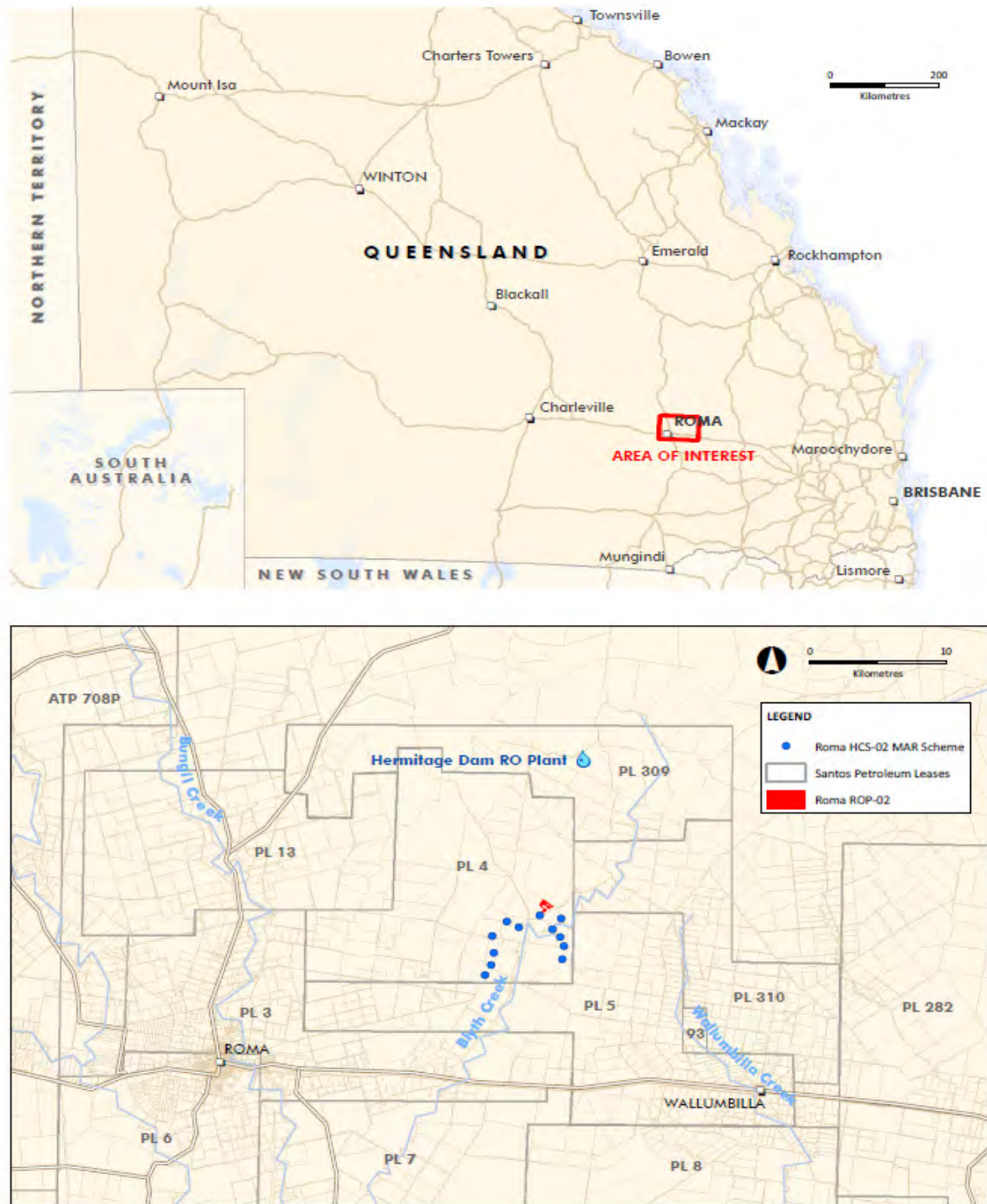


Figure 1 | Site Location Plan – Roma HCS-02 MAR Scheme

March, 2013 | P1(SAR)_Santos/Projects_1231_12-SAR_Roma_MAR_Review/GIS/Maps/SAR_1231 - site locality.mxd

Figure 1: Roma MAR Project – Site location plan

1.2.2.1 Current Status of the Roma MAR Project

Approval is being sought to inject up to 24 ML/d into up to twelve injection bores. Currently, however, only six injection bores have been constructed. These are bores labelled as TBDIG01, TBDIG02, TBDIG03, TBDIG04, PASIG05 and PASIG07. Injection in these bores is expected to be operational as early as June 2014, pending environmental approval to do so.

Injection bore locations CWRIG08, TBDIG09, RTRIG11, PASIG12, CWRIG13 and CWRIG14 are additional injection bore locations that are considered as potential locations for future injection bores. Land access and compensation agreements are currently being negotiated for these bores that have not yet been constructed. However these injection bores may not be required if the actual volume of water available for injection remains low (<15 ML/d) and the injection efficiency of the currently constructed injection bores remains adequate. Therefore these additional injection locations may, in time, be considered redundant. Injection of fluid into these six additionally proposed bores will not commence until all relevant construction details are provided to the regulator, and permission by the regulator is subsequently granted for their use to inject fluid into the subsurface.

1.2.2.2 Scheme Trial

To investigate the implementation of the MAR of treated CSG water into the Gubberamunda Sandstone aquifer, Santos implemented a MAR injection trial at site approximately 4 km north of The Roma MAR site at the location of its Hermitage Dam RO plant (herein referred to as the Hermitage MAR Trial). The Hermitage MAR Trial is referenced throughout this document. The location of the trial is shown in Figure 3.

It should be noted that the Hermitage site will not be used for longer-term MAR and no further approvals are sought for injection at this location. The RO plant at the Hermitage Dam site is to supply water for irrigation purposes only.



Figure 2: Roma HCS-02 MAR bore field layout

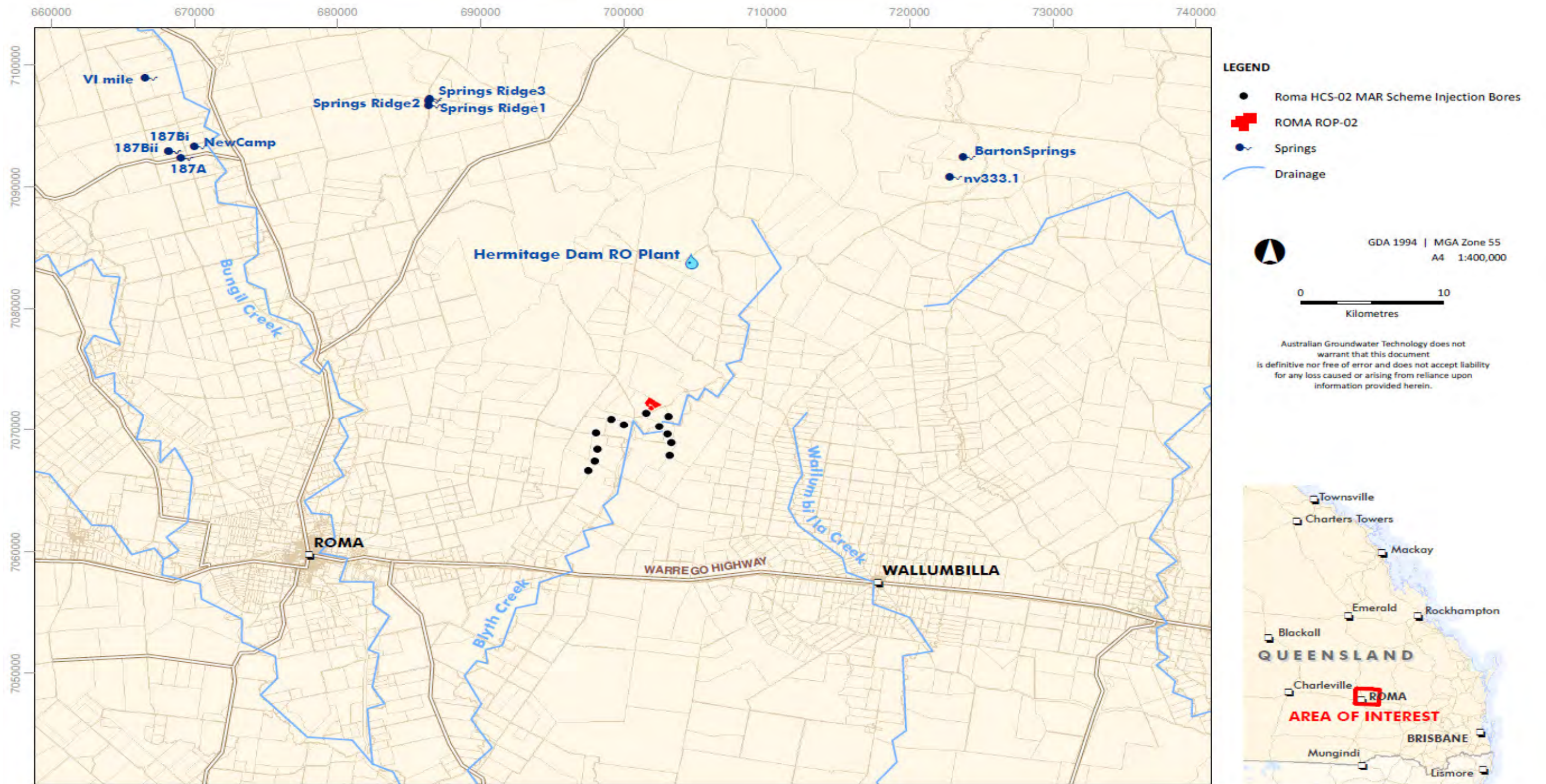


Figure 3: Hermitage MAR Trial Location

1.3 EA Permitting Conditions

This IMP has been prepared to satisfy Roma Shallow Gas Project Area Fluid Injection Conditions, Schedule BE. A copy of the draft EA conditions is presented as Appendix A.

The conditions required to be addressed, and the location of the corresponding information intended to satisfy the condition, are presented in Table 1-1.

Table 1-1: EA IMP requirements

EA IMP Requirements		Corresponding Information Section
a)	Estimated volumes and rates of water to be produced and injected	Section 3.1
b)	A description of the physical, chemical and biological components and their concentrations of the water to be produced	Section 3.4
c)	Details of how and where the fluid will be produced, aggregated, stored and kept separate from other waters until it is, treated and reinjected into the source aquifer	Section 3.2
d)	Details of where the fluid is proposed to be treated including a description of the treatment process	Section 3.3
e)	A demonstration that the injection fluid has inconsequential reactivity with the target formation and native groundwater it will come into contact with	Section 4.3
f)	The characteristics of the receiving environment	Section 2
g)	Identification of the water quality impact zone and the hydraulic impact zone	Section 4.2 and 4.3
h)	Identification of all existing bores, springs, lakes, wetlands, environmental assets and water courses connected to groundwater, faults and other geologic features that occur within the water quality impact zone and the hydraulic impact zone	Section 2.4.5 Section 4.2 and 4.3
i)	Identification of proposed fluid injection wells	Section 3.5
j)	Identification of the environmental values and water quality objectives of the potential water quality impact zone of the target formation in accordance with the Environmental Protection Act 1994, Environmental Protection Regulations 2008, Environmental Protection (Water) Policy 1997 and the Queensland Water Quality Guidelines 2006.	Section 4.4 and Section 4.5
k)	An assessment of the potential impacts on the environmental values of the receiving environment including migration of injection fluid or native groundwater out of the target formation through wells, bores, springs, connected water courses, faults or other geologic features likely to impact on the other aquifers	Section 4.5

EA IMP Requirements		Corresponding Information Section
l)	A risk assessment consistent with the risk framework specified in Australian Guidelines for Water Recycling: Managed Aquifer Recharge, identifying potential hazards, their inherent risk, preventative measures for the management of potential hazards and after consideration of the operational monitoring to manage potential hazards identified in the risk assessment including details on sampling and analysis methods including frequency and locations, and quality assurance and control	Section 5 Appendix A
m)	Verification methods to assess performance of the injection activities	Section 5.2
n)	Control measures that will be implemented for fluid storage, treatment and injection to prevent or control the release of a contaminant or waste to the environment	Section 3
o)	The indicators or other criteria against which the performance of fluid injection will be assessed	Section 5
p)	Procedures that will be adopted to regularly review the monitoring program and to report to management and the administering authority should unforeseen or noncompliant monitoring results be recorded	Section 5.3 and 5.4
q)	Procedures that will be implemented to prevent unauthorised environmental harm from unforeseen or non-compliant monitoring results	Section 5.2
r)	Procedures for dealing with accidents, spills, failure of containment structure, and other incidents that may arise in the course of fluid injection	Section 3.2 and 3.3
s)	A program to monitor impacts on the environmental values of the receiving environment identified by Condition (BE 7)	Section 5.2
t)	Appropriate records and documents which support and indicate mechanical integrity and which hold a certificate of mechanical integrity prepared and certified by a suitably qualified person, available for inspection such that: <ul style="list-style-type: none"> i. there is no significant leakage in the casing, tubing, or packer; and ii. there is no significant fluid movement into a water resource aquifer through vertical channels adjacent to the well bore hole. 	Appendix D
u)	Demonstrate that: <ul style="list-style-type: none"> i. injection must only occur through injection tubing. ii. the dry overburden pressure of the base of the overlying aquitard for injection at depth less than 100m; or iii. 90% of the formation fracture pressure for injection at depth greater than 100m. 	Section 3.5

2 Hydrogeology

This section presents the environmental setting of the MAR borefield which addresses parts f h and j of the EA IMP requirements.

EA IMP Requirements		Corresponding Information Section
f)	The characteristics of the receiving environment	Section 2
h)	Identification of all existing bores, springs, lakes, wetlands, environmental assets and water courses connected to groundwater, faults and other geologic features that occur within the water quality impact zone and the hydraulic impact zone	Section 2.4.5
j)	Identification of the environmental values and water quality objectives of the potential water quality impact zone of the target formation in accordance with the Environmental Protection Act 1994, Environmental Protection Regulations 2008, Environmental Protection (Water) Policy 1997 and the Queensland Water Quality Guidelines 2006.	Section 4.4 and Section 4.5

2.1 Environmental Setting

The Roma MAR Project is located on the eastern margin of the Great Artesian Basin (GAB) approximately 20 km north-east of Roma, Queensland (refer to Figure 1). The GAB encompasses three major depressions, the Carpentaria, Eromanga and Surat Basins with The Roma MAR Project located in the northern part of the Surat Basin.

The Roma MAR Project is located within the Santos Roma lease area (PL4) which covers approximately 255 km² and is predominantly used for cattle grazing or farming.

2.2 Climate

Climate information was historically collected from the Roma Post Office (Station No. 043030) from 1870 until the station was closed in 1992. Roma airport (Station No. 043091) installed a weather measurement station in 1985 and is currently active. Mean annual rainfall is calculated to be approximately 600 mm as calculated from both data sets. Rainfall is dominant in the summer months (refer to Figure 4). Evaporation is reported to be 2,100 mm per year (URS, 2011).

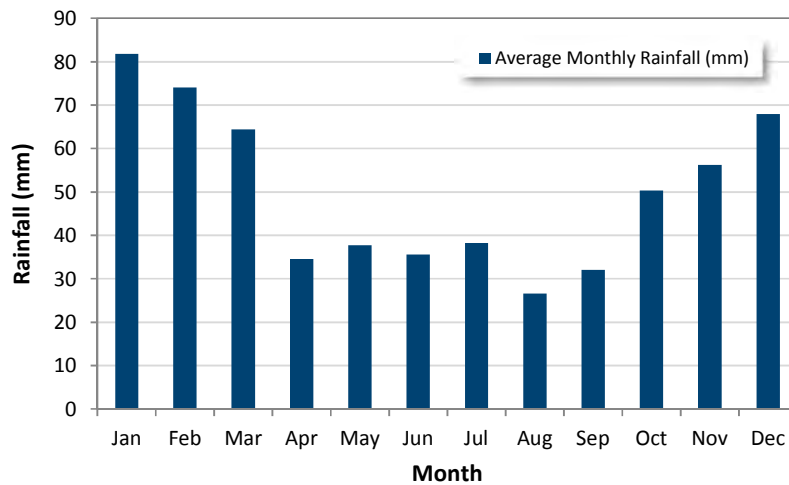


Figure 4: Average monthly rainfall recorded at Roma post office (Station No. 043030) and Roma airport (Station No. 043091)

2.3 Surface Hydrology

The Roma MAR Project area is located adjacent to the Blyth Creek which flows in a south-westerly direction along with the Bungil Creek which runs through the township of Roma to the west and Wallumbilla Creek which runs through the town of Wallumbilla to the east which all drain to the Balonne River in the south.

Springs associated with the GAB were not identified within the Roma lease area (Golder, 2009 as reported by URS, 2011). Four springs (refer to Figure 3) are located to the north of the lease area, VI Mile (44.5 km from site), New Camp (38 km from site), Spring Ridge (30 km from site) and Barton Springs (30.7 km from site) (DEHP Database accessed January 2013). The springs are located within the Gubberamunda Sandstone outcrop and are considered to be in hydrogeological connection with the Gubberamunda Sandstone aquifer system.

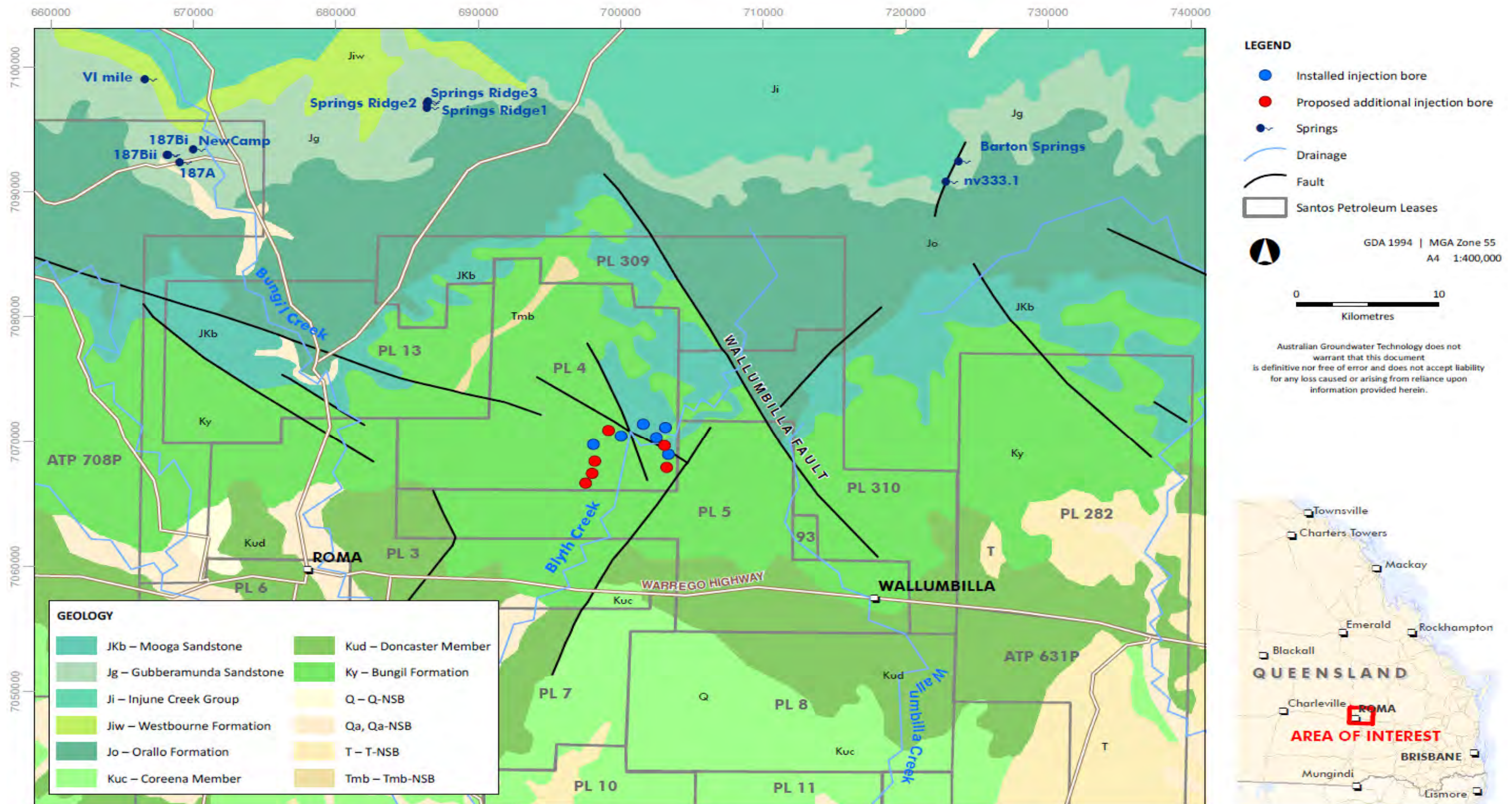


Figure 5: Santos Roma lease area and geological features

2.4 Hydrogeological Setting

2.4.1 Geology

The Roma MAR Project is located within the Surat Basin, part of the GAB. There is over 1,000 m of Mesozoic sedimentary rock underlying the project area which contains various alternating aquifers and aquitards. Water supplies are predominantly extracted from the shallowest potable aquifers of the Mooga Sandstone and the Gubberamunda Sandstone.

The geology of the Mesozoic sequence, summarised by URS from Exon (1971) and AWRC (1975) is presented in Table 2-1 and subsurface lithology observed in TBDIG01 presented in Table 2-2. A geological cross-section of the Surat Basin is presented as Figure 6.

Geological features are presented as Figure 5. The Wallumbilla Fault is located to the north-east of The Roma MAR site. Additional faulting features are documented in the vicinity of the MAR site and the immediate surrounds.

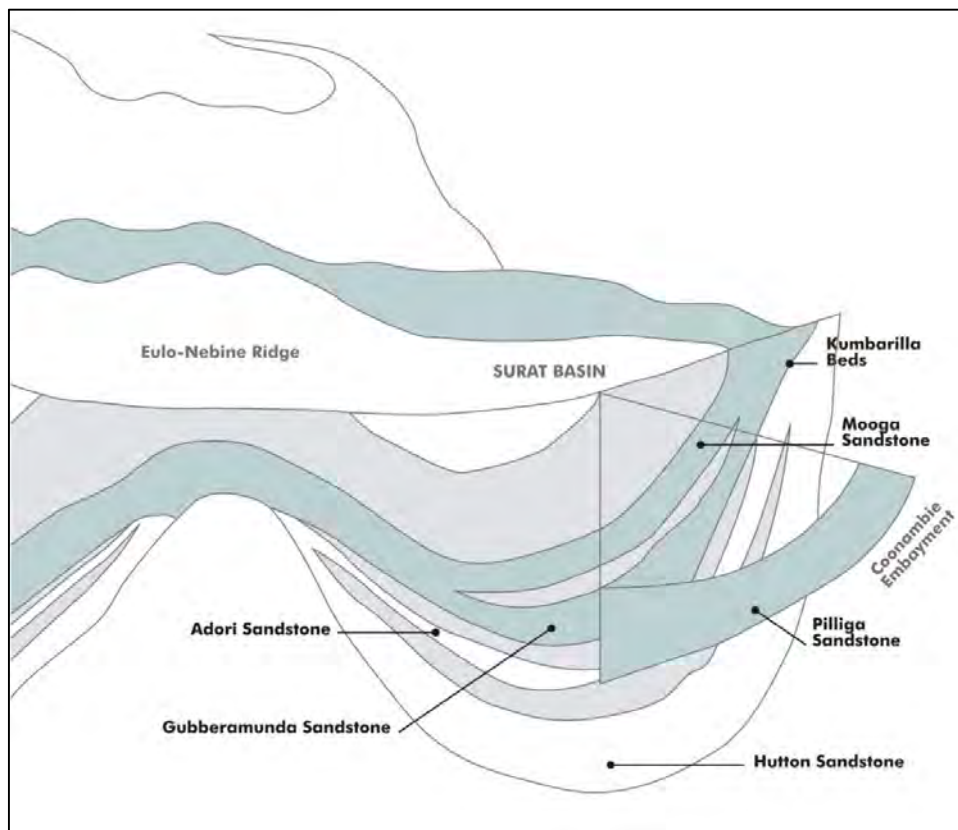


Figure 6: Surat Basin geological cross section (after Habermehl & Lau, 1997)

Table 2-1: Geology and hydrogeology within the project area (URS, 2013)

Unit	Age	Description	Observed Formation Thickness (m)		Literature Average Thickness (m)	Aquifer/Aquitard
Bungil Formation	Lower Cretaceous	Quartzose sandstone, siltstone mudstone. Carbonaceous in part.	0	0	80–230	Minor Aquifer
Mooga Sandstone	Lower Cretaceous	Well-bedded to cross-bedded quartzose sandstone, in part clayey, calcareous, pebbly; mudstone; conglomerate at base.	>20	60	25–200	Aquifer
Orallo Formation	Upper Jurassic	Very fine to medium grained, cross-bedded, lithic sandstone calcareous or clayey; siltstone and mudstone, carbonaceous in part; clay, some bentonite; minor coal.	162	167	70–270	Aquitard
Gubberamunda Sandstone	Upper Jurassic	Quartzose to clayey lithic medium grained sandstone, some conglomerate, siltstone.	43	46	20–260	Major Aquifer
Westbourne Formation	Upper Jurassic	Grey carbonaceous micaceous siltstone grading to mudstone, very fine quartzose to sublabile sandstone.	–	–	60–200	Aquitard
Springbok Sandstone	Jurassic	Fine to coarse labile sandstone, in part calcareous; siltstone mudstone; minor coal.	–	–	–	Minor Aquifer
Walloon Coal Measures	Jurassic	Thin-bedded, claystone, shale, siltstone, lithic and sublithic arenites, coal seams and partings.	–	–	100–460	

Table 2-2: Stratigraphical and lithological information obtained from bore TBDIG01 (URS, 2012)

Formation	Top Elevation (m)	Bottom Elevation (m)	Summary
Mooga Sandstone	52 m bgl	76 m bgl	Calcareous sandstone with minor conglomerate at base.
Orallo Formation	76 m bgl	227 m bgl	Siltstone and mudstone, fine interbedded sand lenses, some bentonite and minor coal.
Gubberamunda Sandstone	227 m bgl	267 m bgl	Fine to medium grained quartz rich sandstone. Grain size increases down profile.
Westbourne Formation	267 m bgl	–	Siltstone and mudstone.

2.4.1.1 Bungil Sandstone

The Bungil Formation was deposited in a shallow marine and deltaic environment, and comprises siltstone, mudstone and quartzose siltstone, and is up 200 m thick in areas within the Surat Basin. Recharge into the Bungil Formation occurs within local outcropping areas of the formation north of Roma. As such, the Bungil Formation is unconfined and potentially connected to surface water features within the project area.

The Bungil Formation has specific yields ranging between 0.2 and 6.3 L/s, with an average 1.7 L/s (Exon, 1976 as reported by URS, 2013). Available groundwater records suggest that the groundwater in the Bungil Formation is brackish (>1,000 mg/L TDS) and is Na-Cl dominant. The Bungil Formation aquifer is utilised for local stock and domestic purposes.

2.4.1.2 Mooga Sandstone

The Mooga Sandstone occurs only within the Surat Basin between the Nebine and Kumbarilla Ridges and grades upwards into the Bungil Formation (Exon, 1976 as reported by URS, 2013). The Formation comprises fluvial quartzose to sublabilite sandstone with thinly interbedded dark grey mudstone and siltstone of swampy origin. The sandstone is thin (approximately 20 m thick at The Roma MAR Project site (URS, 2013)).

The Mooga Sandstone aquifer is recharged on the northern and eastern margins of the Surat Basin. However, it is limited in outcrop and in many areas it is difficult to distinguish from the Bungil and Orallo Formations.

The Mooga Sandstone is an important aquifer in the Surat Basin and provides supplies of good quality groundwater and reported yields of up to 35 L/s. It is believed to be presently augmenting Roma, Wallumbilla and Yuleba town water supplies within the local region proximal to the project area.

2.4.1.3 Orallo Formation

The Orallo Formation acts primarily as a confining bed for the Gubberamunda Sandstone. This formation occurs only in the Surat Basin east of the Nebine Ridge. The formation comprises lithic sandstone, siltstone and mudstone deposited dominantly in swamps and as overbank deposits (Exon, 1976 as reported by URS, 2013). The thickness of the formation varies from 140 to 270 m, averaging 200 m. The Formation is not present on the Nebine Ridge where the Mooga Sandstone rests directly on the Gubberamunda Sandstone. Recharge to the minor aquifer in this Formation occurs along the northern and eastern margins of the Surat Basin.

Groundwater quality within the Orallo Formation is vertically heterogeneous due to lithological banding of sandstone and mudstone, and is assumed to be used for stock and domestic purposes. Limited data is available in the project area on groundwater quality within the Orallo Formation.

2.4.1.4 Gubberamunda Sandstone

The Gubberamunda Sandstone, encountered approximately 230 m bgl, comprises fluvial sandstone, minor conglomerate siltstone and mudstone, with a thickness ranging from 45 to 300 m (Day, 1964 as reported by URS, 2013). The formation contains aquifers over more than half its total thickness (Habermehl, 1980). This formation occurs only within the Surat Basin between the Nebine and Kumbarella Ridges. In adjacent basins, the Gubberamunda Sandstone is equivalent to the Hooray Sandstone in the Eromanga Basin, and is laterally continuous with Pilliga Sandstone within the Coonamble Embayment in New South Wales.

The Gubberamunda Sandstone provides good quality water with reported yield of up to 40 L/s, but averages around 6 L/s. The Gubberamunda Sandstone is near artesian in places, and is the most highly developed aquifer in the Surat Basin.

Recharge to the Gubberamunda Sandstone occurs in northern and eastern margins of the Surat Basin, where the outcrop is generally intensely leached and ferruginised. Springs, some with high conservation values, also occur in these outcrop areas (see Section 2.3).

The general water quality within the Gubberamunda Sandstone aquifer can be described as fresh, and is NaCl dominant (URS, 2011). Groundwater in this aquifer is reported to have an average total dissolved solids (TDS) of 760 mg/L at Roma which is in excess of the aesthetic Australian Drinking Water Guideline (ADWG, 2011) values of 600 mg/L (NHMRC-NRMMC, 2011).

Sampling of groundwater in the Gubberamunda Sandstone aquifer from the Hermitage Trial MAR injection bore (HIG 1) at Hermitage Dam, and from numerous Roma town water supply bores, revealed that sodium, chloride, manganese and iron concentrations are typically greater than aesthetic ADWG guidelines.

2.4.1.5 Westbourne Formation

Underlying the Gubberamunda Sandstone aquifer is the low permeability Westbourne Formation. This formation comprises alternating sequences of mudstone and lithic sandstone with minor siltstone and coal in the upper portions, and thinly-bedded siltstone and low permeability sandstone in the lower portions. The Westbourne Formation reaches a thickness of over 60 m in the project area, and was deposited in a low energy fluvial and marginal-marine environment. These sediments also outcrop at the surface in the northern part of the Surat Basin (Exon, 1976 as reported by URS, 2013).

2.4.1.6 Springbok Sandstone

Underlying the Westbourne Formation, and unconformably overlying the Walloon Coal Measures, is the Springbok Sandstone. The formation is a clayey lithic to very lithic sandstone with localised calcareous deposits interbedded with carbonaceous mudstone and siltstones. It is part of the Injune Creek Group which is also comprised of the Westbourne Formation and Walloon Coal Measures.

2.4.1.7 Walloon Coal Measures

The Walloon Coal Measures (WCM) is the main gas bearing unit within the Surat Basin, encountered some 580 m bgl, and is the principal target formation for CSG operations within the Santos GLNG Roma CSG Field. The thickness of the WCM in the Roma CSG Field range between 100 to 460 m however the total thickness of coal in any single bed is generally less than 30 m. Groundwater from the WCM generally has a salinity ranging from 1,000 mg/L to over 20,000 mg/L and yields between 0.2 L/s and 3 L/s (QWC, 2012).

The WCM are mostly composed of siltstone and silty sandstones, and only relatively small intervals of coal (approximately 10%), deposited by swamps or lakes and sluggish streams (Exon, 1976 as reported by URS, 2013). They can be mapped as having six recognisable formations, (a) Upper Walloon Formation (aquitard), (b) Macalister Coal Seams (aquifer/aquitard), (c) Juandah Sandstone (aquifer), (d) Lower Juandah Coal Measures (aquifer/aquitard), (e) Tangalooma Sandstone (aquifer), and (f) Taroom Coal Measures (aquifer/aquitard).

2.4.2 Hydrogeology

The regional groundwater flow regime in the project area is broadly consistent with the southward dip direction of the local geology. Therefore groundwater typically flows south to south-westerly from the recharge areas in the north where the geology outcrops (see Figure 7).

Groundwater movement within the project area is dominated by sub-horizontal flow in the aquifers. Some vertical leakage from the aquifers occurs, though this is significantly constrained by low permeability aquitards.

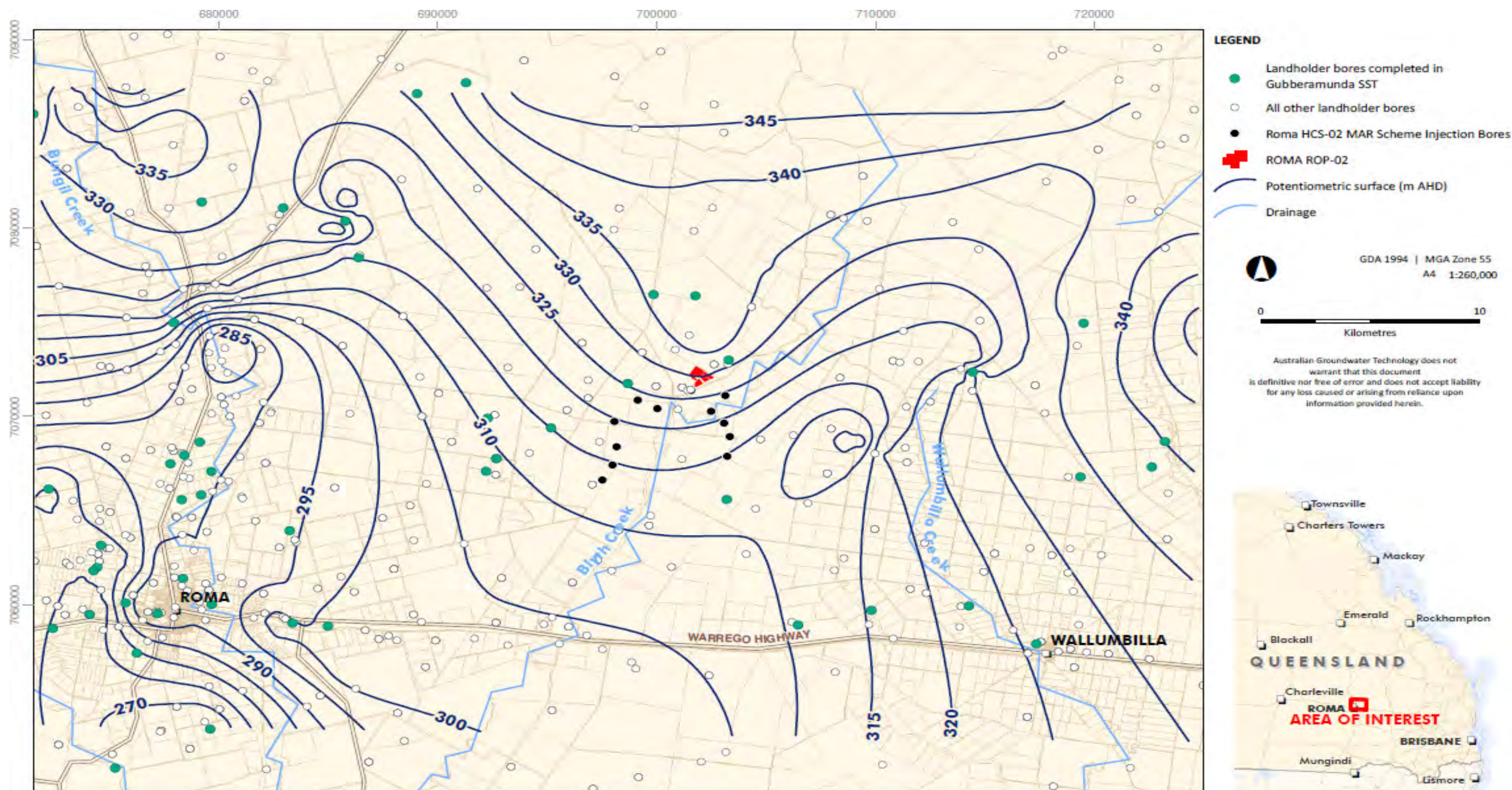


Figure 7: Gubberamunda aquifer potentiometric surface m AHD (after URS)

Within the Gubberamunda Sandstone around the township of Roma, natural flow directions have been modified by significant extraction of groundwater for the Roma TWS. It is not known to what extent vertical leakage between aquifers has been modified as a result of this extraction.

At the site of the Roma MAR Project, the Gubberamunda Sandstone groundwater is sub-artesian with groundwater approximately 35 to 40 m below ground level (URS, 2011 and URS, 2012). Four kilometres to the north, at the location of the Hermitage MAR Trial, groundwater in the Gubberamunda Sandstone is approximately 105m below ground level.

2.4.3 Aquifer Hydraulics

An aquifer transmissivity of 118 m²/d for the Gubberamunda aquifer has been estimated from pumping test data for the Roma Town Water Supply bores (URS, 2011). These bores are located approximately 25 km to the south west of The Roma MAR site.

The following hydraulic properties were derived for the Gubberamunda Sandstone from a Constant Rate Discharge Test (CRDT) on the injection bore used in the Hermitage MAR Trial (AGT, 2013), located approximately 4 km to the north of the Roma MAR site:

- Transmissivity (T) = 41 to 44 m²/d.
- Storage Coefficient (S) = 0.000028–0.00007.

During bore construction, airlift development of the bores at The Roma MAR Project site suggest an aquifer transmissivity of between 30 and 60 m²/d.

2.4.3.1 Pumping test results

The results of pumping tests undertaken of the six constructed MAR injection bores is summarised in Appendix H. Initial estimates of aquifer transmissivity values provided by the analysis of step rate tests are provided in Table 2-3. The transmissivity values for the six bores tested have a range of between 45 and 79 m²/day.

The analysis of a three-day constant rate test carried out on MAR bore TBDIG02 during April, 2013 (the worst performing bore, according to the step test results shown in Table 2-3) provided parameter estimates of:

- Transmissivity (T) = 30 - 90 m²/d; and
- Storage Coefficient (S) = 0.00006 to 0.0001

The analysis of a three-day constant rate test carried out on MAR bore TBDIG04 during April, 2013 (one of the better performing bores, according to the step test results shown in Table 2-3) provided parameter estimates of:

- Transmissivity (T) = 76 - 112 m²/d; and
- Storage Coefficient (S) = 0.00009 to 0.0003

Table 2-3: Results of the Roma MAR Project step tests undertaken in April 2013

MAR bore	No. of steps	Maximum stepped pump rate	Drawdown at the end of five steps	Min specific capacity	Transmissivity (<i>Eden-Hazel</i> Method)
		(L/s)	(m)	(L/s/m)	(m ² /d)
TBDIG01	5	30	66.33	0.41	36
TBDIGI02	5	21	53.31	0.38	37
TBDIGI03	5	40	56.04	0.63	68
TBDIGI04	5	30	52.41	0.53	63
PASIGI05	5	35	59.21	0.56	70
PASIG07	4	30	68.23	0.44	43

2.4.4 Water Quality of the Receiving Aquifer

The quality of groundwater from the Gubberamunda Sandstone is described as fresh, NaCL dominant (URS, 2009 as reported in URS, 2011). Regionally, it has an average total dissolved solids (TDS) of around 760 mg/L, though typically less than 1,500 mg/L. This compares to the aesthetic Australian Drinking Water Guideline (ADWG) value of 600 mg/L (NHMRC-NRMMC, 2011).

Groundwater was sampled from four of the Roma town water supply bores (Table 2-4) that were completed in the Gubberamunda Sandstone on 13 April 2010 (URS, 2011). Groundwater analytical results are presented in Table E.1 of Appendix E. These results indicate TDS above ADWG aesthetic guideline (maximum concentration of 943 mg/L compared to a guideline value of 600 mg/L). A maximum sodium concentration of 264 mg/L was reported which is also in excess of the ADWG aesthetic value of 180 mg/L.

Groundwater was sampled from five of the bores at The Roma MAR Project to determine ambient groundwater conditions specific to the MAR site. Similar to the Roma Town water supply bores, the water quality was found to exceed the ADWG aesthetic drinking water quality standard for sodium and TDS. Groundwater analytical data is presented in Table E.2 of Appendix E and summarised in Table 2-4.

Table 2-4: Key analyte concentrations for Gubberamunda Sandstone groundwater samples taken from the Roma MAR Project site.

Parameter	Min	Mean	Max	Median	Q90	No. Samples
Chloride (mg/L)	122	142	159	143	122	7
Fluoride (mg/L)	0.2	0.2	0.3	0.2	0.2	7
Sulphate as SO ⁴ (mg/L)	17	27	35	28	17	7
Calcium (mg/L)	2	5.3	8	6	2	7
Magnesium (mg/L)	0.5*	0.6	1	0.5	0.5	7
Potassium (mg/L)	1	1.7	2	2	1	7
Sodium (mg/L)	20.5	30.0	46.9	24.7	20.5	7
Sodium Adsorption Ratio	20.5	30.0	46.9	24.7	20.5	7
Total Dissolved Solids @180 °C (mg/L)	515	581	637	578	515	7
Boron (Dissolved) (mg/L)	0.025*	0.06	0.15	0.05	0.025	7
Strontium (Dissolved) (mg/L)	0.047	0.144	0.249	0.163	0.047	7
Boron (Total) (mg/L)	0.025*	0.04	0.07	0.025	0.025	7
Strontium (Total) (mg/L)	0.044	0.16	0.283	0.177	0.044	7
Electrical Conductivity @25 °C (Lab Test) (µS/cm)	931	982	1060	965	931	7
pH (Lab Test)	7.88	8.25	8.5	8.37	7.88	7

* Minimum values were below detection limit. Therefore the minimum values were assumed to be half the detection limit for the purpose of calculating statistical values

2.4.5 Town Supply and Industrial Groundwater Use

Of the nearest licensed water extractions, 12 bores recorded in the register of landholders bores near the township of Roma and are utilised for the town's potable water supply. There are licensed water extractions also recorded in the town of Wallumbilla (one bore) and Yuleba (also one bore). The location of these municipal water supply bores for Roma and the location of the town of Wallumbilla are presented on Figure 8. Yuleba is approximately 20 km east of Wallumbilla. A summary of the Town Water Supply (TWS) bores is presented in Table 2-5.

Table 2-5: Summary of municipal water supply wells in the Roma MAR Project Area

Bore Record	Easting	Northing	Date Drilled	Name	Formation
392	675259	7051337	01/11/1897	ROMA TOWN NO 1	GUBBERAMUNDA SANDSTONE
394	677202	7059536	12/03/1910	ROMA TOWN NO 3	GUBBERAMUNDA SANDSTONE
48860	676523	7059188	16/10/1975	BORE NO 9	GUBBERAMUNDA SANDSTONE
48993	678361	7061409	06/06/1980	ROMA TOWN NO 13	GUBBERAMUNDA SANDSTONE

58148	675739	7060102	19/03/1984	ROMA TOWN NO 14	GUBBERAMUNDA SANDSTONE
58353	674100	7059494	6/05/1988	ROMA TOWN NO 15	GUBBERAMUNDA SANDSTONE
58352	684987	7058878	15/09/1988	ROMA TOWN NO 16	GUBBERAMUNDA SANDSTONE
393	977207	7059651	17/10/1900	QGT QGT 2 HOSPITAL	GUBBERAMUNDA SANDSTONE
8045	677365	7059587	11/02/1930	ROMA TOWN NO 4	INJUNE CREEK GROUP
48975	679221	7059746	13/12/1979	ROMA TOWN NO 12	MOOGA SANDSTONE
8044	676757	7059627	19/02/1929	ROMA TOWN NO 5	MOOGA SANDSTONE
16093	683195	7059064	01/01/1962	ROMA TOWN BORE NO 8	Not identified
48871	716966	7057436	29/03/1976	WALLUMBILLA TOWN	MOOGA SANDSTONE
58023	737254	7054371	06/12/1980	YULEBA TOWN BORE	MOOGA SANDSTONE

2.4.6 Agricultural and Domestic Groundwater Use

This section provides a high level review of the DNRM (Queensland Government Department of Natural Resources and Mines) database of non-licensed landholder bores (herein referred to as the register of landholder bores) within 10 km of the Roma MAR Project site. From the register a total of 115 bores are identified to lie within a 10 km radius of the Roma HCS-02 MAR scheme. A summary of the target formation and source aquifer recorded within the register of landholder bores is summarised in Table 2-6. The location of all landholder bores within 10 km of the Roma MAR Project is shown in Figure 8. A review of the metadata supporting the register of landholder bores identified that information regarding the purpose of the bore such as stock/domestic, irrigation, mineral is incomplete and none of the bores within the 10 km radius had attributes assigned in this field.

Table 2-6: Target formation of all registered water bores located with 10 km of the Roma MAR Project

Target Formation	Number of records
Bungil/Mooga Sandstone	34
Gubberamunda Sandstone	7
Winton	2
Kingull Member	1
Orallo Formation	1
Unknown	70

A baseline survey of all landholder water supply bores has undertaken by Santos in accordance with its obligations under the Water Act (2000). The aim of the survey is to provide an assessment of all water bores prior to onset of CSG activities that may impact upon them.



2.4.7 Groundwater Springs

Four spring complexes have been identified to the north of The Roma MAR Project site. They are the VI Mile, New Camp, Springs Ridge and Barton Springs complexes. These are assumed to be sourced from the Gubberamunda Sandstone since the springs are located within an outcrop area of the Gubberamunda Sandstone (refer to Figure 8). The springs are associated with the outcropping Gubberamunda Sandstone.

Section 4 aims to identify what possible impacts on groundwater flow (pressure) and quality are likely to be caused to these springs by the implementation of the Roma MAR Project.

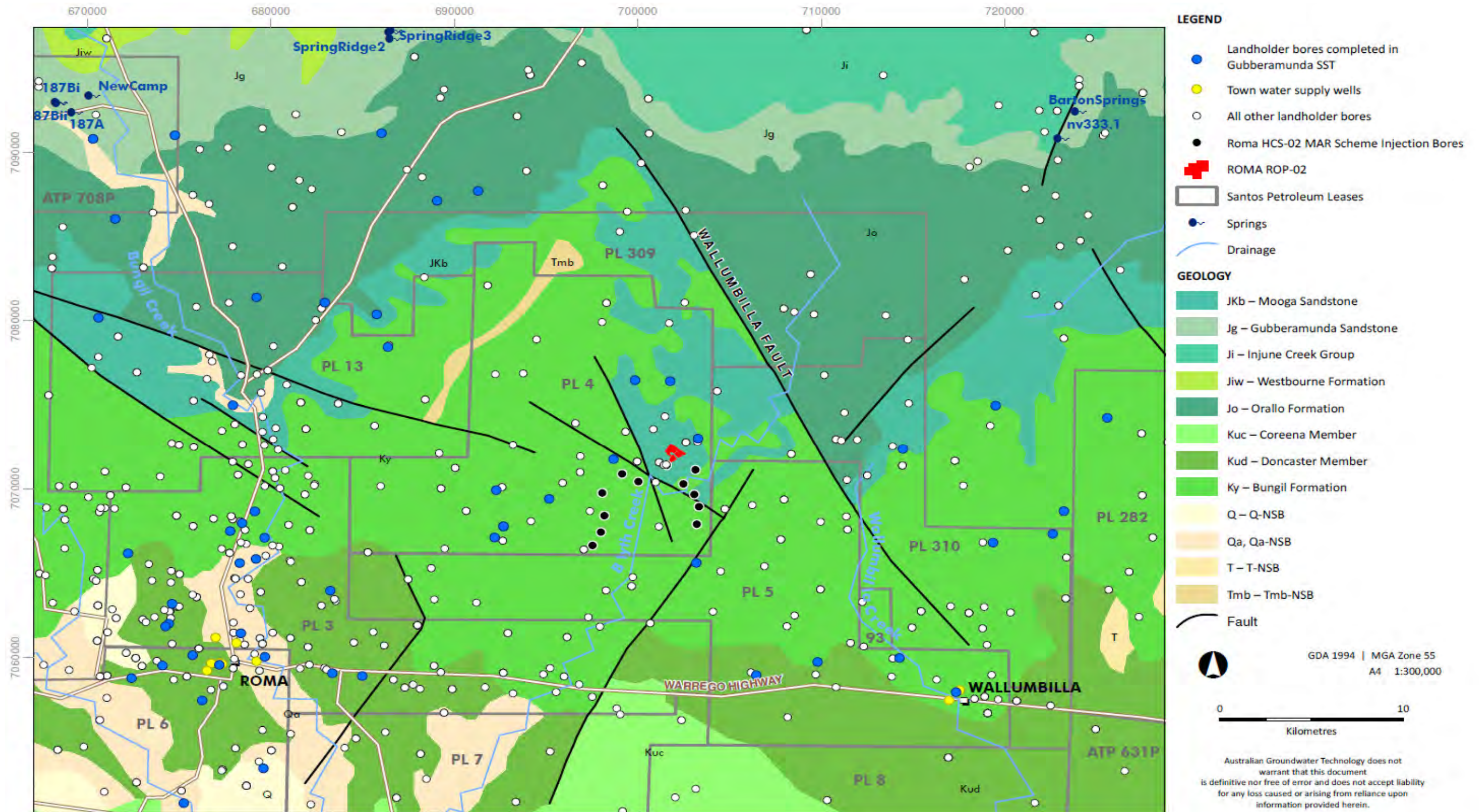


Figure 8 | Location of relevant environmental values

Figure 8: Location of relevant environmental values

3 Roma MAR Project Design

This section presents the system overview and general layout of the Roma MAR bore field which addresses parts a, b, c, d, i, n, r and u of the EA IMP requirements.

EA IMP Requirements		Corresponding Information Section
a)	Estimated volumes and rates of water to be produced and injected	Section 3.1
b)	A description of the physical. Chemical and biological components and their concentrations of the water to be produced	Section 3.4
c)	Details of how and where the fluid will be produced, aggregated, stored and kept separate from other waters until it is, treated and reinjected into the source aquifer	Section 3.2
d)	Details of where the fluid is proposed to be treated including a description of the treatment process	Section 3.3
i)	Identification of proposed fluid injection wells	Section 3.5
n)	Control measures that will be implemented for fluid storage, treatment and injection to prevent or control the release of a contaminant or waste to the environment	Section 3
r)	Procedures for dealing with accidents, spills, failure of containment structure, and other incidents that may arise in the course of fluid injection	Section 3.2
u)	Demonstrate that: i. injection must only occur through injection tubing. ii. the dry overburden pressure of the base of the overlying aquitard for injection at depth less than 100m; or iii. 90% of the formation fracture pressure for injection at depth greater than 100m.	Section 3.5

3.1 CSG Water Production Rates and Volumes

Production of coal seam gas requires the extraction of coal seam water (referred to as “CSG water”) from the coal bearing formation in order to reduce the water pressure and release gas from the coal. The volume of water that will be extracted during the life of CSG production can be estimated from pilot trials and CSG production data. Generally, water storage and treatment designs must cater for upper estimates of potential water production rates to allow for worst-case water production scenarios.

Currently the design for water treatment at the Roma HCS-02 facility is in the order of up to 15 ML/d. However, Santos is seeking environmental approval to inject up to 24 ML/d into the Gubberamunda Sandstone aquifer at the location of the Roma HCS-02 site over a 20 year period to allow for operational flexibility.

Approval to inject at rate of 24 ML/d over a 20 year period equates to approval to inject a total volume of 175,300 ML. Given that the expected rate of CSG water production is expected to decrease over time, it is very likely that actual volumes of water injected into the Gubberamunda Sandstone will be less than the volume that would be authorised by the Environmental Authority.

3.2 CSG Water Collection and Storage

For the Roma MAR Project, CSG water will be piped from the CSG production wells (Appendix B) to a central CSG water management pond (90 ML design capacity) located adjacent to the Roma ROP-2 treatment facility. The pond is designed and constructed as a turkey's nest type storage (i.e. with no external catchment) with earth fill embankments and a substantial portion of the storage contained in an excavated void below natural grade. The design philosophy of the pond centres on the control of seepage using zoned earth fill embankments with geosynthetic liners to satisfy dam safety requirements and to mitigate migration of CSG water into the natural formation.

The construction, monitoring and management of this CSG water management pond is undertaken in accordance with DEHP requirements and EA conditions under which those facilities are licensed to operate. Procedures for dealing with accidents, spills, failure of containment structure in relation to the performance of the storage of raw CSG water is beyond the scope of this document.

In order to prevent or control the release of contaminant or waste to the environment, the design of all the Roma CSG water management pond comprises:

- Prevention of flood waters entering the regulated dam from a watercourse or drainage line or design of insufficient storage that causes overtopping of the spillway (to acceptable flood design standards);
- Prevention of wall failure due to erosion by floodwaters arising from a watercourse or drainage line (to acceptable flood design standards);
- A floor and side wall material that contains the wetting front and any entrained contaminants within the bounds of the containment system during its operational life including any period of decommissioning and rehabilitation; and
- A system to detect any passage of the wetting front or entrained contaminants through the floor or sides of the dam.

3.3 CSG Water Treatment

A process diagram of the Roma MAR treatment system is presented as Figure 9 and detailed in Appendix C.

Raw CSG water that is collected from surrounding CSG wells is transferred to the CSG Water Balance Pond located at the Roma RO plant. The Roma RO plant treatment process removes suspended and dissolved solids through the following steps:

- Clarification – via Actiflo System which consists of coagulation, sand recirculation, polymer injection, floc maturation and settling;
- Oxidation;
- Media Filtration;
- Disinfection;
- Ion Exchange;
- Reverse Osmosis; and
- De-oxygenation (mechanical).

The chemicals adopted in the treatment process are summarised in Table 3-1:

Table 3-1: Chemicals used in the water treatment process

Product/Chemical Name	Storage Volume (m ³)	Nominal Usage (L/day)
Ferric Chloride Solution	20	654
Magnafloc LT25 (Polymer)	25kg bag	25 kg/day
Sodium Hypochlorite Solution 12.5%	15	903
Sodium Metabisulphite	1 x IBC	85
Hydrochloric Acid 33%	28	461
Sulphuric Acid 98%	15.4	390
Sodium Hydroxide 50% (Caustic Soda)	50	1647
Hydrex 4202 (Biocide)	1 x IBC	35
Calcium Chloride 35%	10	100
Ammonium Hydroxide 20% (Aqueous Ammonia)	2 x IBC	60
Microsand 99% Silica	25kg bag	-
Actisand P	-	-
Hydrex 4129 (Antiscalant)	2 x IBC	106

The MSDS (material safety data sheets) for these chemicals are provided in Appendix C.

Following treatment, the permeate is transferred to a water storage tank (0.15 ML capacity) via transfer pumps prior to de-oxygenation before being transferred direct to the MAR injection bores, as shown in the Figure 9.

The system design will utilise vacuum membrane contactors that use nitrogen as the deoxygenating medium. Use of nitrogen avoids introducing chemicals into the processed RO stream prior to injection into the aquifer via the MAR bores. The target dissolved oxygen content for the MAR injection water is 0.5 mg/L. The treated, deoxygenised CSG water will then also be amended with calcium chloride to increase the TDS and reduce the SAR (sodium adsorption ratio) value of the injection water to decrease the reactivity with the target formation.

The various filters and the disinfection stage that the water is required to pass through prior to treatment will remove all cellular organisms from the water, and therefore no organisms such as bacteria or algae can be present in the treated water. The ion exchange and reverse osmosis process cannot tolerate particles as large as cellular organisms and therefore must be removed from the untreated water in order for the treatment process to be effective. Following RO treatment, treated water intended for MAR only be stored in closed tanks (i.e. never in open ponds) and therefore at very low risk from pathogen contamination.

The 90 ML permeate tank shown in Figure 10 is designed to hold treated CSG water that is intended to be used for irrigation only and is not part of the water treatment and storage process intended for MAR.

The brine waste generated from the RO plant will be sent to the brine containment ponds (two ponds of 300 ML capacity each) prior to further treatment or disposal.

The construction, monitoring and management of this treatment facility and the brine and permeate storage ponds is undertaken in accordance with DEHP requirements and EA conditions under which those facilities are licensed to operate. Procedures for dealing with accidents, spills, failure of containment structure in relation to the performance of the storage of these fluids is beyond the scope of this document.

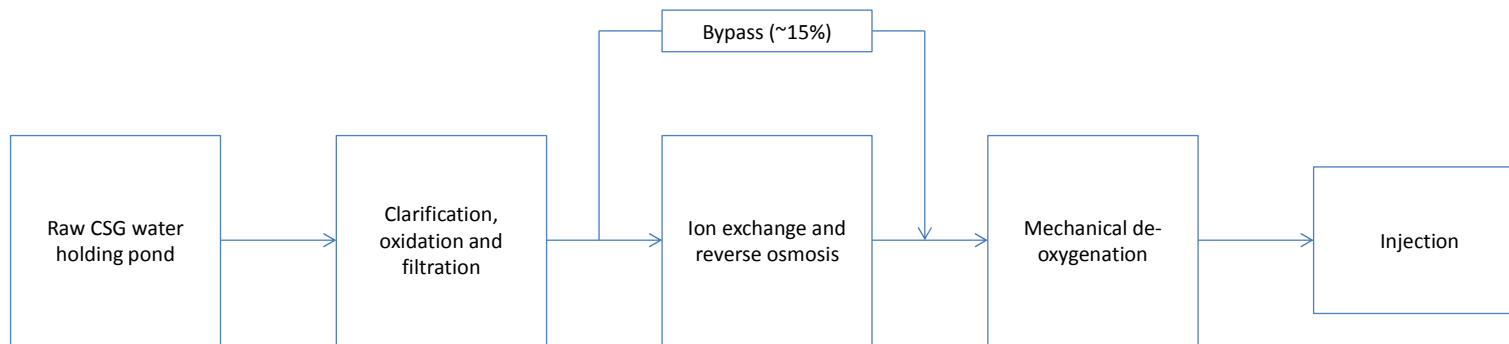


Figure 9: The Roma MAR Project scheme process diagram

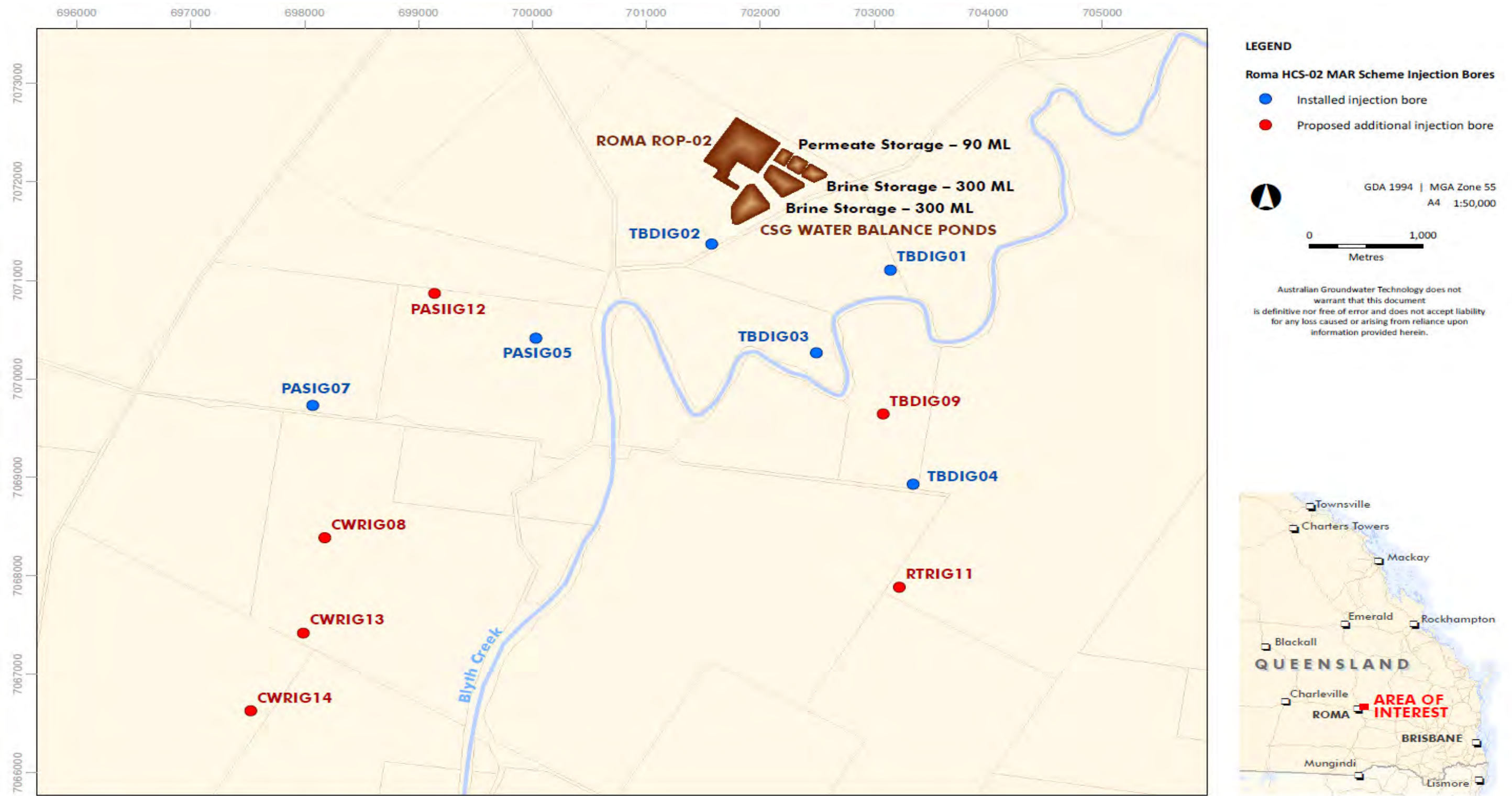


Figure 10: The Roma MAR Project scheme layout plan

3.4 Injection Water Quality

3.4.1 Untreated CSG Water

Two sets of laboratory results are available which describe the potentially water quality of CSG water prior to treatments. The largest dataset (up to 77 samples) have been taken of CSG water across the entire Roma field. The results are summarised in Table 3-2.

A second and smaller data set of CSG water comes from CSG collected from (old) Coxon Creek Dam, Hermitage Dam Pleasant Hills Dam, Pine Ridge Dam and Raslie Dam. This data set provide a more a comprehensive list of analytes (more than 70 analytes including metals, organic and no-organic chemistries) and are presented in Table E.3 of Appendix E. These dams are those that will initially feed directly into the Roma treatment plant. In the longer term, CSG water will be collected at the CSG well head and be transferred directly to storage ponds at the treatment plan itself.

Salinity of untreated CSG water from the Roma CSG field is expected to range in TDS from 2,000 mg/L to 5,000 mg/L (URS, 2011). However a maximum value of up to 7010 mg/L TDS has been recorded.

Microbiological E.coli testing was undertaken at Hermitage Dam with a concentration of <2 CFU/100 ml reported.

For comparison, none of the analytes tested were in excess of the Australian Drinking Water Guideline (ADWG) values, with the exception of TDS, sodium, chloride which were in excess of the aesthetic guideline values, and fluoride which was in excess of the guideline value for human health (i.e. 1.5 mg/L fluoride).

Table 3-2: Roma CSG Field Water Composition Summary

Parameter	Min	Mean	Max	Median	Q90	No. Samples
Chloride (mg/L)	354	1121	3130	767	2442	77
Fluoride (mg/L)	1.2	2.8	5.9	2.6	4.4	77
Sulphate as SO ⁴ (mg/L)	1.0	1.8	15.0	1.0	2.4	77
Calcium (mg/L)	1.0	6.5	21.0	4.0	15.4	77
Magnesium (mg/L)	1.0	1.4	5.0	1.0	3.0	77
Potassium (mg/L)	2.0	22	270	8.0	42	77
Sodium (mg/L)	520	1000	1970	823	1758	77
Sodium Adsorption Ratio	84	106	128	106	116	60
Total Dissolved Solids @180 °C (mg/L)	1240	2532	7010	2010	4460	77
Boron (Dissolved) (mg/L)	0.1	0.6	0.9	0.6	0.8	74
Strontium (Dissolved) (mg/L)	0.2	1.2	4.2	0.7	3.3	74
Boron (Total) (mg/L)	0.3	0.6	1.2	0.6	0.8	64
Strontium (Total) (mg/L)	0.3	1.5	4.8	0.8	3.4	64
Electrical Conductivity @25 °C (Lab Test) (µS/cm)	2180	4534	10000	3620	8260	77
pH (Lab Test)	8.0	8.3	8.8	8.3	8.6	77

3.4.2 Treated CSG Water

3.4.2.1 Reverse Osmosis (RO) Permeate

Water quality results of CSG water treated at Hermitage Dam RO plant can be used to provide indicative characteristics of the treated CSG water the Roma RO plant. Both the Hermitage and Roma RO plants utilise reverse osmosis to treat CSG water. Water quality information is presented in Table 3-3.

The various filters that the water is required to pass through will remove all cellular organisms from the water, and therefore no organisms such as bacteria or algae can be present in the treated water. Following RO treatment, treated water intended for MAR will never be stored in open ponds and is therefore at very minimal risk from pathogen contamination.

3.4.2.2 Blended RO Permeate

RO permeate water is heavily de-ionised and chemically speaking, would not occur anywhere in the natural environment. In its pure form, RO permeate would be considered highly reactive with subsurface minerals (i.e. the minerals that make up the non-porous portion of an aquifer matrix) in that certain mineral salt species would rapidly dissolve upon contact with the RO permeate. The reaction potential is theorised and described in detail in Appendix I.

To manage and reduce the reactivity of the RO permeate with the target formation, the water treatment facility is designed to allow the blending of part-treated CSG water (i.e. CSG water that has passed through clarification, oxidation and filtration) with the RO permeate water. This blending will markedly reduce the reaction potential of the RO permeate. Blending rates will be controlled to keep the TDS below that of the target formation. The “part-treated CSG water:RO permeate” ratio will not exceed 1:4 (i.e. the maximum percentage of part-treated CSG water will not exceed 20%).

Prior to injection, the blended RO permeate water may be amended with calcium chloride and other minerals to further decrease the SAR (sodium adsorption ratio) value of the water to enable it to better match that of the ambient groundwater of the Gubberamunda Sandstone aquifer.

3.5 MAR Bore Field

Approval is being sought to inject up to 24 ML/d into up to twelve injection bores. Currently, however, only six injection bores have been constructed. These are bores labelled as TBDIG01, TBDIG02, TBDIG03, TBDIG04, PASIG05 and PASIG07.



Injection bore locations CWRIG08, TBDIG09, RTRIG11, PASIG12, CWRIG13 and CWRG14 are additional injection bore locations that are considered as potential locations for future injection bores. Land access and compensation agreements are currently being negotiated for these bores that have not yet been constructed. However these injection bores may not be required if the actual volume of water for available for injection remains low and the injection efficiency of the currently constructed injection bores remains adequate. Therefore these additional injection locations may, in time, be considered redundant. Injection of fluid into these six additionally proposed bores will not commence until all relevant construction details are provided to the regulator, and permission by the regulator is subsequently granted for their use to inject fluid into the subsurface.

The location of the injection bores is shown on Figure 2. A summary of injection well construction details is provided in Table 3-4. Land access agreements are currently being negotiated for the remaining bores that have not yet been constructed (i.e. TBDIG09, RTRIG011, CWRIG11, PASIG12, CWRIG13 and CWRG14).

Bore construction logs and geological logs for all constructed bores are provided in Appendix D.

Table 3-3: Water quality of RO Permeate from Hermitage Dam water treatment plant

Analyte	15/11/2012	15/11/2012
Bicarbonate Alkalinity as CaCO ₃ (mg/L)	4	6
Boron (Dissolved) (mg/L)	0.22	0.33
Boron (Total) (mg/L)	0.22	0.34
Calcium (mg/L)	<1	<1
Carbonate Alkalinity as CaCO ₃ (mg/L)	<1	<1
Chloride (mg/L)	6	13
Dissolved Oxygen (Lab Test) (mg/L)	9	8.5
Electrical Conductivity @25 °C (Lab Test) (µS/cm)	27	53
Fluoride (mg/L)	<0.1	<0.1
Hydroxide Alkalinity as CaCO ₃ (mg/L)	<1	<1
Magnesium (mg/L)	<1	<1
Nitrate as N (mg/L)	<0.01	<0.01
Nitrite + Nitrate as N (mg/L)	<0.01	<0.01
Nitrite as N (mg/L)	<0.01	<0.01
pH (Lab Test)	6.64	6.49
Potassium (mg/L)	<1	<1
Reactive Phosphorus as P (mg/L)	<0.01	<0.01
Residual Alkali (meq/L)	0.08	0.12
Sodium (mg/L)	6	11
Sulphate as SO ₄ 2- (mg/L)	<1	<1
Total Alkalinity as CaCO ₃ (mg/L)	4	6
Total Anions (meq/L)	0.25	0.49
Total Cations (meq/L)	0.26	0.48
Total Dissolved Solids @180 °C (mg/L)	12	22
Total Nitrate Nitrogen as N (mg/L)	<0.1	<0.1
Total Nitrogen as N (mg/L)	<0.1	<0.1
Total Phosphorus as P (mg/L)	<0.01	<0.01

Table 3-4: The Bend injection bore construction details

Table 6-4: The Bend Injection Bore construction details											
Bore	Easting	Northing	Ground Elevation (m AHD)	SWL (m bgl)	Total Depth (m bgl)	Pre Collar Interval (m bgl)	Gravel Pack Interval (m bgl)	Slotted Screen Interval (m bgl)	Casing Material	Casing Size (mm)	Screen Aperture (mm)
TBDIG01	703142	7071103	327.8	~30	270	0–48	255–270	234–264	Schedule 40 stainless steel	255	1
TBDIG02	701574	7071369	335.03	35.47	275	0–45	231–270	234–264			
TBDIG03	702492	7070264	323.63	41.46	274	0–35	221–274	237–267			
TBDIG04	703342	7068925	339.05	~40	298.3	0–38	251–298.5	264–294			
PASIG05	700030	7070411	??	~40	259	0-40	214-259	226-256			
PASIG07	698073	7069729	??	31.9	250.7	0-30	197-244	201-243			
TBDIG09*	703080	7069642	Details to be provided when constructed								
RTRIG11*	703221	7067882	Details to be provided when constructed								
CWRIG08*	698177	7068384	Details to be provided when constructed								
PASIG12*	699141	7070866	Details to be provided when constructed								
CWRIG13*	697989	7067415	Details to be provided when constructed								
CWRIG14*	697528	7066628	Details to be provided when constructed								

*Indicates that site location has been scouted and agreements for land access are pending. Final location and construction details will be provided to the regulator prior to the each individual bore's use to inject fluid

3.5.1 MAR Bore Head Works Design

Delivery of water to the MAR bores will be driven by transfer pumps located at the site of the Roma RO plant. Treated CSG water will be transferred from the RO plant transfer pumps via GRE pipe (epoxy), before reaching the bore head works arrangement where it will be converted to a stainless steel pipe.

The design philosophy is such that line pressure and flow rates to each bore control can be detected and controlled either manually or automatically via a central control panel located at the site of the Roma RO plant. The arrangement of the head works is presented in Figure 12.

The head works design components and their function is presented in Table 3-5.

Table 3-5: Head works design components at each injection bore

Component*	Function
Gate valve	Manually isolate individual wells (e.g. for maintenance), without affecting injection in other bores.
Ball valve	To allow manual sampling of injection water.
Motorised flow control valve	Automated flow control. May be manually or automatically controlled to allow variable flow rates or bore shut-in. The aim is to automate flow control to individual bores by incorporating telemetered head works data (e.g. injection flow rate or line pressure).
Pressure Gauge	Telemetered pressure data to individual bores will be automatically recorded and fed through to a central control panel. Triggers and alarms can be programmed. Pressure data can be programmed to automatically adjust the motorised flow control valve.
Flow meter	Telemetered flow data will be automatically recorded and fed through to a central control panel. Triggers and alarms can be programmed. Flow data can be programmed to automatically adjust the motorised flow control valve.
Ball valve vent	Releases air from the injection pipeline to eliminate entrainment of air into the injection flow line.
Bore injection pipe	The injection line will be installed below the water level in the bore, and thus minimise cascading and air entrainment. A diffuser will be located at the base of the injection pipe to limit occurrence of cascading water within the injection pipe.
Air release valve on the surface casing cap/flange	This allows release of air that is held within the bore annulus, above the water level, during injection start-up as the water level in the bore rises in response to commencement of injection.

* The order in which the components are presented here represent the order in which the component is encountered (i.e. upstream to downstream) prior to injection.

3.5.2 MAR Bore Down Hole Design

The down-hole design of the injection bores is a simple system that may comprise a delivery line and a down-hole diffuser¹. However, in some instances an injection line and down hole diffuser may not be required. With or without an injection line and down-hole diffuser, the design does not cater for any means of down-hole flow control. Delivery flow rates and injection pressures of injection water into the target formation is controlled at the surface. The injection bore is sealed and cased throughout its length, with the exception of the screen section of the bore throughout the majority of the thickness of the Gubberamunda Sandstone aquifer where it was encountered.

Construction details for the existing bores are presented in Table 3-4. Geological logs and construction details are presented in Appendix D. A typical bore completion diagram for the constructed injection bores is presented as Figure 11. All bores have been and will be constructed in accordance with the 'Minimum Construction Requirements for Water Bores in Australia' Edition 3, dated February 2012.

Construction details will be submitted to the regulator prior to injection of water into any newly constructed injection bore.

Stainless steel casing has been employed as it eliminates the potential problem of rust scale which can occur when the casing is subjected to alternating wetting and drying between injection and rest periods.

3.5.3 Injection Pressure

Pumps will be used to deliver water under pressure to the well head. The injection pressure at each injection bore will be controlled using the motorised globe valve and pressure gauge located upstream of the bore head works. A maximum injection pressure is therefore required to be defined for each injection bore.

A maximum injection pressure (measured at the surface) will be adopted for the MAR injection scheme based on 90% of the formation fracture pressure. This value is calculated by estimating of grout injection pressures that would avoid hydraulic fracturing of a foundation. This type of approach is more applicable to the Roma MAR study than an effective stress estimate which may be conservative when adopted for rock strata.

Houlsby (1977, 1978) provides an estimate of grout injection pressures to avoid hydraulic fracture of the rock foundation. The procedure is based on the assumption that the maximum pressures at the base of the stage being grouted is given by:

¹ It is noted that Condition BE4 of PEN103814911 states that only wells used for untreated coal seam water or brine fluid injection must maintain an inert fluid in the annulus between the injection tubing and production casing, above a packer installed at the junction of the aquitard and the target formation. Since only treated CSG water is proposed to be injected, Condition BE4 is not deemed applicable and an injection tube/packer system has not been incorporated into the design.

$$[PB = \alpha d]$$

Where:

- PB denotes the pressure at base of hole in KPa;
- α denotes factor depending on the rock conditions; and
- d denotes depth below ground surface in metres.

The pressure which can be applied depends on the rock conditions. Factors influencing α include the quality, degree of fracturing, weathering and in situ stresses. Housby recommends the following α factors:

- 70 for sound rock
- 50 for average rock
- 25 to 35 for weak rock

These factors allow for the weight of the overlying rock plus some spanning effect.

The Gubberamunda sandstone aquifer may be weak in parts, though it is unlikely to be weathered. However an α factor of 25 is considered conservative in respect of the properties of the target rock. Table 12 summarises the determination of the maximum injection pressure that may be utilised in each of the injection bores to avoid fracturing the target formation.

Injection will be applied gradually and the water injection rate and well head pressure will be monitored during the initial pressure application via a pressure meter located on the well head works at ground level.

Table 3-6: Formation fracture pressure calculated for each of the constructed injection bores.

Injection well	Maximum Depth (m below ground level)	Formation fracture pressure at the base of the well (KPa)	Formation fracture pressure at the surface* (KPa)
TBDIG01	270	6750	4030
TBDIG02	275	6875	4105
TBDIG03	274	6850	4090
TBDIG04	298	7450	4450
PASIG05	259	6475	3865
PASIG07	251	6275	3745

* Allowing for the pressure of the water column in the bore to the ground surface, plus an additional 2 metres to account for the water in the head works above ground level, at the elevation of the pressure gauge where the pressure will be measured.

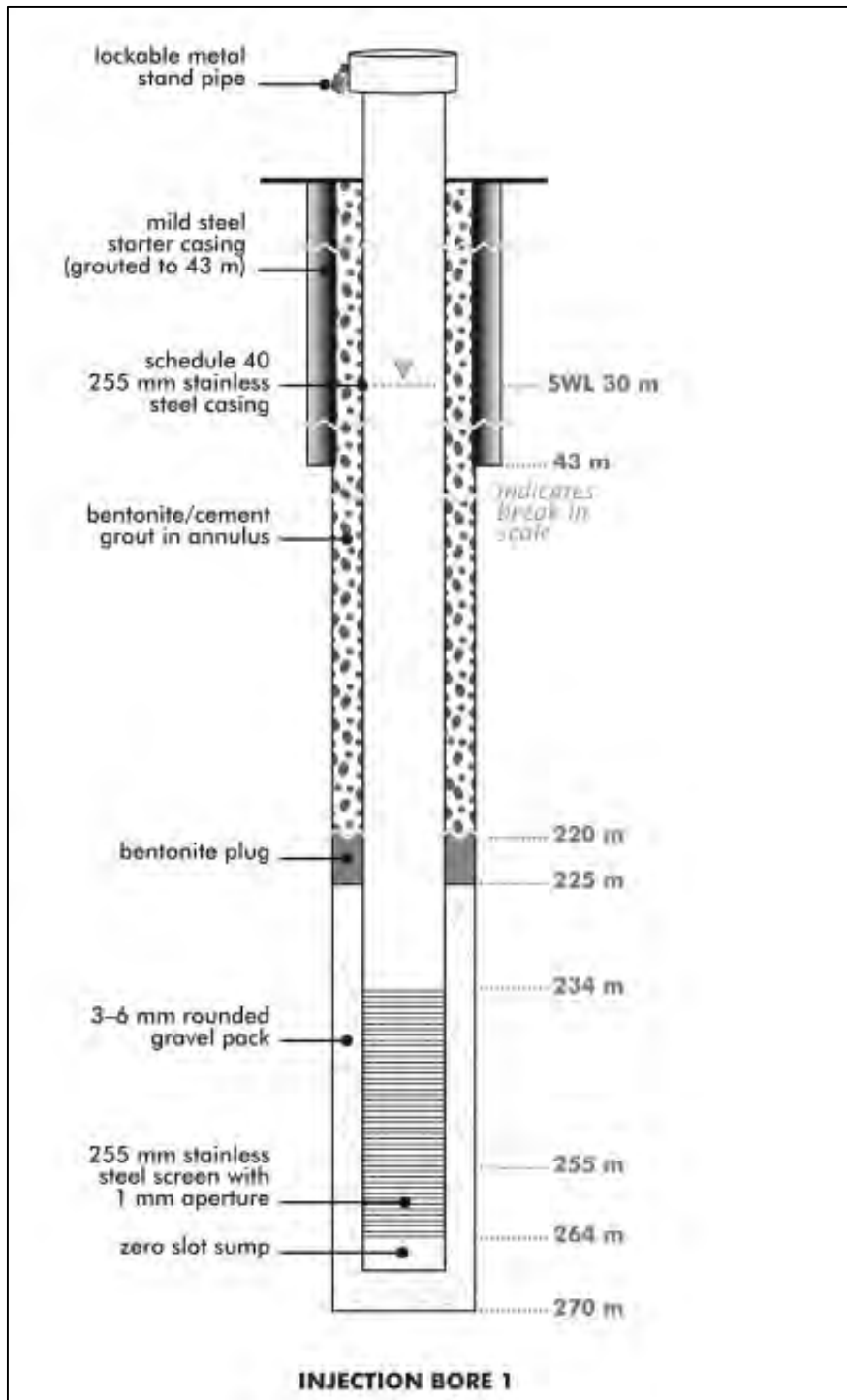


Figure 11: Typical bore construction details, injection bore TBDIG01

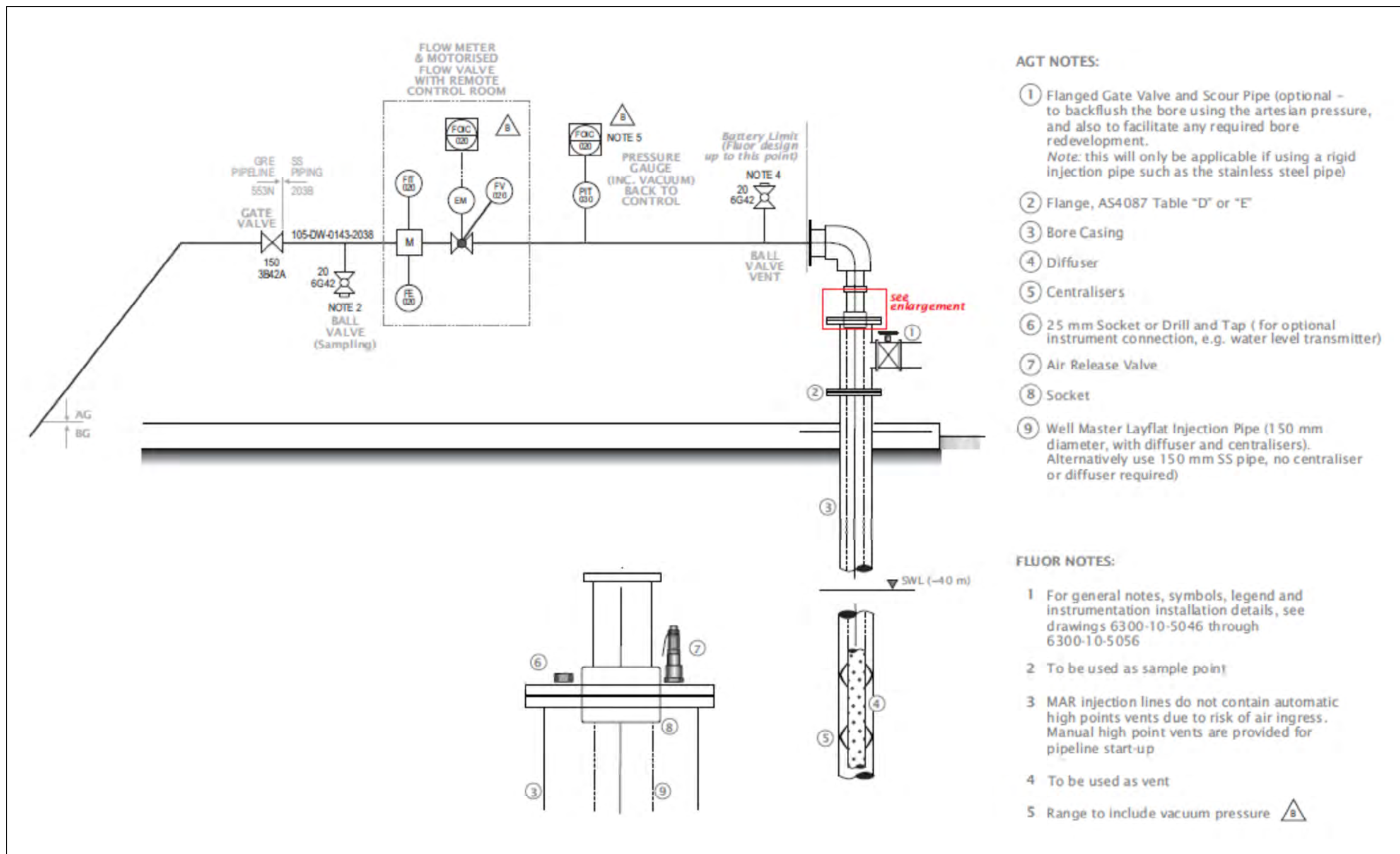


Figure 12: Well head design

4 Impact Prediction

This section presents the predicted impacts of the Roma MAR Project to address parts e, g, h, j and k of the EA IMP requirements.

EA IMP Requirements		Corresponding Information Section
e)	A demonstration that the injection fluid has inconsequential reactivity with the target formation and native groundwater it will come into contact with	Section 4.3
g)	Identification of the water quality impact zone and the hydraulic impact zone	Section 4.2 and 4.3
h)	Identification of all existing bores, springs, lakes, wetlands, environmental assets and water courses connected to groundwater, faults and other geologic features that occur within the water quality impact zone and the hydraulic impact zone	Section 4.2 and 4.3
j)	Identification of the environmental values and water quality objectives of the potential water quality impact zone of the target formation in accordance with the Environmental Protection Act 1994, Environmental Protection Regulations 2008, Environmental Protection (Water) Policy 1997 and the Queensland Water Quality Guidelines 2006.	Section 4.4 and Section 4.5
k)	An assessment of the potential impacts on the environmental values of the receiving environment including migration of injection fluid or native groundwater out of the target formation through wells, bores, springs, connected water courses, faults or other geologic features likely to impact on the other aquifers	Section 4.1 and 4.2

4.1 Guideline Risk Assessment

A maximal risk assessment and residual risk assessment were undertaken for the Roma MAR Project during initial feasibility stage and then after the Hermitage MAR trial, respectively, in accordance with the Australian MAR guidelines (NRMMC, 2009) and are summarised in Appendix G.

The conclusion from these risk assessments was that the residual risk of the Roma MAR project remained the risk to aquifer pressure and groundwater levels. Furthermore, water quality changes within the aquifer will be reiterated to in this section to demonstrate suitable water quality criteria for injection water.

Therefore the remainder of this section outlines the assessment of hydraulic impact and water quality impact.

4.2 Hydraulic Impact

The MAR risk assessment (summarised in Appendix G) identifies that over-pressurisation of aquifers caused by the Roma MAR Project may have negative effects such as:

- Artesian conditions in nearby bores that are within the zone of hydraulic influence; and
- Failure of poorly completed bores within the zone of hydraulic influence.

A summary of the predicted hydraulic effect of the Roma MAR Project on the Gubberamunda Sandstone and the Mooga Sandstone aquifers is presented in Figure 13 and Figure 14 respectively.

A numerical model of The Roma MAR Project (see Appendix F) simulated the injection of 28 ML/day across 14 bores for a period of 20 years. In respect of the determination of hydraulic and water quality impact zones for a scheme that is designed to inject up to 24 ML/d across 12 bores (2 ML/d per bore) for 20 years, the modelled results slightly overestimate possible hydraulic and water quality hydraulic impact zones since they are based on a greater overall injection volume over a greater number of injection bores. As such, they are deemed appropriate for use within this assessment of impact.

In regard to the location of the injection bores that have not yet been constructed, the exact location will be provided to the regulator and approval sought prior to any injection at these locations taking place. This will include a brief update of hydraulic assessment should the location of the injection bores deviate significantly from that which is presented in this report.

4.2.1 Offsetting Drawdown Impact

There are two sources of existing and potential future depressurisation of the confined sandstone aquifers in the Roma area, these are:

- The historic and continued extraction of groundwater to supply agricultural, household domestic, municipal and industrial water supplies. For example, the Gubberamunda Sandstone aquifer under the town of Roma has seen a depressurisation of up to 80 m over the last 100 years; and
- The future development of the CSG industry in the Surat and Bowen Basins. Though current predictive models conclude that depressurisation of the Gubberamunda Sandstone aquifer in the Roma is (for the most part) less than around five metres, in very limited areas the drawdown is predicted to be greater and may approach 20 m of drawdown impact throughout the life of the project (OGIA, 2012).

In broad terms, therefore, recharging of the sandstone aquifers in the Roma area is considered of positive environmental benefit because it will offset the impact of these existing and future activities.

However, for the purposes of determining possible hydraulic impact of the Roma MAR Project due to over-pressurisation, and in particular for the purpose of determining adequate impact monitoring, these effects shall be ignored because:

- Current groundwater abstraction practices in the area will have evolved with the decreasing regional groundwater pressures due to over-extraction (lowering of pumps, drilling of new bores, etc.), and therefore may not necessarily be equipped to cope with a return to the 'pre-development' groundwater condition; and
- The predictive assessment of the underground water impact of the CSG industry in the Surat and Bowen basins is conservative, i.e. it is a worst case scenario that has been developed to drive impact mitigation programs for the CSG industry. There is no certainty that the depressurisation effects predicted by the assessment will ever be realised, and therefore no certainty that any potential MAR over-pressurisation impacts will, in-turn, be mitigated by CSG development.

Therefore for the purposes of determining hydraulic impact of the Roma MAR project, the off-setting of current or predicted depressurisation effects will be ignored.

4.2.2 Artesian Hydraulic Impact Zone

The Roma MAR project groundwater model predicts that artesian conditions may extend approximately 5.5 km from the injection area after 20 years of continuous injection (see Figure 15).

Within the area of predicted artesian effect, there are no bores that are recorded by the database of landholder bores as being screened in the Gubberamunda Sandstone. However, 12 bores exist within this artesian zone that have no source aquifer identified, and therefore may be affected by artesian groundwater conditions within the life of the project. A summary of the timing and extent of the impact to these bores is summarised in Table 4-1.

Table 4-1 shows that four landholder bores may be impacted by artesian conditions within the first year of operation, and an additional five landholder bores may be affected within 5 years following the onset of the Roma MAR Project.

Of the 12 bores identified within the artesian zone, all but one (i.e. RN8143, a water bore screened in the Mooga Sandstone and therefore not affected by changes in pressure in the Gubberamunda Sandstone) will have been plugged and abandoned as part of the Santos Roma Cap and Abandonment Project (RCAP) within the first year of Roma MAR Project operation. Prior to injection into any bore, the four bores that are identified as being affected by artesian conditions in the first year will have been plugged and abandoned in accordance with requirements of the Petroleum and Gas Act. Where a landholder's water bore is abandoned by the RCAP programme, landholders will be adequately compensated.

4.2.3 Five Metre Hydraulic Impact Zone

4.2.3.1 Gubberamunda Sandstone

The numerical groundwater model predicts that the zone where the groundwater pressure increases by up to five metres will extend up to 10 km from the Roma MAR Project site.

Within this area, the database of landholder bores identifies seven bores that are screened within the Gubberamunda Sandstone aquifer. The predicted impact to these bores is shown in Table 4-2 which shows most of the impact is predicted to occur within the first year of operation.

A further 33 landholder bores within the zone of >5 m change in aquifer pressure have no source aquifer identified by the landholder bore database. The details of these bores, including the total depth according to the landholder bore database, are shown in Table 4-3.

Of the 33 bores within the >5 m impact zone, four bores are unlikely to be screened in the Gubberamunda Sandstone since they are too shallow. The remaining 29 landholder bores are all former conventional gas wells, as such they will be targeted by the Santos RCAP for plugging and abandonment.

4.2.3.2 Mooga Sandstone

The numerical groundwater model predicts that the zone where the groundwater pressure increases by up to five metres will extend up to 2 km from the Roma MAR Project site.

Within this area, the database of landholder bores identifies one bore that is screened within the Mooga Sandstone aquifer (RN 14337).

4.2.4 0.2m Hydraulic Impact Zone

The numerical groundwater model predicted that a hydraulic impact zone >0.2 m (as defined by MAR Guidelines, NRMCC et. al. 2009) would extend approximately 15 km in the Gubberamunda Sandstone aquifer after 20 years of continuous injection. The extent of the 0.1 m hydraulic impact is presented in Figure 13.

The 0.2 m impact zone does not extend as far as either the Roma or Wallumbilla TWS's located south-west and south-east of the Roma MAR Project, respectively. The 0.2 m impact zone does not extend as far as the springs located to north of the area. This is shown in Figure 13 and Figure 14.



Roma MAR Project
Injection Management Plan

Table 4-1: Registered landholder bores within the modelled artesian zone

Registration Number	Conventional Gas Well name	Latitude (MGA94)	Longitude (MGA94)	Total depth (mbgl)	Surface elevation (mAHD)	Source of depth/elevation	Stratigraphic Unit Bottom	Water pressure in the Gubberamunda Sandstone, m above ground level		
								After 1 year	After 5 years	After 20 years
8143	-	-26.502597	148.992788	74.07	326	OGIA	Mooga Ss	Unlikely to be screened across the Gubberamunda Sandstone		
22411	PINE RIDGE 3	-26.508708	149.020010	1116	327	QDEX	Clematis Ss			4
22465	PINE RIDGE 6	-26.477042	148.977788	1078	330	QDEX	Clematis Ss		6	15
22491	PINE RIDGE 11	-26.492875	148.977788	1055	337	QDEX	Moolayember Fm			16
22843	PINE RIDGE 13	-26.455098	149.011120	1175	348	QDEX	Permian Fm			33
22401	PINE RIDGE 1	-26.491486	149.018343	1098	316	QDEX	Rewan Gp		16	34
22490	PINE RIDGE 10	-26.491486	149.027509	1118	321	QDEX	Clematis Ss		18	34
22480	PINE RIDGE 8	-26.492875	148.993899	1080	325	QDEX	Clematis Ss		15	39
22459	PINE RIDGE 5	-26.477042	148.993898	1071	328	QDEX	Clematis Ss	5	32	50
22455	PINE RIDGE 4	-26.477042	149.011676	1082	322	QDEX	Rewan Gp	1	35	51
22832	PINE RIDGE 12	-26.480375	149.044453	1174	326	QDEX	Bandanna Fm	4	37	52
23769	PINE RIDGE 15	-26.474264	149.022787	1096	318	QDEX	Moolayember Fm	5	15	53



Roma MAR Project
Injection Management Plan

Table 4-2: Registered landholder bores registered as being screened in the Gubberamunda Sandstone and within hydraulic impact zone >5m

Registration Number	Conventional Gas Well name	Latitude (MGA94)	Longitude (MGA94)	Total depth (mbgl)	Surface elevation (mAHD)	Source of depth/elevation	Stratigraphic Unit Bottom	Change in groundwater pressure modelled (m)		
								After 1 year	After 5 years	After 20 years
15379	-	-26.41815	149.00390	213.5	382	OGIA	Gubbermunda Ss	<10 m	<10 m	<10 m
22496	WINSTON 1	-26.50371	148.92862	301.9	325	QDEX	Gubbermunda Ss	<10 m	<10 m	<10 m
58939	-	-26.47832	148.92903	271	383	OGIA	Gubbermunda Ss	<10 m	<10 m	<10 m
123131	-	-26.49762	148.93330	282	-		Gubbermunda Ss	<10 m	<10 m	<10 m
123335	-	-26.41844	149.02309	225	-		Westbourne Fm	<10 m	<10 m	<20 m
58663	-	-26.48260	148.95810	210	350	OGIA	Gubbermunda Ss	<20 m	<20 m	<30 m
22407	PINE RIDGE 2	-26.51565	149.03918	350.7	348	QDEX	Gubbermunda Ss	<30 m	<30 m	<30 m



Roma MAR Project
Injection Management Plan

Table 4-3: Registered landholder bores within hydraulic impact zone >5m when the source aquifer is not recorded

Registration Number	Conventional Gas Well name	Latitude (MGA94)	Longitude (MGA94)	Total depth (mbgl)	Surface elevation (mAHD)	Source of depth/ elevation	Stratigraphic Unit Bottom	Water Pressure Rise		
								After 1 year	After 5 years	After 20 years
22493	BLYTHEDALE NORTH 1	-26.53454	148.96140	1118.6	336	WIS	Moolayember Fm	< 20m	< 20m	< 20m
23425	RASLIE 6	-26.48760	149.08056	1254	365		Rewan Gp	< 20m	< 20m	< 20m
22358	RASLIE 3	-26.49510	149.06612	1249.9	355		Bandanna Fm	< 30m	< 30m	< 30m
22468	PINE RIDGE 7	-26.46315	148.97779	1109.4	341	QDEX	Rewan Gp	< 30m	< 30m	< 30m
22485	PINE RIDGE 9	-26.49149	148.96168	1070.7	350	QDEX	Moolayember Fm	< 30m	< 30m	< 30m
23558	BURGOYNE 1	-26.49788	149.05807	1280	357	QDEX	Permian Fm	< 30m	< 30m	< 30m
22411	PINE RIDGE 3	-26.50871	149.02001	1116.1	327	QDEX	Clematis Ss	< 40m	< 40m	< 40m
22465	PINE RIDGE 6	-26.47704	148.97779	1077.4	330	QDEX	Clematis Ss	< 40m	< 40m	< 40m
22843	PINE RIDGE 13	-26.45510	149.01112	1174.3	348	QDEX	Permian Fm	< 40m	< 40m	< 40m
22491	PINE RIDGE 11	-26.49288	148.97779	1054.9	337	QDEX	Moolayember Fm	< 40m	< 50m	< 50m
22401	PINE RIDGE 1	-26.49149	149.01834	1098.5	316	QDEX	Rewan Gp	< 50m	< 50m	< 50m
22490	PINE RIDGE 10	-26.49149	149.02751	1118.3	321	QDEX	Clematis Ss	< 50m	< 50m	< 50m
22480	PINE RIDGE 8	-26.49288	148.99390	1080.5	325	QDEX	Clematis Ss	< 50m	< 50m	< 60m
22455	PINE RIDGE 4	-26.47704	149.01168	1082	322	QDEX	Rewan Gp	< 60m	< 60m	< 60m
22459	PINE RIDGE 5	-26.47704	148.99390	1070.7	328	QDEX	Clematis Ss	< 60m	< 60m	< 60m
22832	PINE RIDGE 12	-26.48038	149.04445	1174.3	326	QDEX	Bandanna Fm	< 60m	< 60m	< 60m
23769	PINE RIDGE 15	-26.47426	149.02279	1095.5	318	QDEX	Moolayember Fm	< 60m	< 60m	< 60m

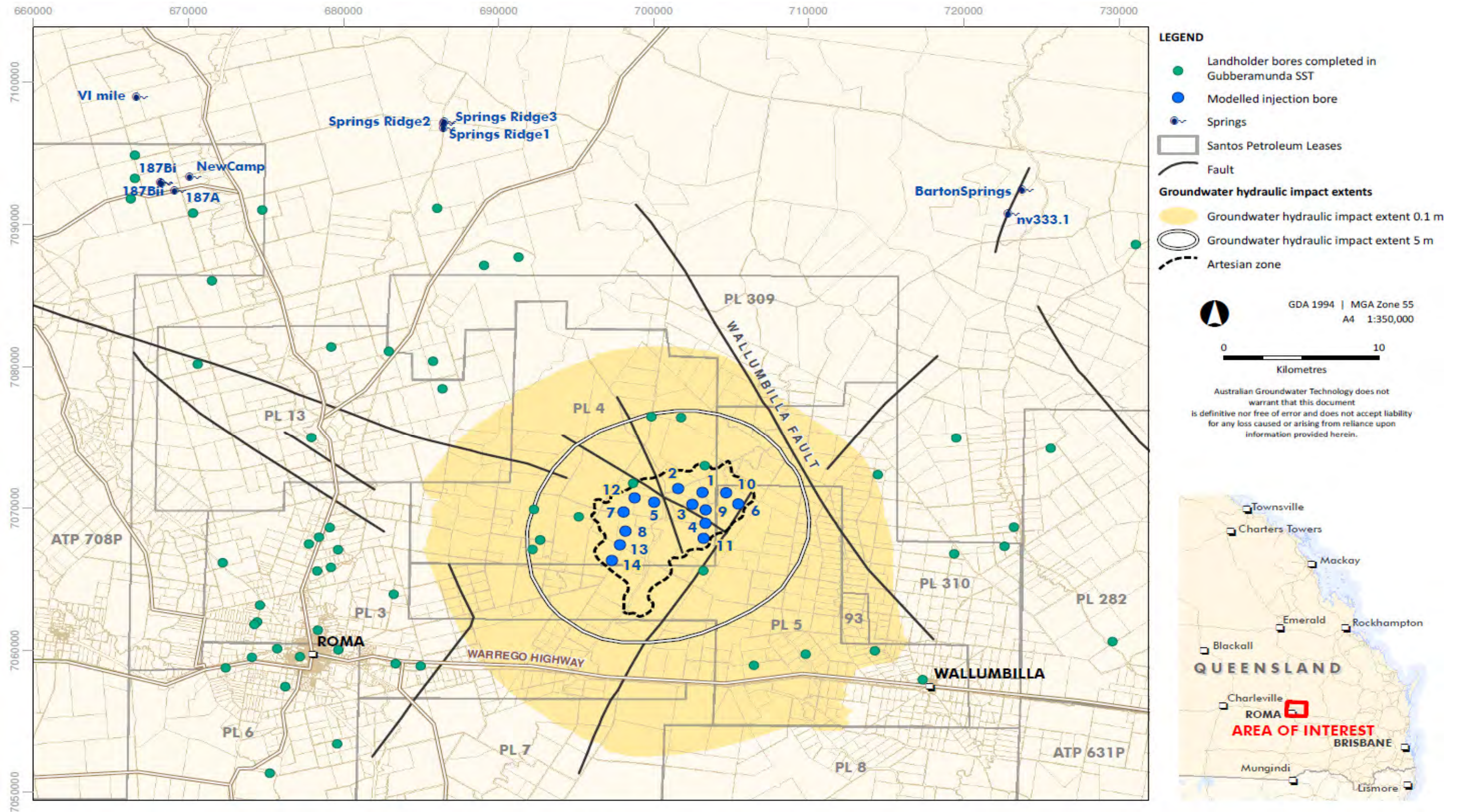


Figure 13 | Modelled Hydraulic Impact Zone in the Gubberamunda Sandstone after 20 years injection @ 28 ML/d into 14 injection bores

Figure 13: Modelled Hydraulic Impact Zone in the Gubberamunda Sandstone after 20 years injection at 28 ML/d into 14 injection bores

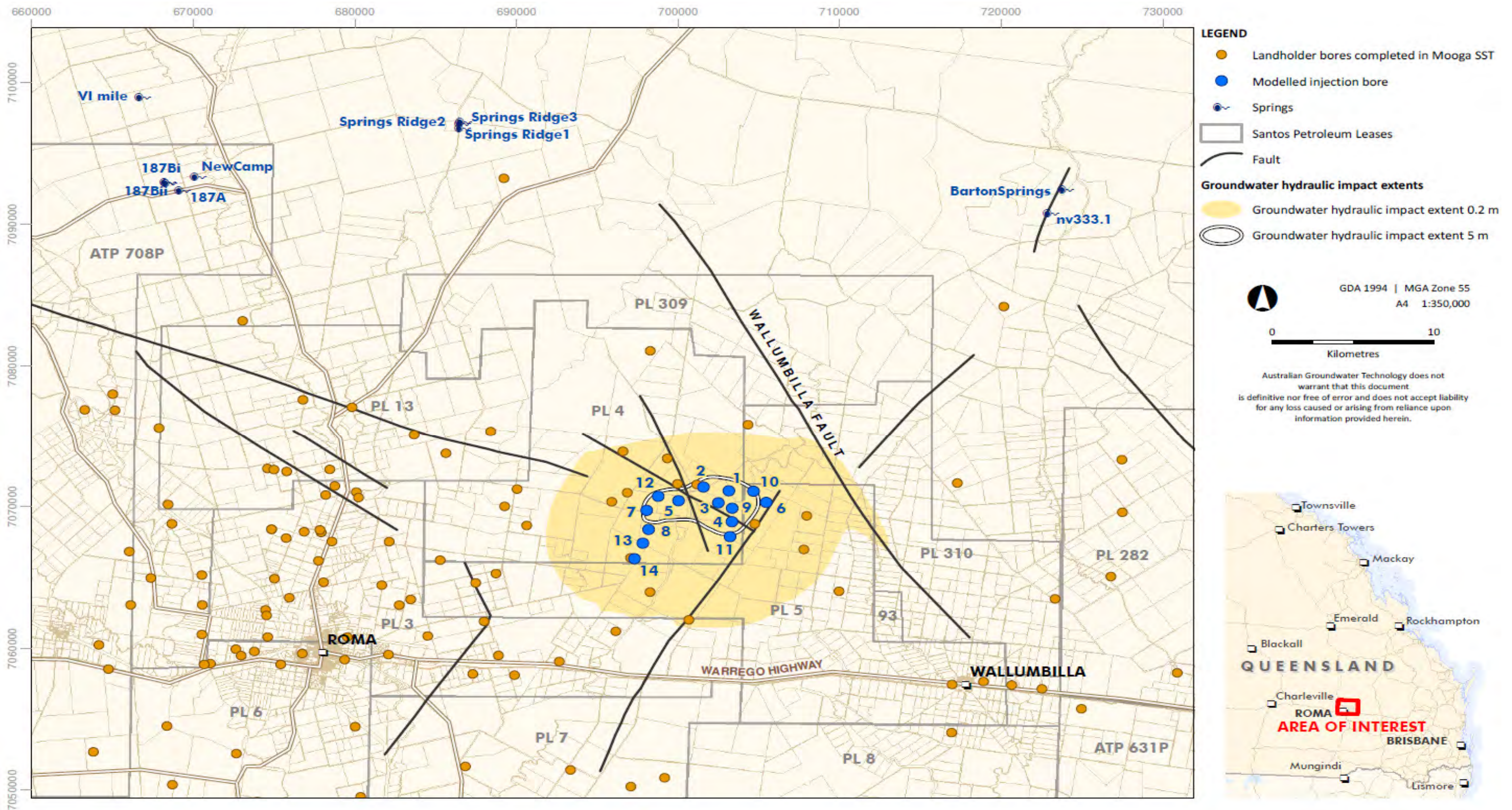


Figure 14 | Modelled Hydraulic Impact Zone in the Mooga Sandstone after 20 years injection @ 28 ML/d into 14 injection bores

Figure 14: Modelled Hydraulic Impact Zone in the Mooga Sandstone after 20 years injection at 28 ML/d into 14 injection bores

4.3 Water Quality Impact

4.3.1 Water Quality Impact Zone

The groundwater model was used to predict the extent of the water quality impact zone that would be expected after 20 years of injecting 28 ML/d into 14 injection bores, and the migration of the impact zone after 1000 years following the cessation of MAR injection.

It is deemed appropriate to use these marginally higher injection rates, although slightly conservative, for the determination of the potential hydraulic impact zone. The results are summarised in Figure 15 and Table 4-4.

The modelling showed that throughout the modelled life of the injection scheme the water quality impact zone extends up to around 1.5km from the injection bores. On cessation of injection, the natural hydraulic gradient causes the injected groundwater to migrate approximately 4 km in the following 1000 year period, generally in a southerly direction.

Within the modelled area of water quality impact after 1000 years, there is just one bore that is recorded as being screened in the Gubberamunda Sandstone aquifer in the database of landholder bores. A further 15 bores in this area are recorded with no source aquifer determined.

The water quality impact zone does not extend to the TWS bores in Roma or Wallumbilla or the Gubberamunda Sandstone springs located to the north. Once injection has stopped, the model predicts that the water quality impact zone migrates in a southerly direction, under the influence of the natural and regional groundwater flow regime.

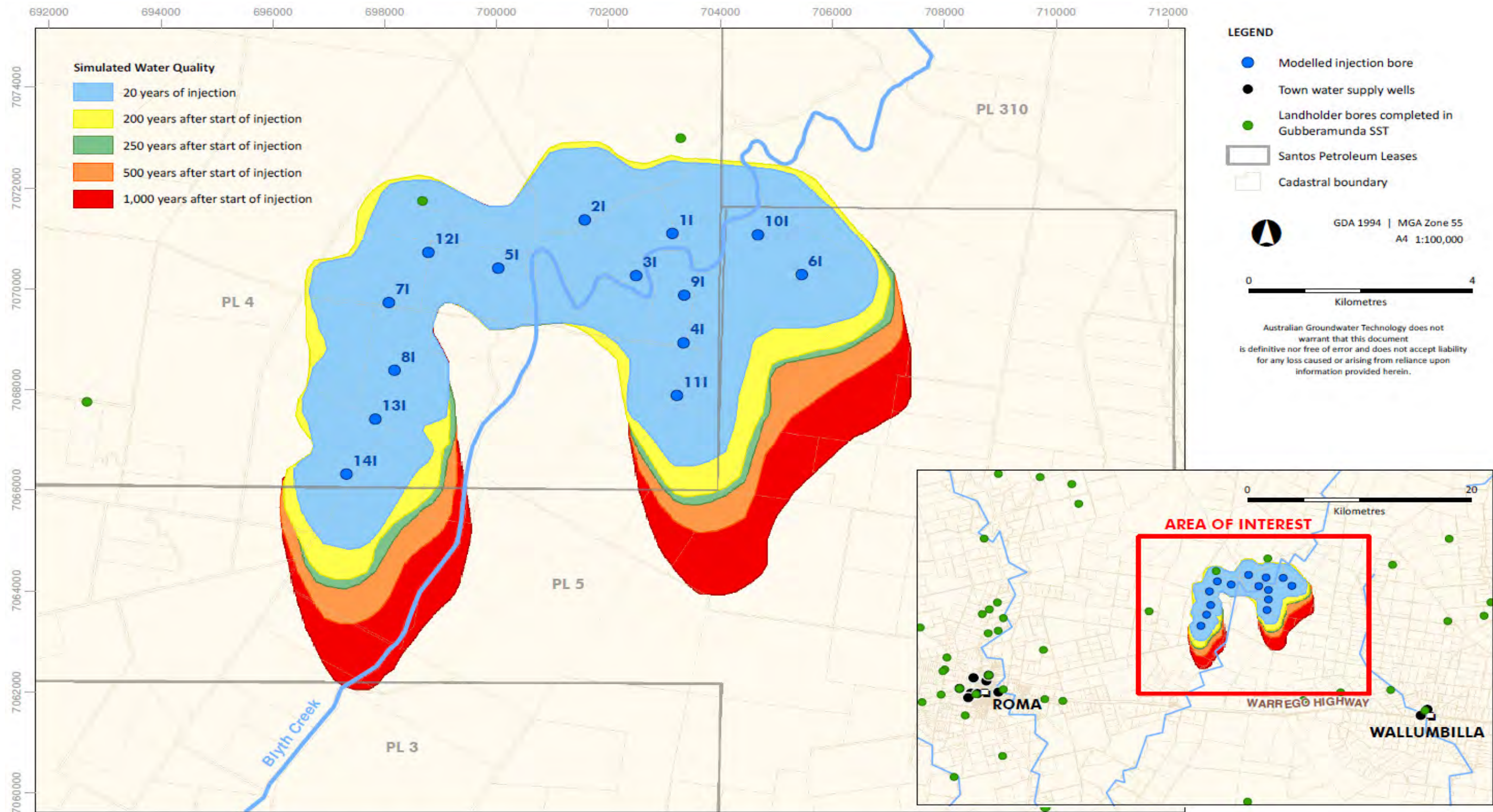


Table 4-4: Registered landholder bores within water quality impact zone

Water Quality Impact Zone – Years after start of injection				
0 – 20 years	20 – 200 years	200 – 250 years	250 – 500 years	500 – 1000 years
RN22455	RN22455	RN22455	RN22455	RN22455
RN23769	RN23769	RN23769	RN23769	RN23769
RN22843	RN22843	RN22843	RN22843	RN22843
RN22832	RN22832	RN22832	RN22832	RN22832
RN22465	RN22465	RN22465	RN22465	RN22465
RN22491	RN22491	RN22491	RN22491	RN22491
RN8143	RN8143	RN8143	RN8143	RN8143
RN22480	RN22480	RN22480	RN22480	RN22480
RN58080	RN58080	RN58080	RN58080	RN58080
RN24459	RN24459	RN24459	RN24459	RN24459
	RN8037	RN8037	RN8037	RN8037
	RN22490	RN22490	RN22490	RN22490
			RN22407	RN22407
			RN23558	RN23558
				RN58555
				RN23425

4.3.2 Geochemical Compatibility

A geochemical compatibility assessment was undertaken to determine what reactivity might be expected between the injected treated CSG water and both the native groundwater and the Gubberamunda Sandstone target formation (see Appendix I).

Testing comprised both laboratory studies and desk based geochemical modelling and interpretation.

4.3.2.1 Clogging Issues

URS (2013) reported that the loss in injection rate observed during the Hermitage MAR trial was attributed to aquifer clogging due to the interaction between very low salinity source water and clay minerals within the Gubberamunda Sandstone aquifer.

The CSIRO laboratory studies demonstrated some clay dispersion caused by the injection of low salinity water; however, no clogging was observed in the column studies.

It was very likely that swelling of smectite clays and possibly swelling-induced migration were responsible for the permeability reduction during the Hermitage MAR trial.

Laboratory studies carried out by CSIRO (as reported by URS, 2013) identified the greatest potential for clay dispersion when low salinity treated CSG water (<150 mg/L, SAR >40) was in contact with aquifer material likely to contain clay minerals. Treated CSG water with added calcium and magnesium to increase the salinity to 300 mg/L and a SAR of 3 to 5 was less likely to cause clay swelling or dispersion.

Geochemical modelling undertaken by URS (2013) indicated that mixing between the source water (with elevated reduction potential) and the ambient groundwater could result in iron precipitation and could contribute to clogging at the bore face.

PHREEQC is a computer program that is designed to perform a wide variety of aqueous geochemical calculations. PHREEQC modelling was carried out (URS 2012a) in order to assess the interaction of groundwater and the aquifer material. The modelling identified that within the Gubberamunda Sandstone aquifer, it is unlikely that excessive precipitation will occur. However, in the vicinity of the injection site (well screen and initial mixing zone), it is predicted that there may be potential for clogging induced by the precipitation of carbonate mineral phases.

4.3.2.2 Environmental/Human Health

The Hermitage MAR trial injected RO permeate into the Gubberamunda Sandstone aquifer. Water was then subsequently extracted from the injection well and tested to see how the water quality changed within the aquifer besides an obvious blending between injected water and native aquifer groundwater.

Recovered water from the Hermitage MAR trial indicated an increase in salinity, iron and manganese compared with the quality of the injected water. The increase in salinity would have resulted from blending of the injected water with the native Gubberamunda Sandstone groundwater. The elevated iron and manganese concentrations are expected to be due to the mobilisation of particulates that had accumulated in and around the bore during injection (groundwater reactivity with mild steel casing (i.e. rusting) was observed) and are unlikely, therefore, to indicate a general increase in these dissolved species in the Gubberamunda Sandstone aquifer.

Water quality collected from the observation bore further from the injection well gave a better indication of geochemical reactivity within the subsurface, and suggested that metal mobilisation did not take place and no other consequential geochemical reactivity was observed (URS, 2013).

4.4 Environmental Values

Environmental values for water are the qualities of water that make it suitable for supporting aquatic ecosystems and human water uses. These Environmental Values (EVs) need to be protected from the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways are safe for community use.

The EVs potentially present in the GLNG Roma CSG field include:

- agricultural purposes;

- human consumption;
- aquatic ecosystems;
- groundwater dependent ecosystems;
- drinking water;
- recreational purposes; and
- industrial purposes.

A brief discussion on the applicability of each potentially relevant EVs to Roma MAR Project is presented in Table 4-5.

This table shows that the environmental values of the Gubberamunda Sandstone in the location of the Roma MAR Project can be identified as:

- Human and industrial consumption, e.g. town water supply for Roma;
- Agricultural and human consumption, e.g. water supply for stock & domestic use;
- Sandstone aquifers of the GAB; e.g. the water quality of the Gubberamunda Sandstone
- Springs, i.e. where they groundwater dependent ecosystems and environmental values relating to surface water.

These environmental values are discussed in more detail in the following sections.

Table 4-5: Summary of environmental values relevant to CSG water management in the GLNG Roma CSG fields

Natural Resource	Environmental value	Description	Relevance to the Roma MAR Project
Groundwater	Agricultural purposes	Irrigation, water for farm use, and stock watering.	Neighbouring agricultural landholdings are very likely to depend on groundwater for stock watering and farm use. Irrigation is not common however.
	Human consumption	In this area, groundwater is commonly used for drinking water supply as opposed to surface water.	Neighbouring agricultural landholdings are very likely to depend on groundwater for domestic drinking water supply. Furthermore, Roma town depends on groundwater for public water supply.
	Groundwater dependent ecosystems	Springs, or a potential river system receiving base flow is the Condamine – Upper Balonne River System.	Several springs that are possibly sourced from the Gubberamunda Sandstone aquifer are located to the north of the project area.
	Sandstone aquifers of the GAB	Sandstone aquifers of the GAB include the Mooga, the Gubberamunda, and the Springbok Sandstones. In the Roma area however, only the Gubberamunda and the Mooga Sandstone aquifers are important water supply aquifers.	The target aquifer is the Gubberamunda Sandstone. In the long term, the Roma MAR project is designed to replenish the locally and historically depleted Gubberamunda Sandstone aquifer. Restoring groundwater pressures can be considered as having a long term positive impact upon this environmental value. The project has the potential to impact on groundwater quality however.
Surface Water	Aquatic Ecosystem	Waterways exhibit slightly to moderately disturbed ecosystems. Most fish species can tolerate a large range of water quality conditions. Aquatic macro invertebrates indicative of poor to moderate habitat / water quality.	The Roma MAR Project can only affect surface water ecosystems, water supplies, recreational values and cultural values where the hydrology of a groundwater fed spring is affected.
	Human consumption	Suitability for drinking water supplies (only relevant to the Balonne River and downstream of Surat)	
	Agricultural purposes	Irrigation, water for farm use, and stock watering.	
	Recreational purposes	Recreational use (swimming and fishing along the Balonne River) and aesthetics (primary recreation with direct contact, secondary recreation and visual appreciation with no contact).	
	Industrial purposes	Industrial use	
	Cultural and spiritual values	Cultural and spiritual values	
Land	Primary industries such as cropping and grazing	Cattle grazing is the predominant land use, with cropping on alluvial floodplains and around water courses.	Only relevant as far as how much the land use depend on groundwater extraction, and the protected ecosystems and species and cultural values depend on surface water that may be fed by springs and groundwater base flow.

4.4.1 Water Quality Objectives

4.4.1.1 Definition

Water Quality Objectives (WQOs) are the long-term goals for water quality management, and are numerical concentration levels or narrative statements of indicators established for receiving waters to support and protect designated EVs for those waters. They are based on scientific criteria of water quality guidelines but may be modified by other inputs (e.g. social, cultural or economic).

Section 7(3) of the Queensland Environmental Protection (Water) Policy 1999 (EPP) Water outlines a hierarchy for deciding applicable indicator and water quality guidelines for an environmental value.

Water quality objectives are quantitative measures of statements for indicators, including contaminant concentration or sustainable load measures of water that protect a stated environmental value. For particular water, the indicators and water quality guidelines for an environmental value are decided using (in descending order of preference for use) site specific documents for the water, Queensland Water Quality guidelines, Australian Water Quality guidelines (defined as the National Water Quality Management Strategy (NWQMS) and commonly referred to as the Australian and New Zealand Guidelines for Fresh and Marine Water Quality or ANZECC 2000) or other relevant documents published by a recognised entity. As such, the most appropriate WQOs should be adopted for the EVs considered applicable/present.

In absence of state-level or locally derived guidelines, the national guidelines for aquatic ecosystems and human-use environmental values (EVs) are recommended by the Queensland Water Quality Guidelines 2009 (Chapter 9) as defaults. The source guidelines for water quality objectives are shown in Table 4-6.

Table 4-6: Source of guidelines for water quality objectives of different environmental values and water types

Environmental Value	Water quality guidelines for particular water types
Irrigation	Guidelines as per ANZECC 2000
Stock Watering	Guidelines as per ANZECC 2000
Farm Use	Guidelines as per ANZECC 2000
Drinking Water Supply and Drinking Water	Australian Drinking Water Guidelines 2004

4.4.1.2 Potential WQOs

The guideline Water Quality Objectives for a range of key water quality parameters for each of the EV's identified are presented in Table 4-7. These are derived from those WQOs considered applicable to support and protect the EVs of the Gubberamunda Sandstone aquifer.

Table 4-7: Potential guideline values and water quality objectives for the Gubberamunda Sandstone aquifer.

Water Quality Parameter	Unit	Applicable Guidelines				Observed values for the Gubberamunda Sandstone (see section 2.4.4)
		ANZECC Guidelines 2000			ADWG 2004	
		Stock Water	Irrigation ^c	General water use (farm use)	Drinking Water	
pH	-	-	6-9	7-8.5 ^a	6.5 to 8.5	7.88 to 8.5
Electrical Conductivity (at 25°C)	µS/cm	-	<650 ^c	-	-	927 to 1012
Total Dissolved Solids	mg/L	<4,000 ^e	-	-	<600b	515 to 637
Dissolved Oxygen	%Sat.	-	-	-	>85 ^b	-
Turbidity	NTU	-	-	-	5	-
Hardness CaCO ₃	mg/L	-	-	< 60	<200	7.1 to 24.1
Langlier Index	-	-	-	-0.5 to 0.5		-0.61 to -0.13
Ryznar Index	-	-	-	<6		8.1 to 9.2
Log of chloride: carbonate ratio	-	-	-	<2		-0.3 to -0.2
Calcium	mg/L	<1,000	-	-		2 to 8
Chloride	mg/L	-	<175 ^c	-	<250 ^b	122 to 159
Fluoride	mg/L	<2 ^g	1	-	<1.5	0.2 to 0.3
Sodium	mg/L	-	<115 ^c	-	<180 ^b	212 to 241
Sulphate	mg/L	<1,000	-	-	<250	17 to 35
Ammonia	µg/L	-	-	-	<500 ^b	280 to 430
Nitrite	µg/L	<30,000	-	-	<3,000	< 10
Nitrate	µg/L	<400,000 ^k	-	-	<50,000	<1500
Total Nitrogen	µg/L	-	<5,000	-	-	300 to 1500
Total Phosphorous	µg/L	-	<50	-	-	20 to 550
Silica (as SiO ₂)	mg/L	-	-	-	<80	-
Aluminium	µg/L	<5000	<5000	-	<100 ^b	20 to 110 (dissolved)
Arsenic	µg/L	<500 ^f	<100	-	<10	<1 (total)
Beryllium	µg/L	-	<100	-	<60	<1 (total)
Boron	µg/L	<5,000 ^h	<500	-	<400	<50 to 70 (total)
Cadmium	µg/L	<10 ^g	<10	-	<2	<0.1 (total)
Chromium	µg/L	<1,000 ^f	<100	-	<50	<1 to 3 (total)

Water Quality Parameter	Unit	Applicable Guidelines				Observed values for the Gubberamunda Sandstone (see section 2.4.4)
		ANZECC Guidelines 2000			ADWG 2004	
		Stock Water	Irrigation ^c	General water use (farm use)	Drinking Water	
Cobalt	µg/L	-	<50		-	<1 (total)
Copper	µg/L	<1,000 ^f	<200	-	<1000 ^b	<1 to 6 (total)
Iron	µg/L	-	<200	-	<300 ^b	<50 to 90 (dissolved)
Lead	µg/L	<100 ^f	<2,000	-	<10	<1 (total)
Manganese	µg/L	-	<200	-	<100 ^b	10 to 23 (dissolved)
Mercury	µg/L	<2 ^g	<2	-	<1	<0.1 (total)
Nickel	µg/L	<1,000 ^f	<200	-	<20	<1 to 2 (total)
Selenium (Total)	µg/L	<200	<200	-	<10	<10 (total)
Uranium	µg/L	-	<10	-	<17	<1 (total)
Vanadium	µg/L	-	<100	-	-	<10 (total)
Zinc	µg/L	<20,000	<2,000	-	<3,000 ^b	6 to 20 (total)

Notes:

A shaded cell indicates where native groundwater from the Gubberamunda Sandstone aquifer exceeds a guideline value

a Assume range for moderate fouling potential of groundwater

b Based on aesthetic problems

c Values for long term irrigation trigger chosen as most conservative

e Suitable for beef cattle and horses

f May be hazardous to animal health if exceeded

g Mercury may accumulate in edible animal tissues >2 µg/L and may therefore pose human health risk

h Higher concentrations of Boron (>5,000µg/L) may be tolerated for short periods of time.

- indicates no value available

4.5 Impact on Environmental Values

The groundwater modelling has predicted that continuous injection of up to 24 ML/d into 12 injection bores results in:

- Hydraulic impact zone (>0.2 m) in the Gubberamunda Sandstone extending up to approximately 15 km from the injection bores.
- Hydraulic impact zone (>0.1m) in the Mooga Sandstone extending up to approximately 2 km from the injection bores

- Water quality impact zone extending up to 1.5 km following 20 years of injection, then migrating up to 4 km over the next 1000 years in the Gubberamunda Sandstone only.
- Water quality impact zone intersecting up 1 bore screened in the Gubberamunda Sandstone.

4.5.1 Town Supply and Industrial Groundwater Use

Section 4.2 identifies that there are no municipal town water supplies in the vicinity of the Roma MAR Project that extract water from the Mooga and Gubberamunda Sandstones. The nearest of these water supply bores are located beyond the 0.1 m hydraulic impact zone and the water quality impact zone. Therefore no municipal or industrial water supplies are deemed to be impacted by the Roma MAR Project.

4.5.2 Agricultural and Domestic Groundwater Use

Section 4.2 identifies that a number of existing landholder groundwater bores in the vicinity may be affected both in terms of increased groundwater pressures in the Gubberamunda and Mooga sandstones. The potential hydraulic impact to landholder bores in the vicinity of the Roma MAR is variable. An artificial artesian zone is expected within the Gubberamunda Sandstone, and a zone of >5 m change in hydraulic head is also expected in the Gubberamunda and Mooga Sandstones. A mitigation, monitoring and management scheme in relation to undesirable pressure effects is presented in Section 5.2.3.

Section 4.3 identifies that a number of existing landholder bores may also be impacted by a change in groundwater quality within the Gubberamunda Sandstone. The potential water quality impact zone also has the potential to impact upon potential landholder bores. A mitigation, monitoring and management scheme in relation to the potential for aquifer contamination is presented in Section 5.2.2.

4.5.3 Groundwater Springs

Section 4.2 and Section 4.3 demonstrate that the nearest springs sourced from the Gubberamunda Sandstone are beyond the 0.1 m impact zone and the water quality impact zones, respectively. Therefore no springs are determined to be impacted by the Roma MAR Project.

4.5.4 Sandstone aquifers of the GAB

Section 4.2 and Section 4.3 identify the size and extent of the hydraulic impact zone and water quality impact zone that will impact upon the Gubberamunda and Mooga Sandstones. These formations are considered sandstone aquifers of the GAB.

The pressure and water quality changes that may be induced by the Roma MAR Project are deemed to be inconsequential to the environmental value of the Gubberamunda and Mooga Sandstone aquifers with the exception for their use as agricultural and domestic water supplies (see Section 4.5.2 above). A mitigation, monitoring and management scheme in relation to the potential for aquifer contamination and undesirable pressure effects is presented in Section 5.2.2 and Section 5.2.3, respectively.

The potential for the hydraulic integrity of the Gubberamunda Sandstone to be impacted through hydraulic fracturing is to be managed by the mitigation, monitoring and management scheme presented in Section 5.2.1.

4.6 Adopted Water Quality Objectives

A summary of the adopted water quality objectives for injection water is shown in Table 5-4 (in-line monitoring) and Table 5-5 (laboratory monitoring) in Section 6. These WQOs are based upon the summary of potential guidelines presented in Table 4-6, and the groundwater quality of the Gubberamunda Sandstone where these values exceed the potentially applicable guideline values (e.g. for electrical conductivity and total dissolved solids). The suite of parameters are sufficient to demonstrate that the Roma MAR Project is being operated in a safely in respect of potential harm to human health and the environment.

5 Operational Monitoring, Management and Reporting

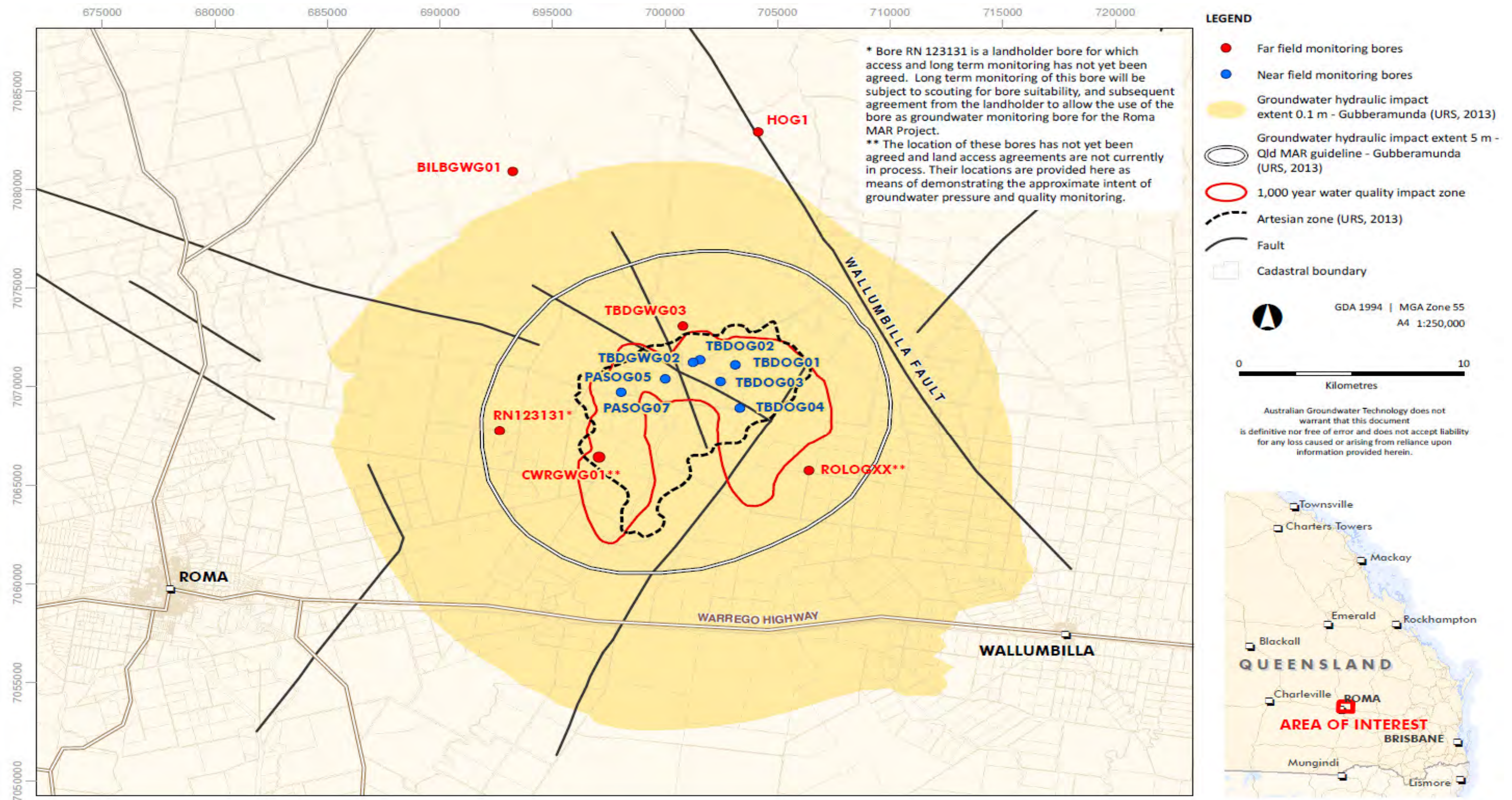
This section presents the management and monitoring of the MAR scheme which addresses parts l, m, o, p, q and s of the EA IMP requirements.

EA IMP Requirements		Corresponding Information Section
l)	A risk assessment consistent with the risk framework specified in Australian Guidelines for Water Recycling: Managed Aquifer Recharge, identifying potential hazards, their inherent risk, preventative measures for the management of potential hazards and after consideration of the operational monitoring to manage potential hazards identified in the risk assessment including details on sampling and analysis methods including frequency and locations, and quality assurance and control	Section 5 Appendix A
m)	Verification methods to assess performance of the injection activities	Section 5.2
o)	The indicators or other criteria against which the performance of fluid injection will be assessed	Section 5
p)	Procedures that will be adopted to regularly review the monitoring program and to report to management and the administering authority should unforeseen or noncompliant monitoring results be recorded	Section 5.3 and 5.4
q)	Procedures that will be implemented to prevent unauthorised environmental harm from unforeseen or non-compliant monitoring results	Section 5.2
s)	A program to monitor impacts on the environmental values of the receiving environment identified by Condition (BE 7)	Section 5.2

5.1 Groundwater Monitoring Bores

As part of the MAR scheme, ten observation bores have been constructed. An additional landholder bore is being considered for inclusion as a long term groundwater monitoring location for the Roma MAR Project, and a further two observational wells are planned to be drilled prior to commencement of injection.

A summary of these observation bores (13 in total) is provided in Table 5-1, and locations shown in the construction and bore log details of those that have been constructed by Santos are provided in Appendix D. The baseline survey of the landholder bore is also provided in Appendix D.



Each of these bores will be installed with telemetered monitoring equipment. The equipment will be capable of recording groundwater pressure, temperature and electrical conductivity of the groundwater in the observation well at the depth of the screened interval. Readings will be transmitted instantaneously via the mobile phone network to a central holding repository.

Each bore will be capable of providing groundwater samples for laboratory analysis. Each will also be fitted with ports to enable manual measurement of sub-artesian groundwater levels.

5.1.1 Near field monitoring bores

Of the 13 observation bores, seven are located within the immediate vicinity of or in between injection wells. As such, they are predicted to see very large pressure increases in groundwater levels in response to injection, and are predicted to become artesian throughout the life of the scheme.

Artesian groundwater levels are expected in the near field observation wells. They will therefore be fitted with sealed bore head works that allow for groundwater sampling under artesian conditions, and pressure gauges that can be read without opening the bore and will not allow groundwater to freely discharge from the bore.

5.1.2 Far field monitoring bores

The remaining six observation bores are located more than a kilometre from the injection bore field. These are considered as far field groundwater monitoring bores.

Of these six far field groundwater monitoring bores, four are located between 1 km and 10 km from the Roma MAR Project. They are predicted to see groundwater level changes in the order of 5 m to 25 m throughout the life of the Roma MAR Project and will be used to assess the accuracy of the predictive groundwater model.

The remaining two far field observation bores are located more than 10 km from the Roma MAR Project and beyond the limit of the predicted 0.1m hydraulic impact zone. They are designed to act as sentinel monitoring locations to detect for any potential change to groundwater levels that may be greater than predicted and which might potentially alter the hydrology of groundwater springs that are located north of the Roma MAR bore field.

All monitoring wells will be constructed to allow representative samples of groundwater to be taken from the Gubberamunda Sandstone aquifer, in accordance with Australian or Queensland Government guidelines, as appropriate.

Table 5-1: Groundwater monitoring bores proposed for the Roma MAR Project

Bore	Easting	Northing	Ground Elevation (m AHD)	Approx water level (mbTOC)	Total Depth (m bgl)	Gravel Pack Interval (m bgl)	Slotted Screen Interval (m bgl)	Casing Size (mm)	Distance from nearest MAR well	Closest well	Distance category
TBDOG01	703124	7071107	327	32.7	274	230.5–265	257–264	110	18.7 m	TBDIG01	Near field
TBDOG02	701558	7071365	336	41.6	271	222–271	252–255 257–264	110	16.3 m	TBDIG02	Near field
TBDOG03	702471	7070260	323	30.2	275	221–271.5	259–265	110	21.2 m	TBDIG03	Near field
TBDOG04	703322	7068913	338	46.4	301.2	243–301.2	273–279 291–294	110	23.3 m	TBDIG04	Near field
PASOG05	700014	7070404	–	39.4	280.4	213–258	226–229 241–247	110	16 m	PASIG05	Near field
PASOG07	698059	7069722	–	–	257	211–254	238–244	104	14 m	PASIG07	Near field
TBDGWG02	701254	7071234	340	40.02	275	222.5–254	247–253	100	347 m	TBDGIG02	Near field
TBDGWG03	700794	7073079	–	–	256	224–256	249 - 256	110	1.9 km	TBDIG02	Far field
ROLGWG01**	706395	7065737	Planned observation well						4.3 km	TBDIG04	Far Field
RN123131*	692658	7067769	-	-	282***	-	250–282***	135	5.8 km	PASIG07	Far field
CWRGWG01**	695337	7064618	Planned observation well						6.2 km	PASIG07	Far Field
HOG1	704142	7082922	425	-	230.2	185-224	202-223	100	11.8 km	TBDIG02	Far field
BILBGWG01	693242	7080918	433	119	294	269–290	283–289	104	12.6 km	TBDIG02	Far field

* Bore RN 123131 is a landholder bore for which access and long term monitoring has not yet been agreed. Long term monitoring of this bore will be subject to scouting for bore suitability, and subsequent agreement from the landholder to allow the use of the bore as groundwater monitoring bore for the Roma MAR Project.

** The location of these bores has not yet been agreed and land access agreements are not currently in process. Their locations are provided here as means of demonstrating the approximate intent of groundwater pressure and quality monitoring.

*** Bore construction details confirmed from the Queensland Government landholder bore database.

5.2 Injection Monitoring Programme

The purpose of monitoring is to ensure that the scheme is operating in accordance with the performance specifications detailed in the design and systems manuals and that the water quality is within the values specified on the operating licence. Monitoring involves real time data acquisition through instrumentation and the collection of representative groundwater water samples for analytical determination of key chemical parameters.

Table 5-2 presents the operational monitoring programme that is proposed to be undertaken throughout implementation of the Roma MAR Project.

- The operational monitoring programme in Table 5-2 specifies both non-reportable operating limits and reportable operating limits. The reportable limits are those limits that Santos deems to be the maximum possible operational limits. The exceedance of a reportable limit would be considered non-compliant and therefore reportable to the regulatory authority.
- The non-reportable limits are provided here to provide context in regard to the way in which the exceedance of the reportable limit shall be avoided in practice. At this stage, the non-reportable limits are provided for information only, and may be developed and adjusted throughout the lifetime of the scheme to maximise the operational efficiency of the scheme whilst avoiding possible exceedance of reportable operational limits.

The monitoring programme outlined in Table 5-2 is designed to manage following risks to the Gubberamunda Sandstone aquifer that were identified by the residual risk assessment:

- Formation fracturing;
- Aquifer contamination; and
- Undesirable aquifer pressurisation effects.

The following sections describe the reportable and non-reportable operating limits that are determined to be appropriate in respect of the residual risks of the Roma MAR Project

Monitoring of flows and water levels and the collection of water samples will be carried out by appropriately trained personnel according to relevant standards. Laboratory testing of water samples will be administered by Santos with all water quality analysis carried out, where possible, by a laboratory that has National Association of Testing Authority (NATA) certification for the proposed analysis.

Table 5-2: Summary of operational monitoring programme and system controls

Risk	Monitoring data	Description of system controls	Monitoring frequency**		Monitoring review period	Non-reportable operating limit *	Non-reportable limit response	Reportable operating limit
			<1 year operation	>1 year operation				
Formation fracture pressure exceeded	Injection bore pressure	<p>Injection pressures are generated by pumps located at the water treatment plant. A pressure metre will record the injection pressure at each bore.</p> <p>Bore pressure readings will be fed to central control room. The readings are used to control the motorised globe valve located at each bore's head works can be automatically controlled.</p> <p>Readings may also control flow by-pass valves.</p>	Every minute		Instant	Refer to Table 5-3	Automated closing of the globe valve to trim flow rates and allow the pressure to subside.	Refer to Table 5-3
Aquifer contamination	In-situ analysis of injection water quality	<p>Live (in line) monitoring of pH, EC, turbidity of water leaving the treatment plant.</p> <p>In line water quality readings will be fed to the central control room.</p>	Every minute		Instant	Refer to Table 5-4	<p>Possible diversion of treated water to the pre-treatment pond.</p> <p>Throttling and closing of flow control valves on bore head works.</p>	Refer to Table 5-4
	Lab analysis of injection water quality	Water quality sampling and laboratory analysis of treated injection water.	Fortnightly	Monthly	As soon as laboratory results become available (typically <1 month)	There are no operational limits to injection water quality analysed in the lab.	Re-sampling of the injection water shall be undertaken to verify the water quality result. Possible source of exceedance will be investigated.	Refer to Table 5-5
	Groundwater quality monitoring	<p>At least three representative groundwater samples will be taken from each monitoring bore prior to start up of injection to establish water quality baseline.</p> <p>Down-hole transducers will record EC at least daily to be used to provide comparative data.</p> <p>More frequent sampling and review during first year of start up.</p>	Monthly	Every six months	One month following sampling	There are no operational limits to groundwater quality.	Not applicable	There are no reportable limits for groundwater quality.
Undesirable aquifer pressure effects	Groundwater pressure monitoring	<p>Bore pressure monitoring will be recorded and transmitted by telemetry and automatically reviewed at least daily.</p> <p>Manual readings of groundwater level will be taken more frequently during the first six months of operation.</p>	Daily telemetry, supported by monthly manual dips	Daily telemetry, supported by six-monthly manual dip	Instant	There are no operational limits for groundwater pressure.	<p>Manual dipping of the aquifer pressure in the bore to verify the telemetered reading.</p> <p>Assessment of operational field data to determine if reportable limit exceedance is likely.</p> <p>Possible revision to groundwater impact assessment.</p>	There are no reportable limits for groundwater pressure.

Risk	Monitoring data	Description of system controls	Monitoring frequency**		Monitoring review period	Non-reportable operating limit *	Non-reportable limit response	Reportable operating limit
			<1 year operation	>1 year operation				
	Artesian flowing groundwater observed discharging to grade	Baseline assessment completed for all bores within the predicted artesian zone. RCAP of conventional gas wells within first year of operation. All known bores will be checked more frequently during first year of operation. Notify landholders of the potential issue, encourage early reporting of any observable discharges to DEHP and Santos.	All known bores visited monthly	All known bores visited annually	Immediately following confirmed observation	There are no non-reportable operating limits.	None.	Flowing water at the surface is reported and/or observed within the predicted artesian zone.
	Injection volume	In line flow monitoring rates will be controlled by automated throttling of the flow control valve on the bore head works to maintain instantaneous injection rates below the target 2 ML/d per bore.	Live flow monitoring		Instantaneous	There are no non-reportable operating limits.	None.	More than 2 ML/d injected into any single injection bore.

* Operational limits may be adjusted to be different from that presented here. The design intention is to develop operational limits to minimise reportable limit exceedances, and therefore minimise disruption to water treatment and injection.

** First year of operation, or after at least 3000 ML have been injected, whichever is later.

5.2.1 Formation Fracturing

The risk of fracturing the target formation will be managed by monitoring the injection pressure at each injection bore. The determination of the formation fracture pressure for each bore is presented in Section 3. The assessment of formation fracture pressure is based on a conservative assessment of formation rock strength.

The reportable operating limit is considered to be 90% of the formation fracture pressure. The non-reportable operating limit for maximum injection pressure has been determined, assuming 85% of the maximum allowable pressure. This is presented in Table 5-3.

The limits represent the pressure that will be measured by the pressure gauge located upstream of each injection bore's head works (see Section 3). The pressure readings will be alarmed and adjusted to automatically open and close the motorised globe valve located at each injection to increase or decrease the injection pressure, respectively.

Table 5-3: Operating limits for injection pressure at the surface

Injection well	Formation fracture pressure (at surface) (KPa)	Reportable limit at surface (90% formation fracture pressure) (KPa)	Non-reportable limit at surface (85% formation fracture pressure) (KPa)
TBDIG01	4030	3627	3420
TBDIG02	4105	3695	3490
TBDIG03	4090	3681	3480
TBDIG04	4450	4005	3780
PASIG05	3865	3479	3285
PASIG07	3745	3371	3185

5.2.2 Aquifer contamination

The risk of potential aquifer contamination will be monitored and managed by three means:

- In-line (live) monitoring of the injection water quality
- Sampling and subsequent laboratory analysis of the injection water quality
- Sampling and subsequent laboratory analysis of groundwater taken from the target formation

5.2.2.1 In-line analysis of injection water quality

An in-line water quality meter will be located on the flow line downstream of the de-oxygenation unit and the pump skids that will be used to pump and distribute water to the injection bore flow lines. The reportable and non-reportable limits for the parameters that will be measured by the in-line water quality meters are presented in Table 5-4.

The operating limit for in-line conductivity is only deemed reportable if it exceeds the maximum water quality limit of 1000 $\mu\text{S}/\text{cm}$ for a period of 30 minutes or more. This recognises that the control system that blends pre-treated CSG water with RO permeate may have a lag time between water quality sensor and flow rate adjustment. Shorter lag times could be achieved but are not desirable since they may lead to larger variations in injection water quality (i.e. large flow rate adjustments over short time spans) and increase the risk producing injection water with a very low electrical conductivity (i.e. below the minimum non-reportable operating limit) that could cause irreversible clogging of injection wells.

Table 5-4: Operating limits for injection water quality monitored in-line

Parameter	Non-reportable operating limit	Reportable operating limit	Source of trigger value
Conductivity ($\mu\text{S}/\text{cm}$)	300 to 1000	> 1000 over a duration of 30 minutes or more	Lower value as determined by geochemical compatibility assessment. Upper value as observed for the native groundwater of the Gubberamunda Sandstone aquifer
Turbidity (NTU)	5 NTU	None	To reduce the long term risk of mechanical clogging
pH	7.0-8.0	6.5–8.5	ADWG 2004
Dissolved oxygen (mg/L)	0.5	1.0	As modelled by compatibility assessment

5.2.2.2 Laboratory analysis of injection water quality

Injection water will be sampled from the tap located on each injection bore head works. Sampling will occur fortnightly during the first year of operations, then monthly after that. Sampling will only be required in any given month or two week period (in the first year) that water has been pumped to the bore.

The target injection water quality is outlined in Table 5-5. Note that most of the limits are based on Australian Drinking Water Guideline (ADWG) values which are generally the lowest of the guidelines values presented in Table 4-6. The reportable limit of dissolved oxygen is based upon modelling which shows that increasing the dissolved oxygen concentration may increase the risk of aquifer clogging. The reportable limits for TDS, total iron and total manganese concentrations are based on those values observed within the target aquifer.

Table 5-5: Minimum detection limits and reportable operating limits for injection water quality

Parameter	Minimum detection limit	Reportable operating limit (mg/L)	Relevant WQO achieved (see Table 4-7)
Electrical Conductivity (mg/L)	1	>1000	Gubberamunda Sandstone
Dissolved oxygen (mg/L)	0.1	1	-
Ammonia as N (mg/L)	0.01	0.5	ADWG, 2004
Total nitrite as N (mg/L)	0.01	50	ADWG, 2004
Faecal coliforms (cfu/100ml)	<1	1	ADWG, 2004
Total chlorine (mg/L)	0.01	5	ADWG, 2004
Benzene (mg/L)	0.001	0.001	ADWG, 2004
Toluene (mg/L)	0.002	0.8	
Ethylbenzene (mg/L)	0.002	0.3	
Xylene (mg/L)	0.002	0.6	
Aluminium (total) (mg/L)	0.01	0.1	ADWG, 2004
Arsenic (mg/L) (total)	0.001	0.01	ADWG, 2004
Beryllium (mg/L) (total)	0.001	0.06	ADWG, 2004
Boron (mg/L) (total)	0.001	0.4	ADWG, 2004
Cadmium (mg/L) (total)	0.0001	0.002	ADWG, 2004
Chromium (mg/L) (total)	0.001	0.05	ADWG, 2004
Copper (mg/L) (total)	0.001	1	ADWG, 2004
Iron (mg/L) (total)	0.001	0.3	ADWG, 2004
Lead (mg/L) (total)	0.001	0.01	ADWG, 2004
Manganese (mg/L) (total)	0.001	0.1	ADWG, 2004
Mercury (mg/L) (total)	0.0001	0.001	ADWG, 2004
Selenium (mg/L) (total)	0.01	0.01	ADWG, 2004
Zinc (mg/L) (total)	0.005	3	ADWG, 2004

5.2.2.3 Laboratory analysis of groundwater

Groundwater will be sampled from a number of monitoring wells that have been nominated for ongoing groundwater level and groundwater quality monitoring (see Section 5.1). The list of water quality parameters are specified in Table 5-6.

Table 5-6: Water quality parameters and minimum detection limits for groundwater quality monitoring

Water quality parameter	Units	Minimum detection limit
Biological Oxygen Demand (BOD)	mg/L	2
Total dissolved solids (TDS)	Mg/L	1
pH	pH units	0.01
Oxidation Reduction Potential	mV	0.1
Temperature	°C	0.1
Total Organic Carbon (TOC)	mg/L	1
Turbidity (NTU)	NTU	0.1
Suspended Solids	mg/L	5
Calcium (Ca)	mg/L	1
Magnesium (Mg)	mg/L	1
Sodium (Na)	mg/L	1
Potassium (K)	mg/L	1
Bicarb (HCO ₃)	mg/L	1
Chloride (Cl)	mg/L	1
Fluoride (F)	mg/L	0.1
Sulphate (SO ₄)	mg/L	1
Aluminium (Al) - total	mg/L	0.1
Antimony – (Sb) – total	mg/L	0.001
Arsenic (As) – total	mg/L	0.001
Barium (Ba) – total	mg/L	0.001
Beryllium (Be) – total	mg/L	0.05
Boron (B) - total	mg/L	0.001
Cadmium (Cd) - total	mg/L	0.0001
Chromium (VI) (Cr)	mg/L	0.01
Copper (Cu) - total	mg/L	0.001
Iron (Fe) – total	mg/L	0.001

Water quality parameter	Units	Minimum detection limit
Lead (Pb) – total	mg/L	0.001
Manganese (Mn) – total	mg/L	0.001
Mercury (Hg) – total	mg/L	0.0001
Molybdenum (Mo) - total	mg/L	0.001
Nickel (Ni) – total	mg/L	0.001
Selenium (Se) – total	mg/L	0.01
Silver (Ag) - total	mg/L	0.001
Thallium (Ti) – total	mg/L	0.001
Vanadium (V) – total	mg/L	0.01
Zinc (Zn) - total	mg/L	0.005

5.2.3 Undesirable Pressure Effects

The risk of undesirable pressure effects will be monitored and managed by three means:

- Groundwater pressure monitoring
- Observing artesian groundwater discharging to grade
- Injection volume

5.2.3.1 Groundwater pressure monitoring

Changes in groundwater pressures will be observed and recorded in 13 monitoring wells that have been nominated for ongoing groundwater level and groundwater quality monitoring (see Section 5.1). Pre-injection conditions shall be monitored for at least three months before any injection via the Roma MAR Project.

Near field pressure monitoring

Seven of the 13 observation wells are installed immediately adjacent to, or in between, injection wells. They are designed to monitor the injection performance of the injection wells themselves, and will provide information on how the injection well, and aquifer immediately adjacent to the injection well, are performing. Therefore they do not represent suitable monitoring locations for monitoring of undesirable, far-field pressure effects. They are all expected to become artesian throughout the life of the scheme.

Far field pressure monitoring

Four monitoring wells will be located more than 1 km from the nearest injection well and within the 5 m hydraulic impact zone. These are nominally TBDGW02, TBDGW03, ROLOGWG01, CWRGWG01 and RN123131. The four wells in this zone have been set reportable operating limits for groundwater pressure.

One of the observation bores (BILBGWG01 and HOG1) are located to the south-west of the Roma MAR Project. These bores are located within the 5 m hydraulic impact zone, and in the direction of the Roma town and municipal water supply bores (see Figure 13). This monitoring bore can be monitored to provide additional information of far field effects in the direction of the municipal town supply bores.

Two of the observation bores (BILBGWG01 and HOG1) are located to the north of the Roma MAR Project. These bores are located <5 km beyond the limit of the 0.1 m hydraulic impact zone, and more than 10 km from the Barton Springs and Springs Ridge spring complexes (see Figure 13). Whilst these monitoring bores are not predicted by the model to see any change in groundwater level, they will be monitored and used to provide additional information of far field effects, particularly in the direction of the springs with Gubberamunda Sandstone as their source aquifer.

Landholder water bores

Seven landholder water bores have been identified as potentially seeing an increase in groundwater levels greater than 5 m throughout the life of the Roma MAR Project. These bores are all considered to be screened within the Gubberamunda Sandstone (see Table 4-2).

In mitigation of any potential negative effect that an increase in groundwater level may cause, a bore assessment will be undertaken (as 'bore assessment' it is defined by the Water Act, 2000). A conduct and compensation agreement shall be implemented where deemed necessary by the findings of the bore assessment in relation to the potential impact of the Roma MAR Project upon the operation of these landholder bores.

A bore assessment (as 'bore assessment' it is defined by the Water Act, 2000) will be undertaken on all seven bores prior to the commencement of injection. The findings of the assessment shall be provided to both the landholder and the regulatory authority.

5.2.3.2 Artesian groundwater observed discharging to grade

A baseline assessment of all water bores has been completed across the whole of the Roma CSG Field. This area includes the predicted artesian zone.

All bores that have not been plugged and abandoned and which are also located within the predicted artesian zone will be inspected every two months during first year of operation of the Roma MAR Project. After the first year, all known bores within the artesian zone that have not been plugged and abandoned will be inspected at least annually. Records of the plugging and abandonment activities will be made available to the regulator for inspection.

All landholders within the artesian zone will be notified of the potential change in groundwater pressure as a consequence of the Roma MAR Project. Landholders will be encouraged to report any observable artesian discharges to Santos staff, or the appropriate Regulatory Authority (e.g. DNRM) if they prefer.

Immediately following confirmed observation, a survey of the source of flowing water shall be undertaken which may include, as an example: photographs; location mapping; water quality sampling and testing; flow rate assessment and water pressure assessment. The survey shall be incorporated into a report outlining the possible cause of the artesian flowing water, and determine if it is related to the Roma MAR Project activities.

In response to observable artesian flowing water being attributable to Roma MAR Project activities, the flow of water shall be controlled in the first instance. If the flow cannot be adequately controlled, injection into the nearest injection bore(s) may be throttled until artesian conditions subside and the seepage is controlled.

Long term control may include the plugging and abandoning of a bore. Make good measures (in accordance with the Water Act, 2000) will be implemented to compensate landholders for loss of water production bores due to plugging and abandonment of water bores.

5.2.3.3 Injection volume

The injection volume into each injection bore will be measured using a flow metre installed on the flow line up gradient of each injection bore's head works. Readings from the flow metre will be recorded and monitored in the central control room at the Roma HCS-02 treatment plant. The readings will be used to automatically control the flow rates to less than 2 ML/d per injection bore using the motorised control valve located on the flow line up gradient of each injection bore's head works.

The reportable limit for injection volume is an injection volume greater than 2 ML/d recorded for any single bore.

5.3 Injection Management Response

A summary of the injection management response to reportable operating limit exceedances are summarised in Table 5-7.

5.4 Injection Management Reporting

5.4.1 Internal Review and Reporting

The monitoring data collected in the field (injection pressures, volumes, field parameters and water levels) will be reviewed by a suitably qualified person in comparison to the relevant criteria. Laboratory collected data will be reviewed as soon as it is available and compared to the relevant operating limits.

Monitored values in excess of operating limits will be reported to the relevant project's Facility Supervisor and Environmental Representative. Field technicians shall be able to contact Santos' Water Team Representative and Environmental Representative to confirm the appropriate action in accordance with the response procedures.

Internal compliance reporting will be undertaken in order to document any management actions resulting from an incident/ exceedance.

Internal compliance reporting will include:

- An exceedance register including details of the exceedance;

- Description of any management actions implemented (e.g. cease injection, mechanical maintenance, water quality sampling); and
- A copy of all notifications (government body, landholder, internal).

5.4.2 Reporting to the Regulatory Authority

In accordance with the EA PEN103814911, the regulatory authority (DEHP) will be notified within 24 hours of any non-compliance. Within ten working days of a non-compliance being notified to the regulator, unless a reasonable justification is provided, a report will be submitted to the regulator outlining the non-compliance and any corrective measures intended to be implemented.

A fluid injection report which has been certified by a suitably qualified person will be submitted to the administering authority with each annual return. The fluid injection report will summarise the results of the Injection Monitoring Program and provided interpretation and analysis of those results including, but not necessarily being limited to:

- (a) the results of the monitoring program as required by the EA;
- (b) monthly summaries of injection conditions;
- (c) commentary on changes to injection fluid characteristics or sources;
- (d) annulus performance;
- (e) mechanical integrity tests;
- (f) pressure of the target formation;
- (g) an updated risk assessment providing details on potential hazards including their inherent risk, preventative measures & monitoring and the residual risk;
- (h) quantity of fluid injected; and
- (i) quality parameters of fluid injected.

Table 5-7: Reportable operating limit responses

Risk	Monitoring data	Reportable limit response	Remediation and reporting
Formation fracture pressure exceeded	Injection bore pressure	The motorised globe valve will close, automatically shutting-in or reduce the bore pressure in response to exceedance of 90% of the formation fracture pressure. Possible diversion of treated water to pre-treatment storage pond. If diverted or bore shut-in, injection to recommence once bore head pressures have subsided.	<p>Notify and report to DEHP in accordance with Section 5.4.2.</p> <p>Report to assess impact of exceedance.</p> <p>Report to assess suitable remediation strategy, if required.</p>
Aquifer contamination	In-situ analysis of injection water quality	The motorised globe valve will close, automatically shutting-in all of the bores fed by the flow line that is being monitored for in-line water quality. Possible diversion of treated water to pre-treatment storage pond. Treated water to be re-diverted back to the injection bore flow lines once the in-line water quality is within specification.	
	Lab analysis of injection water quality	Following detection of a reportable limit exceedance, re-sampling of the injection water shall be undertaken to verify the water quality result. Following at least two consecutive exceedances, manual control of valves at the bore head works would immediately shut-in the injection bore and treated water will be diverted away from the injection bores. A full investigation into the source of the limit exceedance. Possible review and adjustment of treatment. If shut down, system will not be re-started until two samples of injection water quality have been analysed to demonstrate that the water quality criteria can be met.	
Undesirable aquifer pressure effects	Groundwater pressure monitoring	Following detection of an exceedance, manual dipping of the aquifer pressure in the bore shall be commissioned to verify the result. Assessment of operational field data will yield improved estimates of sub-surface parameters. Revised assessment will allow for re-calibration and re-run of the predictive groundwater model to transient injection conditions, i.e. to replicate the observed change in groundwater levels, and their future propagation. Groundwater modelling or injection management plan revised and submitted to the regulator within 2 months of observed exceedance. Possible re-assignment of reportable and non-reportable operating limits of groundwater pressure as deemed appropriate by the revised risk assessment.	
	Artesian flowing groundwater observed discharging to grade	Immediate survey of the source of flowing water, including: photographs; location mapping; water quality sampling and testing; flow rate assessment and water pressure assessment (if feasible). Implementation of flow control at the source of discharge If flow controlled cannot be established, injection into the nearest injection bore(s) may be throttled until artesian conditions subside and the seepage is controlled. A full investigation into the source of the limit exceedance. Control may include the plugging and abandoning of a bore. Make good measures to be implemented.	
	Injection volume	Live monitoring of bore flow rate provides feedback to motorised globe valve on the bore head works to control the flow rate. The longer term average injection flow rate shall be balanced to offset injection rates below 2 ML/d for the reporting period	

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Attachment 1 – Roma MAR - Numerical Model Report

Attachment 2 – Geochemical Evaluation and Operational Risk Assessment

Attachment 3 – Hydraulic Estimates and Design Parameters

Attachment 4 – Supporting Documents

URS, (2013b) Roma Managed Aquifer Recharge Scheme – Potential Monitoring Location Summary. Memorandum dated 4 April 2013.

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