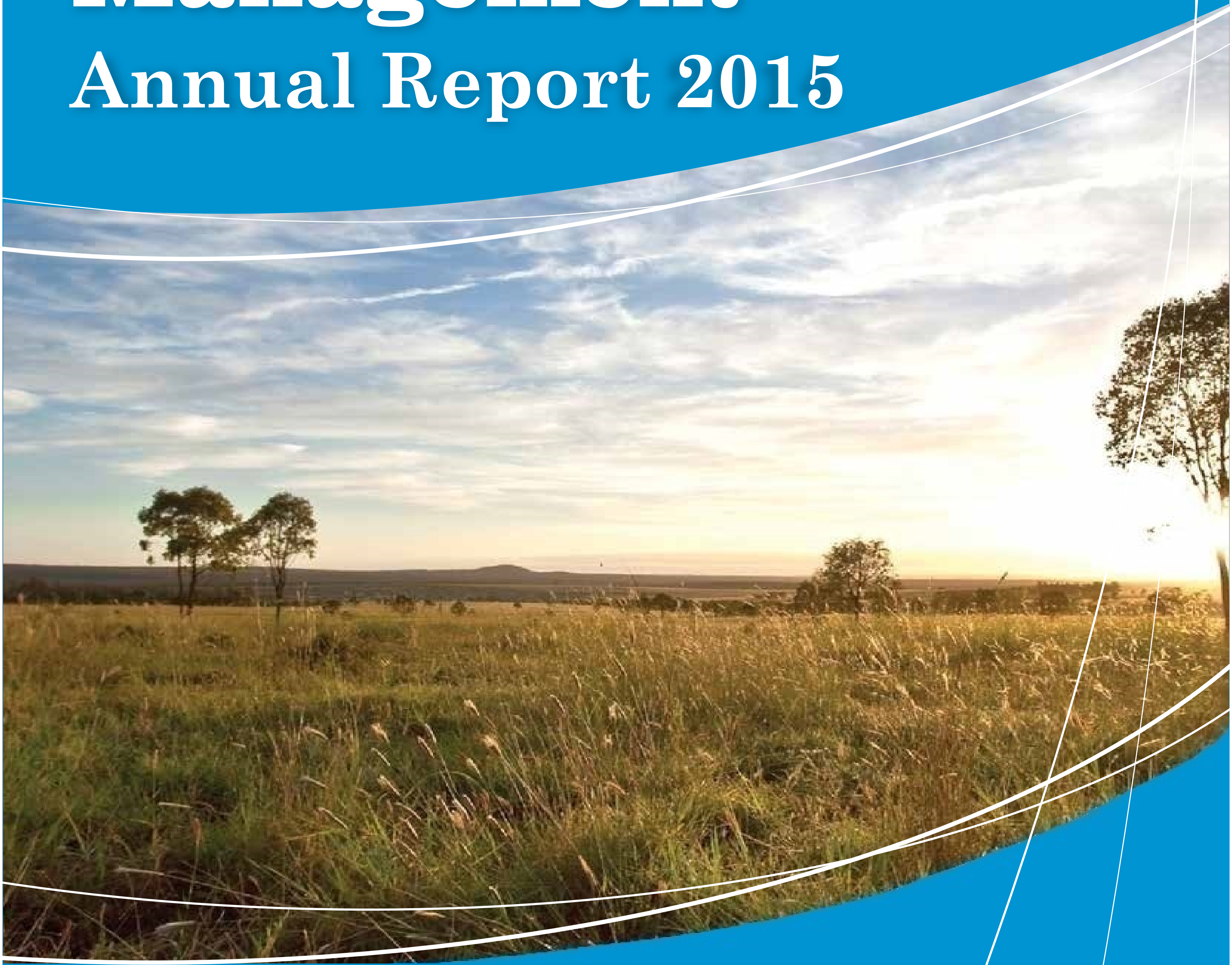
Santos GLNG

Santos GLNG

Coal Seam Water Monitoring and Management

Annual Report 2015



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Executive Summary

Purpose

The Coal Seam Water Monitoring and Management Annual Report 2015 for the Santos GLNG Project, is required by the Commonwealth Department of the Environment (DOTE). This Annual Report:

- Has been prepared in accordance with Conditions 49 i) and 53 c)ix) of *the Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (EPBC Act) Approval 2008/4059;
- Reports progress against the Santos GLNG Stage 2 CSG Water Management and Monitoring Plan (Revision 2) (Stage 2 CWMMP Rev 2); and
- Covers the period 1 January 2015 to 31 December 2015.

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. The potential risk of adverse impact to Matters of National Environmental Significance (MNES) remains low.

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 2015.

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 3
	Installation of Early Warning Spring (EWS) monitoring network.	End 2016.	▶	Section 3
	Ground truthing of a selection of springs to assess the presence of EPBC listed species and EPBC communities.	On and off tenure springs baseline initiated as part of the JIP, to be reported April 2015.	●	Section 3
	Santos GLNG will assume responsibility of mitigation (if required) for on-tenure springs and those off-tenement springs as will be assigned by the Surat Underground Water Impact Report (UWIR)/DOTE.	Ongoing.	♦	Section 3
	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 GLNG is assessing the feasibility of programming 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 3

● 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.	Ongoing monitoring and data assessment.	▶	Section 4
	Contact Zone Program.	Ongoing after installation.	▶	Section 4
	Wallumbilla Fault Program.	Installation planned for 2014.	●	Section 4
	Aquifer Response.	Ongoing.	▶	Section 4
	Isotope and geochemical signature.	Ongoing.	▶	Section 4
	Pumping response observations and assessments.	Annually from 2014.	♦	Section 4
	The outcomes of the conventional oil and gas well and water bore risk assessment will be presented in an update to the CWMMP.	2014. Updated CWMMP is due for submission four months after the revised UWIR as agreed with DOTE in 2015.	▶	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
49c, 53a, 53 d)ii	**Aquifer Re-injection**			
	Santos GLNG has developed a Managed Aquifer Recharge (MAR) pilot program and schedule for gas field piloting of aquifer reinjection.			
	Fairview CSG Field Stage 1– Desktop Study.	Completed March 2012.	●	Section 5
	Roma CSG Field Stage 1– Desktop Study.	Completed January 2011.	●	Section 5
	Roma CSG Field Stage 2 – Investigations and Assessment.	Completed January 2011.	●	Section 5
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning.	Completed Q1/Q2 2012.	●	Section 5
	Roma CSG Field pilot trial (Hermitage) Stage 4 – Operation.	Completed Q4 2012.	●	Section 5
	Roma CSG Field (The Bend) Stage 3 – Construction and Commissioning.	Due for completion Q3 2014. Ongoing, due for completion 04 2016.	▶	Section 5
	Roma CSG Field (The Bend) Stage 4 – Operation.	Due to commence Q3/Q4 2014. Ongoing, due to commence Q1 2017.	▶	Section 5
	Arcadia Valley CSG Field Stage 1 – Desktop Study.	Completed September 2013.	●	Section 5
	All approved Injection Management Plans will be provided in an update to the CWMMP.	Ongoing.	♦	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
49e	**Hydraulic Fracturing**			
	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.	●	Section 6
49f	Santos GLNG has agreed with the DOTE to undertake additional Direct Toxicity Assessment that will include: • an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with hydraulic fracturing chemicals, and (iii) hydraulic fracturing chemicals in freshwater; • assessing the risk of individual hydraulic fracturing chemicals of concern; and • assessing contribution of hydraulic fracturing chemicals to toxicity of hydraulic fracturing fluids and flowback waters (mixture toxicity). 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 DOTE upon completion.	December 2013 Ongoing, due for completion 2016.	▶	Section 6

● 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, data acquisition ongoing.	▶	Section 2
	EPBC spring hydrogeological conceptual model.	Existing models submitted November 2013.	●	Section 3
	Atmospheric pressure monitoring – 1 installation (barrologger or other) at each EPBC spring complex or cluster of spring complexes.	Completed for on-tenure springs 2013.	●	Section 3
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 an update to the CWMMP.	End of 2014. Completed, data acquisition ongoing.	▶	Section 7
49.g.x)	**Brine Management Plans**			
	Provision of Brine Management Plans developed for Arcadia Valley, Roma and Fairview gas fields as a state government requirement within the respective gas field's environmental authorities (EA's). These will be provided in the next update to the CWMMP.	December 2014. The gas field Brine Management Plans will now be submitted to the DOTE in Santos GLNG Coal Seam Water Monitoring and Management Annual Report in 2019, due to an extension granted by the state government (DEHP) for submission of Brine Management Plans to December 2019.	▶	Section 8

● **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 2016 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): ▪ Coal Seam Water Monitoring and Management Annual Report; and ▪ Link to the latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR).	31 March 2016.	●	Section 10
	Santos GLNG will regularly publish data from the water monitoring network on the Santos Water Portal.	Ongoing	♦	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. Updated CWMMP is due for submission four months after the revised UWIR as agreed with the DOTE 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. Completed, data acquisition ongoing.	►	Section 2
	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 Joint Industry Plan (JIP) provides a statistical methodology for groundwater level trend analysis.	●	Section 3
53.d.i.III	**Subsidence**			
	The Subsidence Management Plan provides a response plan into 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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Figures

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 2015 (Annual Report) has been prepared in accordance with 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 1 January 2015 to 31 December 2015.

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 1 January 2015 to 31 December 2015; and
- Provide commentary on findings from completed work.

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

- Section 1 Introduction;
- Section 2 Surface Water and Groundwater Baseline Monitoring;
- Section 3 EPBC Springs;
- Section 4 Aquifer Connectivity;
- Section 5 Managed Aquifer Recharge;
- Section 6 Hydraulic Fracturing;
- Section 7 Surface Water Monitoring;
- Section 8 Brine Management;
- Section 9 Subsidence; and
- Section 10 Reporting.

1.2 Project Context

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. The GLNG project area location is shown in Figure 1-1.

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 has been developed to manage the risk of adverse impact to 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 and covers the proposed management activities from 2013 to the first LNG cargo scheduled for 2015.

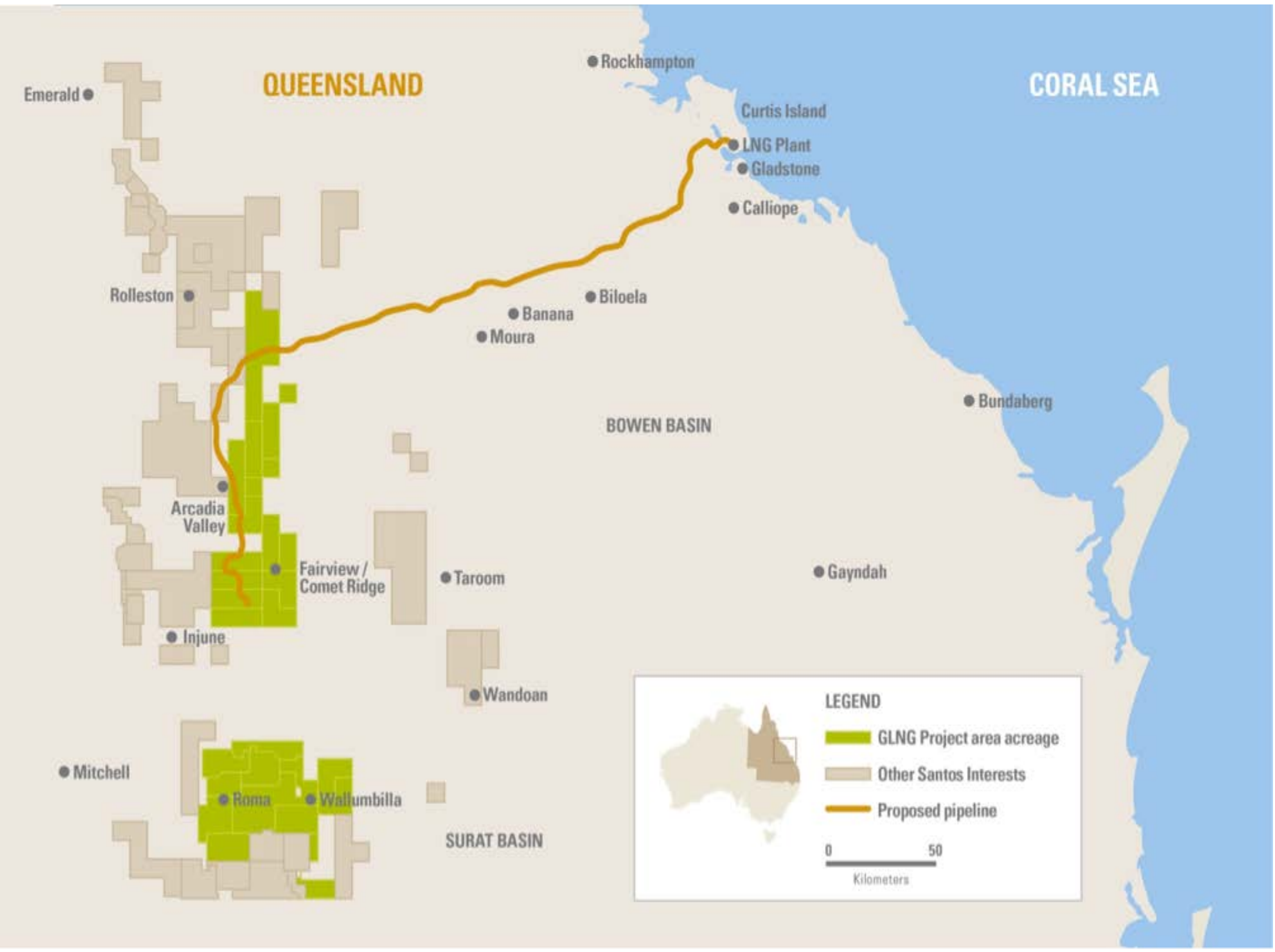


Figure 1-1: Santos GLNG Project Area

2.0 Surface Water and Groundwater Baseline Monitoring

2.1 Overview

Baseline surface water and groundwater data is information which establishes attributes of the water environment prior to the onset of gas field development. This information can be used for comparison in the future to establish if changes have occurred. It may also be possible, dependent upon the nature of the change, to utilise baseline in order to establish a cause, i.e. being potentially related to gas field development activities or not. In relation to MNES, baseline data may also be useful in determining meaningful targets for impact mitigation and management controls.

The water quality baseline data that has been collected over several years, comprises:

- Baseline for surface water quantity and quality;
- Baseline for groundwater pressure and quality; and
- Baseline for springs and wetlands.

The period of data collection that may be required to establish baseline will be location specific, and depend upon the nature of the environment being monitored. This is the case where ambient groundwater conditions are inter- and intra-seasonally dynamic, and affected by a number of interdependent variables such as rainfall, evapotranspiration potential, localised and regional groundwater abstraction activity, land-use changes and more.

Groundwater monitoring may be ongoing throughout the life of Santos GLNG development. It is expected that in most instances, monitoring will continue to gather data many years in advance of potential discernible changes that may be linked to gas field activities, and therefore such data will continue to be considered baseline data. The need for and extent of ongoing monitoring, however, is dictated by the need to monitor and manage specific risks and therefore the potential need for impact mitigation to manage the risk of adverse impact to MNES. Groundwater monitoring proposed in respect of such risks, is described in more detail in the relevant chapters (Chapter 3 – EPBC Springs, Chapter 4 - Aquifer Connectivity and Chapter 5 - Managed Aquifer Recharge).

2.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 2-1 provides an outline of the commitments made in the Stage 2 CWMMP Rev 2 specific to surface water and groundwater baseline monitoring and progress against each commitment.

Table 2-1: Stage 2 CWMMP Rev 2 Commitments – Surface Water and Groundwater Baseline 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.	Completed. Data acquisition ongoing.
49.g.iv)	**Surface Water Baseline**		
	Ongoing collection of surface water baseline data.	End of 2013.	Completed. Data acquisition ongoing.

2.3 Surface Water Baseline Monitoring

A surface water monitoring network has been in place since 2003, with the network increasing significantly in 2009-2012 and includes a number of perennial, ephemeral and spring sampling locations across the Roma, Fairview and Arcadia Valley gas fields. A total of 16 grab samples were collected throughout 2015 from perennial sampling points, across Roma and Fairview gas fields.

Site descriptions and location references are listed in Table 2-2 and Table 2-3 below. Monitoring has included continuous automated flow records, manual and automated water quality sampling, as well as continuous electrical conductivity (EC) and temperature measurements.

Table 2-2: 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	01/04/2009 - Present
S4	Downstream of Dawson River Discharge Scheme - Downstream Dawson River at Yebna Crossing	06/12/2011 - Present
S8	Downstream Baffle Creek U/S confluence of Dawson River	13/04/2009 - 13/11/2013
S12	Upstream Baffle Creek near Waterview	30/04/2009 - Present
S13	Upstream Dawson River at north lease boundary	02/04/2009 - 11/04/2013
S15	Upstream Hutton Creek at Springrock Crossing	19/06/2009 - Present
S16	Midstream Hutton Creek (IWS) (*moved to become S16A*)	09/07/2009 - 7/11/2013
S16A	Midstream Hutton Creek (Relocation)	07/11/2013 - Present
S17	Downstream Hutton Creek	01/04/2009 - Present
ES1	Fairview plateau	07/03/2009 - 14/01/2014
ES2	Eastern side of leucaena area, IR4	08/03/2009 - 01/12/2014
ES3	Eastern side of IR5	18/02/2009 -14/01/2014
ES4	Western side of IR5	08/03/2009 - 14/01/2014
ES5	West of leucaena area, IR4	08/03/2009 - 14/01/2014
ES6	West of Springwater Plateau, IR6	08/03/2009 - 14/01/2014
ES7	Eastern side of Springwater plateau, IR6	08/03/2009 - 17/01/2014
ES8	North East of Springwater plateau, IR6	08/03/2009 - 14/01/2014
ES9	East of pivot plateau	20/07/2009 - 14/01/2014
BLCS1	Blyth Creek S1 - Upstream Mount Hope Irrigation	18/11/2011 - Present
BLCS2	Blyth Creek S2 - Mount Hope Irrigation	17/11/2011 - Present
BLCS3	Blyth Creek S3 - Downstream Mount Hope Irrigation	23/11/2011 - Present
DRMP1	Dawson River Monitoring Point 1 (Formerly DRS1)	07/03/2014 - Present
DRR1	Dawson River Referable Wetland (Formerly DRS2)	06/03/2014 - Present
WLMP1	Wetland Monitoring Point 1 (Formerly DWS1)	06/03/2014 - Present
R014	Roma Water Quality Station	15/01/2009 - Present
R002	Bungil Creek – Downstream Burtons Road Crossing	16/08/2012 - Present
R012	Bungil Creek – Downstream Dunkeld Road Crossing	21/08/2012 - Present
R019	Yuleba Creek - Yuleba	25/10/2012 - Present
RS25	Blyth Creek - The Bend	20/12/2012 - Present
SC3	Glasby Spring	22/07/2009 - Present
SC2	Grandpa Spring	22/07/2009 - Present
SC1	Junction Spring	21/07/2009 - Present

Note: Period of record timeframes may differ to those listed in 2014 Annual Report due to last sampling date and station decommissioning date.

Table 2-3: Surface Water Sampling Period of Record

Site No.	Location	Period of Record
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)	01/06/2013 - Present
BMIS01	Barramundi Creek	01/06/2013 - Present
HGPS01	Highland Plains Creek	01/06/2013 - Present
DEPS01	Deep Creek	01/06/2013 - Present
SHOS01	Shotover Creek	01/06/2013 - Present
DFYS01	Drafting Yard Creek	01/06/2013 - Present
BLCS1	Blyth Creek S1 - Upstream Mount Hope Irrigation	14/11/2011 - 10/11/2015
BLCS2	Blyth Creek S2 - Mount Hope Irrigation	11/12/2011 - 02/02/2012
BLCS3	Blyth Creek S3 - Downstream Mount Hope Irrigation	19/12/2011- 14/01/2015
I14	Midstream Hutton Creek	03/03/2009 - 03/03/2009
I16	Midstream Hutton Creek	02/08/2007 - 02/08/2007
R001	Midstream Bungil Creek at Warrego Hwy (EIS) (S&B Site 5)	17/05/2010 - 09/11/2015
R002	Upstream Bungil Creek at Burtons Rd	11/04/2011 - 04/04/2014
R011	Downstream Blyth Creek at Carnarvon Hwy	28/04/2011 - 04/04/2014
R012	Downstream Bungil Creek at Dunkeld Road (EIS) (S&B Site 8)	18/05/2010 - 04/04/2014
R014	Downstream Wallumbilla Creek at Roma Condamine Road (EIS) (S&B Site 16)	18/05/2010 - 05/04/2014
R019	Upstream Yuleba Creek at Roma Condamine Rd (EIS) (S&B Site 21)	20/05/2010 - 01/06/2014
R021	Upstream Yuleba Creek at Warrego Hwy (EIS) (S&B Site 22)	20/05/2010 - 23/02/2016
R025	Midstream Blyth Creek at North Pickanjinnie Road	28/04/2011 - 10/03/2013
RES1	Midstream Bungeworgorai Creek	20/05/2010 - 20/05/2010
RES10	Downstream Blyth Creek	18/05/2010 - 04/04/2014
RES13	Upstream Wallumbilla Creek	19/05/2010 - 05/04/2014
RES15	Downstream Wallumbilla Creek	20/05/2010 - 20/05/2010
RES17	Midstream Cattle Creek Ephemeral	19/05/2010 - 19/05/2010
RES4	Upstream Bungil Creek	17/05/2010 - 17/05/2010
RES6	Downstream Bungil Creek	18/05/2010 - 18/05/2010
RS11	Midstream Blyth Creek	19/05/2010 - 10/03/2013
RS12	Upstream Blyth at Apple Tree Creek	19/05/2010 - 10/03/2013
RS14	Downstream Wallumbilla Creek	19/05/2010 - 05/04/2014
RS20	Downstream Balonne River	20/05/2010 - 10/08/2014
RS23	Midstream Bony Creek	18/05/2010 - 04/04/2014
RS24	Upstream Balonne River (Warkon)	08/07/2010 - 10/08/2014
RS25	Midstream Blyth Creek	02/11/2010 - 23/03/2015
RS7	Midstream Bungil Creek	18/05/2010 - 18/05/2010
S1	Downstream Dawsons Bend (S&B)	11/09/2003 - 18/04/2013
S10	Dawson River Downstream of confluence with Baffle Creek (S&B)	06/10/2006 - 17/11/2011
S11	Upstream Hutton Creek	05/10/2006 - 19/08/2014
S11a	Upstream Hutton Creek in Kevington (S&B)	11/09/2003 - 21/04/2013

Site No.	Location	Period of Record
S14a	Dawson River Upstream Hutton Creek outflow (S&B)	23/04/2004 - 22/05/2008
S2a	Baffle Creek - 50m Downstream FV12 discharge (S&B)	09/09/2003 - 09/09/2003
S2b	Baffle Creek - 5m Upstream FV12 discharge (S&B)	09/09/2003 - 09/09/2003
S3	Dawson River Downstream Hutton Creek (S&B)	23/04/2004 - 17/04/2013
S5	Downstream Utopia Downs (S&B)	25/05/2005 - 14/11/2013
S6	Midstream Hutton Creek (FV66) (S&B)	19/04/2004 - 15/04/2013
S6a	Upstream Hutton Creek (Carnarvon Development Road) (S&B)	10/09/2003 - 10/09/2003
S7	Upstream Baffle Creek (S&B)	09/09/2003 - 16/04/2013
S9	Upstream Dawson River road crossing #2 (S&B)	09/05/2006 - 16/04/2013
SC1	Glasby Spring	03/11/2009 - Present
SC2	Grandpas Springs	03/11/2009 - 13/05/2014
SC3	Junction Spring	03/11/2009 - Present

Note: Period of record timeframes may differ to those listed in 2014 Annual Report due to last sampling date and monitoring cessation date.

Surface water baseline monitoring requirements have been met for both Fairview and Roma fields and associated surface water threshold values have been calculated, see Section 7.0 (Surface Water Monitoring) for details. As a result, surface water monitoring stations and/or surface water sample locations are no longer required to be monitored at a pre-determined frequency as seasonal trends have been established. However, as Santos GLNG continues to undertake CSG related activities in each of the gas fields, a surface water monitoring program will be implemented on a regional scale with the objective of identifying potential impacts to surface waters relating to Santos GLNG's activities during long-term operations.

Surface water monitoring locations for the Arcadia Valley field have been established to monitor surface water during the phases of exploration and appraisal.

2.4 Baseline for Regional Groundwater Pressure and Quality

Santos GLNG has implemented a program for the regional groundwater level monitoring of private bores, dedicated groundwater monitoring bores and multi-level monitoring installations (such as vibrating wire piezometers (VWPs)) since 2008. The groundwater level monitoring network extends across Santos GLNG tenures and across all relevant aquifers. Development of the monitoring network is ongoing based on field development, a summary of the currently active water level monitoring points, and the number of bores that have become active throughout 2015 are summarised in Table 2-4.

Table 2-4: Summary of Regional Groundwater Level Monitoring Points Active in 2015

Formation	Private Water Bores	GLNG Multi-level Monitoring Points	GLNG Dedicated Monitoring Bores	Total
Alluvium	2	-	-	**2**
Volcanics	1	-	-	**1**
Bungil Formation	1	-	-	**1**
Mooga Sandstone	7	10	3	**20**
Orallo Formation	9	3	3	**15**
Gubberamunda Sandstone	7	16	11 (4)	**34**
Westbourne Formation	-	6	-	**6**

Formation	Private Water Bores	GLNG Multi-level Monitoring Points	GLNG Dedicated Monitoring Bores	Total
Springbok Sandstone	-	5 (1)	4 (4)	**9**
Walloon Coal Measures (WCM, targeting various seams)	3	44 (3)	-	**47**
Eurombah Formation	-	2	-	**2**
Hutton Sandstone	2	4 (1)	3 (3)	**9**
Evergreen Formation	1	2	-	**3**
Boxvale Sandstone	-	2	-	**2**
Precipice Sandstone	8	5	10 (1)	**23**
Clematis Sandstone	2	-	2 (2)	**4**
Rewan Formation	2	-	-	**2**
Bandanna Formation	-		1	**1**
Unknown*	3		-	**3**
TOTAL	**48**	**99**	**37**	**184**

Notes: These numbers may differ from those in the 2014 Annual Report due to ongoing refinement of the monitoring network.
Number of bores that became operational in 2015 shown in brackets.
- no bores present.
** unknown indicates that the aquifer is to be confirmed through ongoing assessment.*
Data source: Santos GLNG (as of December 2015).

Details of the groundwater quality monitoring program undertaken during 2015 are provided below. The summary includes groundwater quality samples taken from dedicated monitoring bores across Roma, Fairview and Arcadia Valley gas fields. Table 2-5 provides a summary of the number of currently active water quality monitoring points.

During January 2015 to December 2015, a total of 127 samples have been collected as part of the groundwater quality monitoring program.

- 65 samples from the Roma field;
- 52 samples from the Fairview field; and
- 10 samples for the Arcadia Valley field.

Table 2-5: Summary of the Number of Regional Groundwater Quality Monitoring Sampling Points in 2015

Formation	Private Bores	GLNG Dedicated Monitoring Bores	Total
Alluvium	1	0	1
Mooga Sandstone	3	2	5
Orallo Formation	1	1	2
Gubberamunda Sandstone	0	6 (1)	6
Springbok Sandstone	0	4 (3)	4
Hutton Sandstone	0	3 (1)	3
Evergreen Formation	1	0	1
Precipice Sandstone	7	9 (3)	16
Clematis Sandstone	2	1	3

Formation	Private Bores	GLNG Dedicated Monitoring Bores	Total
Rewan Formation	1	0	1
Bandanna Formation	0	0	0
Unknown*	4	0	4
TOTAL	**20**	**26**	**46**

Notes: These numbers may differ from those in the 2014 Annual Report due to ongoing refinement of the monitoring network.
Number of bores that became operational in 2015 shown in brackets.
** unknown indicates that the aquifer is to be confirmed through ongoing assessment.*
Data source: Santos GLNG (as of December 2015).

2.6 Baseline for Springs and Wetlands

Baseline conditions at EPBC-listed and non EPBC-listed springs have been established by the Office of Groundwater Impact Assessment (OGIA) on behalf of the CSG industry and are presented within reports by KCB (2012) and Queensland Herbarium (2012), outlined in the Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR 2012).

In addition to this baseline, Santos GLNG has initiated spring monitoring as required under the Surat UWIR and Santos GLNG approval conditions on Santos GLNG tenures. A joint industry spring baseline program is being implemented consisting of quarterly monitoring events and inclusive of ecological and hydrogeological parameters monitoring. The findings of this monitoring is provided by Jacobs (2015).

A summary of the spring complexes that were monitored throughout 2015, is shown in Table 2-6. Monitoring has been conducted in accordance with the monitoring approach identified during the first round of baseline monitoring in 2014. Chapter 3 (EPBC Springs) provides an update on additional activities related to springs commitments.

Table 2-6 Spring Baseline Monitoring Program Summary – Second and Subsequent Monitoring Events

Complex	Spring Vent	Monitoring Type
311 (non-MNES spring)	353	No Further Monitoring
	536	Full Monitoring
	537	Visual Only
	693	Full Monitoring
	704	Full Monitoring
Abyss (592)	286	Full Monitoring
	286.1	Visual Only
	286.2	Full Monitoring
	286.3	Visual Only
	682	Visual Only
	716	Visual Only
Barton (283) (non-MNES spring)	702	Full Monitoring incl adjacent Barton Well
	703	No Further Monitoring
Boggomoss (5)	2	No Further Monitoring
	3	No Further Monitoring
	7	No Further Monitoring
	8	Visual Only
	9	No Further Monitoring
	10	No Further Monitoring
	11	Visual Only
	12	Visual Only
	13	No Further Monitoring
	14	No Further Monitoring
	15	Visual Only
	29	Visual Only
	33	Visual Only
	37	No Further Monitoring
	37.1	No Further Monitoring
	44	No Further Monitoring

Complex	Spring Vent	Monitoring Type
Boggomoss (5)	53	No Further Monitoring
	54	No Further Monitoring
	55	No Further Monitoring
	56	No Further Monitoring
	56.1	Visual Only
	57	Visual Only
	58	Visual Only
	61	Visual Only
	62	No Further Monitoring
	63	No Further Monitoring
	68	No Further Monitoring
	68.1	No Further Monitoring
	683	No Further Monitoring
	691	No Further Monitoring
Cockatoo Creek (9)	64	Full Monitoring incl adjacent RN67229
	64.1	No Further Monitoring
	65	Visual Only
	65.1	No Further Monitoring
	65.2	No Further Monitoring
	66	No Further Monitoring
	319	No Further Monitoring
	320	Visual Only
	320.1	No Further Monitoring
	321	No Further Monitoring
	321.1	No Further Monitoring
	321.2	No Further Monitoring
	321.3	No Further Monitoring
	321.4	No Further Monitoring
	321.5	No Monitoring

Complex	Spring Vent	Monitoring Type
Cockatoo Creek (9)	321.6	No Further Monitoring
	321.7	No Further Monitoring
	321.8	No Further Monitoring
	684	No Further Monitoring
Dawson River (2)	42	Full Monitoring incl adjacent RN89695
Dawson River (6)	1	Full Monitoring
	4	No Monitoring
	5	No Monitoring
	6	No Monitoring
	22	No Monitoring
	23	No Monitoring
	24	Visual Only
	25	Visual Only
	27	No Further Monitoring
	30	No Further Monitoring
	31	Visual Only
	32	Visual Only
	43	No Further Monitoring
	59	No Further Monitoring
	60	Full Monitoring
	681	No Further Monitoring
Dawson River (8)	26	No Further Monitoring
	28	Full Monitoring
	38	Visual Only
Elgin 2 (594)	540	Full Monitoring incl adjacent RN67137
Kangaroo Creek (non-MNES spring)	Kangaroo Creek 1	*Initial baseline visit required*
	Kangaroo Creek 2	*Initial baseline visit required*
	Spring Creek	*Initial baseline visit required*
Lucky Last (230)	287	Full Monitoring

Complex	Spring Vent or Bore RN	Monitoring Type
Lucky Last (230)	340	Full Monitoring
	686	Visual
	687	Visual
	687.1	Visual
	687.2	Visual
	687.3	Visual
	687.4	Visual
	687.5	Visual
	687.6	Visual
	688	Full Monitoring
	689	Full Monitoring
Orana (non-MNES spring)	Orana1	Full Monitoring
Ponies (229) (non-MNES spring)	284	No Further Monitoring
	284.1	Full Monitoring
Prices (580)	40	No Further Monitoring
	41	No Further Monitoring
	52	Full Monitoring
	67	Visual
Scott's Creek (260)	189	Full Monitoring
	190	Visual
	191	Full Monitoring
	192	Visual
	192.1	No Further Monitoring
	RN14881 RN14200 RN14203 RN31097	Full Monitoring
Spring Rock Creek (561) (non-MNES spring)	285	Full Monitoring
Wambo (584) (non-MNES spring)	711	Full Monitoring
	711.1	No Further Monitoring
Yebna 2 (591) (non-MNES spring)	534	Full Monitoring

Notes: "Full monitoring" comprises assessment of: wetland discharge, wetland area, wetland water quality, groundwater level estimation (as a proxy for groundwater flux), and ecosystem condition (flora survey, marco-invertebrate survey, photography).
"Visual" comprises assessment of: wetland area, and ecosystem condition (flora survey and photograph).
"No Further Monitoring" based on assessment methodology these locations are highly physically disturbed, any potential impacts to these sites from gas field development activities are likely to be undiscernible compared to pre-existing impacts.

3.0 EPBC Springs

3.1 Overview

Groundwater drawdown propagating from production in gas 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".

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 adversely impacted by groundwater drawdown associated with gas 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.

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 EBPC Springs and progress against each commitment.

Table 3-1: 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 (2013).
	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 tenure springs baseline initiated as part of the (JIP), to be reported in April 2015.	Completed (2013).
	Santos GLNG will assume responsibility of mitigation (if required) for on-tenure 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.	Initial conceptual models to be provided in November 2013. Additional conceptual models will be provided at completion of spring baseline assessment (April 2015).	Completed April 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 2013.
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.	Ongoing. The JIP provided a statistical methodology for groundwater level trend analysis that has not yet been implemented in practice.

3.3 EPBC Springs Monitoring Progress

Details of activities undertaken during 2015 are summarised in the following subsections.

3.3.1 Progress on the EPBC Springs Early Warning System Implementation

Potential impacts on EPBC Springs continue to be monitored through a network of groundwater monitoring bores, providing early warning of potential impact propagating from the production gas 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 12 groundwater level monitoring installations which fall under Santos GLNG responsibility within the JIP, of which five are operational and the remaining seven were scheduled for completion in 2015. A summary status is provided in Table 3-2.

Table 3-2: Progress on EPBC Springs Early Warning System Monitoring Implementation

Bore	Lat. (WGS84)	Long. (WGS84)	Aquifer	EPBC Spring	Date Water Level Monitoring Commenced	Status
Contact Zone	-25.8098	148.8276	Precipice Sandstone	Abyss, Lucky Last	-	Construction planned 2016
MHTGWH01	-25.8250	148.7916	Hutton Sandstone	Abyss	Nov 2014	Active
MHTGWP01	-25.8250	148.7916	Precipice Sandstone	Lucky Last	Dec 2013	Active
MNHGWP02*	-25.7881	148.9233	Precipice Sandstone	Abyss, Lucky Last	Aug 2015	Active
AVLOP01	-25.9419	150.0742	Precipice Sandstone	Cockatoo Creek	Dec 2015	Active
AVLGWH	-25.9141	150.0736	Hutton Sandstone	Cockatoo Creek	Dec 2013	Active
AVLVWH1 AVLVWH2	-25.9379	150.0739	Hutton Sandstone	Cockatoo Creek	Dec 2012	Active
AVLVWP1 AVLVWP2	-25.9379	150.0739	Precipice Sandstone	Cockatoo Creek	Dec 2012	Active
EWMI7	-24.6074	149.0761	Clematis Sandstone	Elgin 2	-	To be equipped in 2016
SBNGWH01	-25.8263	149.0370	Hutton Sandstone	Yebna 2	-	No groundwater present
SBNGWP01	-25.8263	149.0370	Precipice Sandstone	Yebna 2	Nov 2014	Active
MW0902	-25.7347	149.0829	Precipice Sandstone	Yebna 2	Jan 2011	Active

Notes: * MNHGWP02 replaces MW0905 as originally specified in the JIP.

3.3.2 Spring Baseline Acquisition

The Industry has delivered quarterly spring baseline surveys throughout 2015, these will continue throughout 2016 in accordance with the requirements of the Spring Impact Monitoring Strategy outlined in the UWIR for the Surat CMA.

3.4 EPBC Spring Hydrogeological Conceptual Models

GLNG was required to reconceptualise springs associated with EPBC values by 30th April 2015. Using information collected during the baseline monitoring and additional research conducted both by the OGIA and by GLNG, the OGIA prepared conceptualisation reports for the EPBC listed spring sites. These conceptualisation reports were submitted to the DOTE in a letter from the OGIA dated 30th April 2015.

3.5 Assessment of Trends for Analysis of Groundwater Data

The definition of reference values is ongoing based on the period that the equipped monitoring bores have been able to gather data. Of the bores that have been equipped with monitoring, there are monitoring locations that have data over a period of more than a year. Whilst assessment of the groundwater level trends in these bores is ongoing, a summary of the assessment to date is summarised for each of these bores.

To date apparent generalised upward or downward trends that seem or are conclusively typical across the periods in which monitoring data has been collected have not been identified. Most trends appear to be seasonal, with seasonal (i.e. intra-annual) groundwater pressure variations being less than inter-annual variations.

A statistical methodology is being defined which can objectively define the meaningful threshold values against which the significance of groundwater pressure variations can be assessed against baseline water pressures. It is predicted that several years of data collection before baseline values and threshold trigger values for a change to groundwater pressures at an Early Warning Spring (EWS) can be objectively determined.

The following sections present a summary of the observed groundwater level trends data collected to date.

3.5.1 Yebna 2 Spring Complex

MW0902 and SBNGWP01 are EWS bores for the Yebna 2 EPBC spring complex. Groundwater pressure data for these bores is displayed graphically in Figure 3-1.

MW0902 has been monitoring the Precipice Sandstone since January 2011 and has shown a general upward trend in groundwater level since Q4 in 2012. The groundwater level has increased by approximately 1 metre (m) through 2015, therefore at a rate of approximately 1 m increase per year. Within a year, the groundwater level may vary by up to around 0.5 m more or less than the long-term mean groundwater level.

SBNGWP01 has been monitoring the Precipice Sandstone since December 2014 and has shown a general upward trend in groundwater level since that time. The groundwater level has increased by approximately 1 metre (m) through 2015, therefore at a rate of approximately 1 m increase per year. Within a year, the groundwater level may vary by up to around 0.5 m more or less than the long-term mean groundwater level.

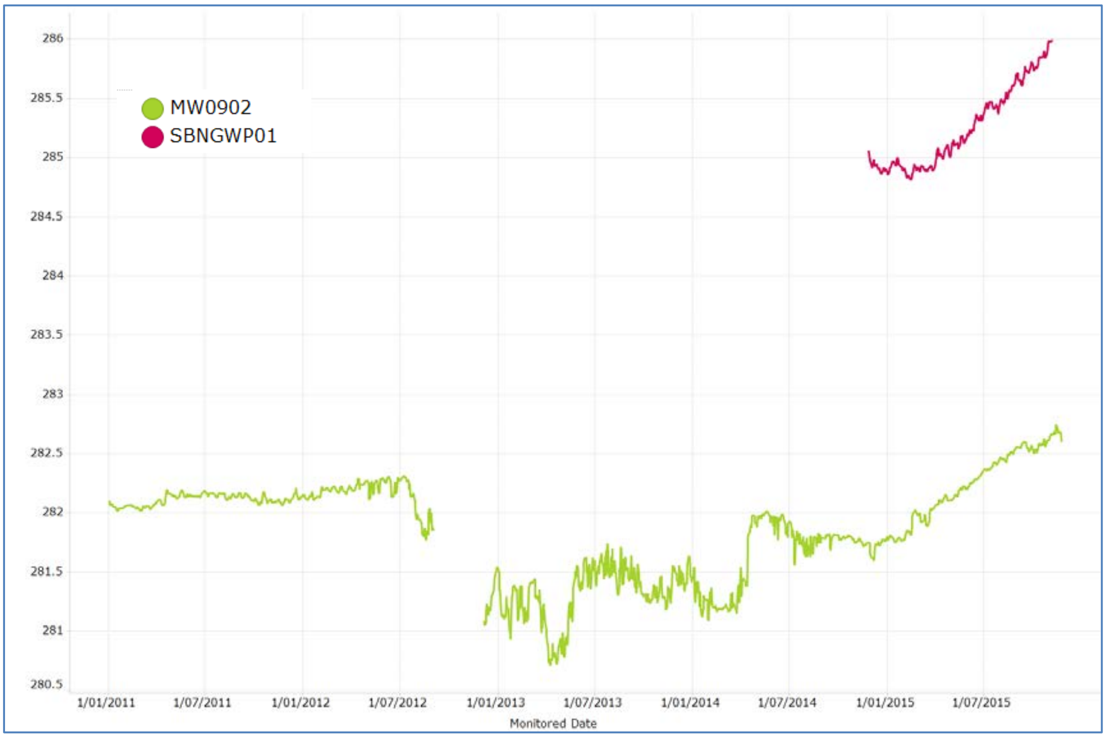


Figure 3-1: Yebna 2 EWS Groundwater Pressure Data

3.5.2 Abyss / Lucky Last Spring Complexes

MHTGWP01, MHTGWH01 and MNHGWP02 are EWS bores for the Abyss and Lucky Last EPBC spring complexes. Groundwater pressure data for these bores is displayed graphically in Figure 3-2 and Figure 3-3.

MHTGWP01 has been monitoring the Precipice Sandstone since December 2013, and is located more than 10 km west of any active gas field development. It generally shows a downward trend since April 2014, and a stable to rising trend since August 2014. Throughout 2015, groundwater pressures vary by up to around 0.2 m.

MHTGWH01 has been monitoring the Hutton Sandstone since November 2014, and is located more than 10 km west of any active gas field development. It generally shows a downward to stable trend since monitoring commenced. Throughout 2015, groundwater pressures vary by up to around 0.2 m.

MNHGWP02 has been monitoring the Precipice Sandstone since August 2015, and is also located more than 10 km west of any active gas field development. It generally shows a downward to stable trend since monitoring commenced. Throughout 2015, groundwater pressures vary by up to around 0.3 m.

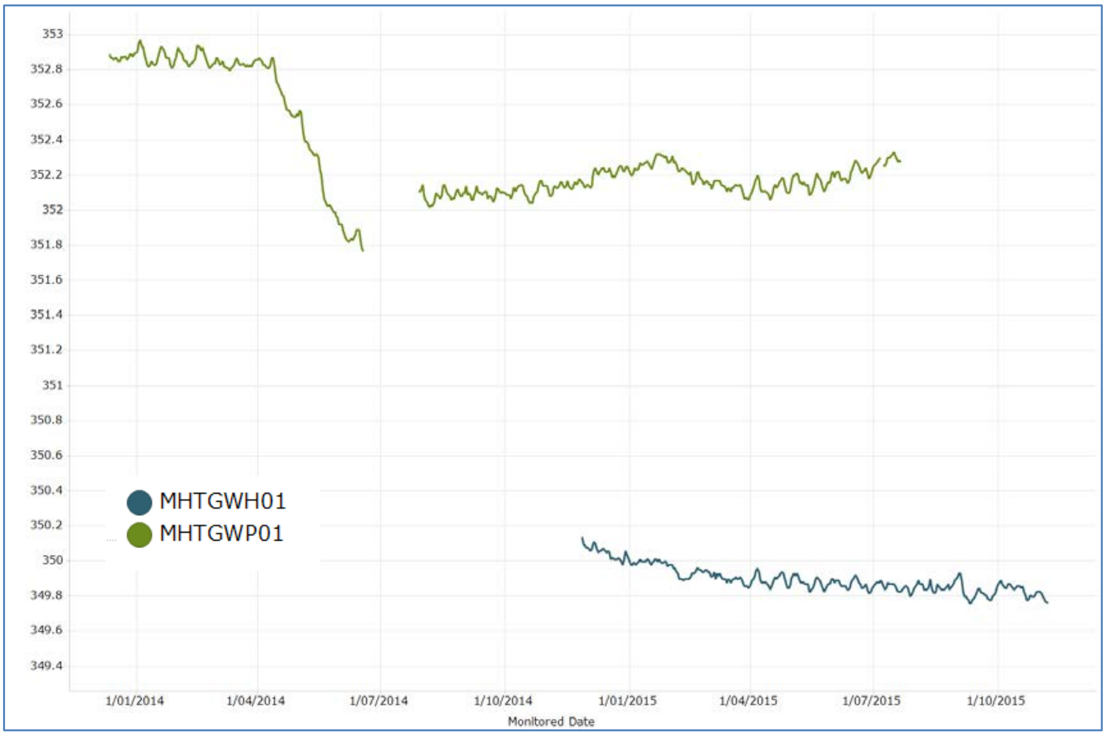


Figure 3-2: Abyss and Lucky Last EWS Groundwater Pressure Data at MHTGWP01 and MHTGWH01

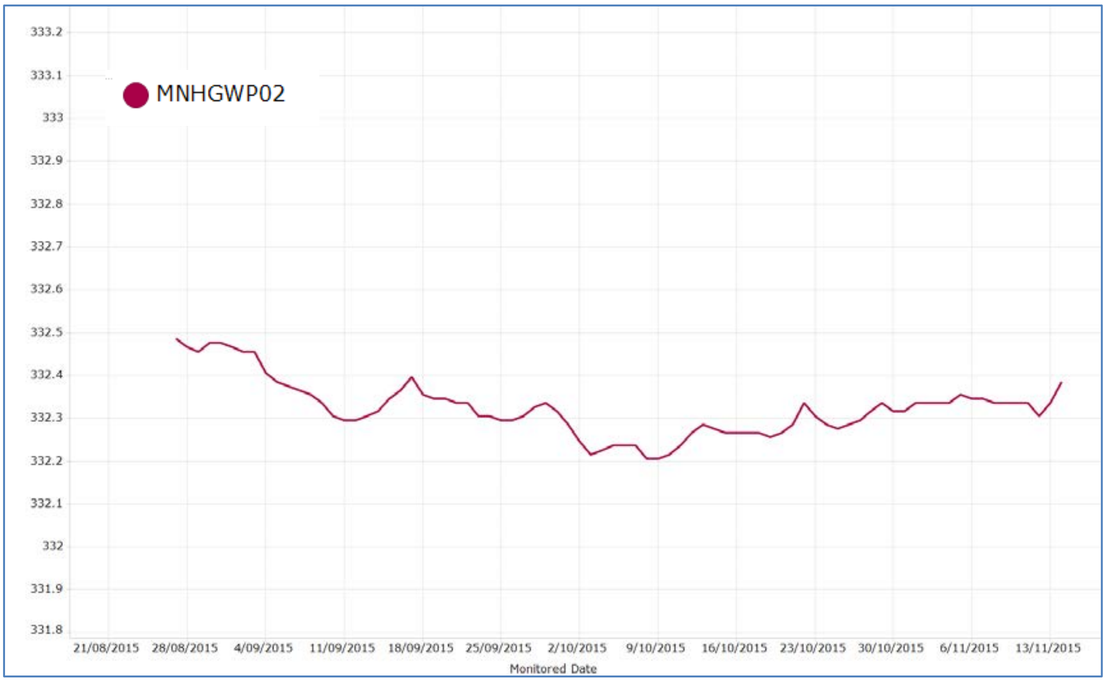


Figure 3-3: Abyss and Lucky Last EWS Groundwater Pressure Data at MNHGWP02

3.5.3 Cockatoo Creek Spring Complexes

AVLGWH01, AVLVWH1, AVLVWH2, AVLVWP1 and AVLVWP2 are EWS bores for the Cockatoo Creek Spring Complex. Groundwater pressure data for these bores is displayed graphically in Figure 3-4.

Figure 3-4: Cockatoo Creek Spring Complex EWS Groundwater Pressure Data

3.5.3.1 AVLGWH01

AVLGWH01 has been monitoring the Hutton Sandstone since January 2013, and is located more than 30 km north of Santos GLNG gas field development areas. AVLGWH01 is a landholder bore that is understood to remain in operation as an active extraction bore.

The observed groundwater pressures in the bore generally show a downward trend since the record began in January 2013. Throughout 2013 the rate of decline was approximately 0.2 m/year, in 2014 the rate of decline was approximately 0.7 m/year.

It is not possible to know if the decrease in groundwater level represents seasonal variation, or longer term decline. Throughout 2015 the water level varied by more than 20 m which most likely comprises the water pressure response to pumping of the bore. The increased rate of decline of the bore water level throughout 2014 most likely corresponds to a period of increased abstraction intensity, rather than gas field development activities. In 2015 it appears that abstraction abated and the water pressures appear more stable, varying around 3 m for the latter half of 2015.

3.5.3.2 AVLVWH1/ AVLVWH2

AVLVWH1 and AVLVWH2 are monitoring points located within the same Vibrating Wire Piezometer (VWP) monitoring location. There is no Santos GLNG gas field development area in close proximity to this location. The two monitoring points are monitoring different depths in the Hutton Sandstone, with H1 being at 155 mbgl and H2 at 250 mbgl.

The VWP has been monitoring the Hutton Sandstone since December 2012. The two monitoring depths show different groundwater level trends.

- H1 (the shallowest) shows a general downward trend in groundwater level since records began. The groundwater level has decreased by approximately 5 m from December 2012 to May 2014. Since May 2014, water levels appeared to have stabilised at approximately 247 mAHD, and increased from around May 2015. Groundwater levels vary around the longer term average water level by up to 4 m seasonally.
- H2 (the deeper) shows a period of increasing groundwater levels from December 2012 to June 2013 (13 m increase), prior to demonstrating a period of decline from June 2013 to April 2015, and appear stable throughout the remainder of 2015. Groundwater levels vary around the longer term average water level by up to 4 m seasonally.

3.5.3.3 AVLVWP1/AVLVWP2

AVLVWP1 and AVLVWP2 are monitoring points located within the same VWP monitoring location. The two monitoring points are monitoring different depths in the Precipice Sandstone, with P1 being at 490 mbgl and P2 at 528 mbgl.

The VWP has been monitoring the Precipice Sandstone since December 2012. The two monitoring depths show different groundwater level trends.

- P1 (the shallowest) shows a general upward trend in groundwater levels, with a more recent decline. The groundwater level has increased by approximately 12 m from December 2012 to December 2014, approximately 6 m/year. In August 2015, groundwater levels dropped rapidly by around 15 m and appear broadly stable throughout the rest of 2015. Within any single year, the groundwater level may vary by up to around 10 m more or less than the long-term mean groundwater level.
- P2 (the deeper) shows a period of decreasing but stabilising groundwater levels from December 2012 to December 2015. Over this period the water level decreased by approximately 3.5 m/year. Within any single year, the groundwater level may vary by up to around 1 m more or less than the long-term mean groundwater level.

4.0 Aquifer Connectivity

4.1 Overview

In accordance with approval conditions Santos GLNG has undertaken its own primary data collection and interpretation related to aquifer connectivity. Santos GLNG has also provided data to various work programs being undertaken by State and Federal Government departments, including the OGIA, Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Office of Water Science.

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.

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 aquifer connectivity and progress against each commitment.

Table 4-1: 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 committed to provide further characterisation on the level of connectivity between the formations. Most of the studies, at this stage, are ongoing and not yet conclusive. Note that the results, where available, will be presented in future updates to the CWMMP.		
	Multi-level monitoring bores.	Ongoing monitoring and data assessment.	Completion of monitoring bores in 2014, ongoing data collection and further installations scheduled for 2016.
	Contact Zone Program.	Ongoing after installation.	Initial monitoring data available, further installations on hold pending results.
	Wallumbilla Fault Program.	Installation planned for 2014, scope currently under development.	Complete. Additional monitoring data not feasible.
	Aquifer response to CSG depressurisation.	Ongoing.	Ongoing.
	Isotope and geochemical signature.	Ongoing.	Ongoing.
	Pumping response observations and assessments.	Annually from 2014.	Ongoing.
	The outcomes of the conventional oil and gas well and water bore risk assessment will be presented in an update to the CWMMP.	2014.	Ongoing. Updated CWMMP is due four months after the revised UWIR.

4.3 Multi-level monitoring

The Santos GLNG monitoring network includes multi-level piezometers and nested single-zone groundwater level monitoring bores. These piezometers target aquifers and specific monitoring zone depths to pre-defined data acquisition objectives. The number of multi-level monitoring locations is summarised in the Table 4-2.

Table 4-2: Number of Active Multi-level Groundwater Level Monitoring Installations

Gas Field	Number of Active, Multi-level Installations or Nested Bore Sites
Roma	21
Fairview	3

Multi-level monitoring data will continue to be collected, such data are provided to the OGIA.

4.4 Contact Zone near the Fairview Field

Erosion of the Rewan Formation in the south western corner of Fairview prior to deposition of the Precipice Sandstone has resulted in an unconformity where the Precipice Sandstone directly overlies the Bandanna Formation. This area is referred to as a contact zone. The contact zone does not underlie an area that is proposed to be an operational gas field for the Bandanna Formation. The nearest potentially producing gas well in the Bandanna Formation is located approximately 3 km from the contact zone.

Since the initial definition of this study program, the location and extent of the contact zone in Fairview has been reviewed using more recently acquired geological data. This has reduced the size of the contact zone.

The project plan was to investigate the geological stratigraphy and monitor the contact zone through the construction of a number of groundwater monitoring bores as defined in Table 4-3. Two vibrating wire piezometers were installed in 2009 (VWP0902 and VWP0903), and one monitoring bore was installed in 2013 (QWC129, also referred to as MTGWP01 or the Mount Hutton bore). Given the revised location of the contact zone, the Mount Hutton bore, VW0902 and VW0903 are no longer interpreted to be in the contact zone. The closest monitoring point is VW0902 which is expected to be less than 400 m from the contact zone.

Santos GLNG has been negotiating to secure the land access agreement required to allow it to drill the location labelled “Contact Zone”. An agreement has not been achieved and alternative solutions are being investigated including the possibility of equipping a private bore nearby with a water level sensor once the target aquifer is confirmed (e.g. by groundwater sampling and downhole geophysics).

The completion and/or equipment of groundwater monitoring location in the Precipice Sandstone will also address a commitment of the JIP for the management and monitoring of EPBC Springs.

Table 4-3: Status of Groundwater Level Monitoring Installations Investigating the Contact Zone in Fairview

Bore name	Monitored Formation	Status
VW0902	Precipice Sandstone	Completed
VW0903	Precipice Sandstone	Completed
Contact Zone (Ok Station)	Precipice Sandstone	Planned 2016
	Hutton Sandstone	-
QWC 129 – Mount Hutton	Precipice Sandstone	Completed
	Hutton Sandstone	Completed
Spring Gully – PB1	Precipice Sandstone	Completed
	Hutton Sandstone	Not completed*

*Proposed bore location is to be delivered by APLNG, drilling and completion schedule not known.

4.5 Hutton-Wallumbilla Fault

The Hutton-Wallumbilla Fault (also called the Wallumbilla Fault) is defined as a complex faulting system. The fault system consists of a main fault to which are associated a number of secondary significant faults. The fault system spreads in width of approximately two kilometres. The main fault is not a straight box offset fault type and its characteristics vary along the fault profile. The main fault offset can be made of a number of offsets with varying displacements. The amplitude of the displacement varies from a few metres to the south to about 50 m to the north of the Roma field.

The fracturing and the displacement do not affect the full stratigraphic profile. The main faulting occurred during a compressive phase of mid-Triassic. The faults were reactivated during the mid-cretaceous causing minor faulting throughout the Secondary sequences or causing folding. Fractures affecting the Secondary could also result from differential sediments compaction and as such be tension fractures.

Using the Boxgrove Ironstone Member (a reliable geophysical/seismic marker) at the top of the Boxvale Sandstone, seismic sections show that the formations above the Evergreen Formation are continuous across the fault. Therefore it is now interpreted that the coal beds of the Walloon Coal Measures and all the aquifers above them are continuous across the fault zone.

Beneath the Walloon Coal Measure, the Precipice Sandstone would have been deposited, over the structure prior to the significant displacement and therefore is hydrogeologically a non-continuous structure across the Roma Shelf. The displacement of the Precipice Sandstone appears to be over 50 m, whereas the Precipice Sandstone at this location is not more than 25 m thick. Besides discontinuity, lateral permeability is limited by lithology with the Precipice Sandstone comprising well cemented fine-grained sands, less typical of the highly permeable, coarse sandstone depositions of Precipice Sandstone observed in other areas of the Surat Basin, away from the Roma Shelf.

In terms of its hydraulic properties, the Hutton-Wallumbilla Fault is not necessarily considered to be a barrier to horizontal flow through aquifers that are younger than the Evergreen Formation. Conversely, lateral extent and integrity of lower permeability aquitards layers above the Evergreen Formation are also considered to be continuous, and as such provide a continuous throttle to vertical pressure prorogation and fluid flow. As such, the fault is not expected to play a major role in controlling drawdown resulting from coal seam depressurisation neither vertically (i.e. between formations) and horizontally (i.e. across formations).

A hydrogeochemistry review was undertaken of bore water chemistries around the Hutton-Wallumbilla Fault in the Roma field to understand whether this data might elude to the presence of vertical flow and connectivity pathways between the shallow (above coal) water bearing formations of the Bungil, Mooga, Orallo and Gubberamunda sandstones. The review concluded that the water chemistry data that had been obtained as part of the regional bore inventory and baseline assessment program did not provide a clear indication of the impact that the Hutton-Wallumbilla Fault may have on vertical and lateral connectivity of shallow aquifers.

4.6 Aquifer Response to Depressurisation

The intention of this program is to continue to monitor aquifer groundwater levels, to periodically review the measured values and to share the data with regulating authorities as they request it.

To date there has been no discernible response to aquifer groundwater levels following onset of field development in Fairview.

4.7 Isotope and Geochemical Signature

Baseline isotope and geochemistry data will continue to be collected from regional groundwater monitoring bores, as required and stipulated by various regulatory drivers which require it. All data is supplied to the regulating authorities as required.

4.8 Pumping Response to Depressurisation

Measurement of groundwater pressures throughout the life of the project will provide evidence of drawdown effects that may be due to depressurisation of gas bearing formations. The ongoing groundwater pressure monitoring program will include the regional groundwater pressure monitoring as stipulated by the UWIR, as in compliance with the *Water Act 2000* (Qld), and as required by other impact assessments such as spring impact monitoring in accordance with the JIP.

4.9 Support of OGIA Research

Future programs of work will focus on supporting the hydraulic connectivity work programs that are identified and implemented by the OGIA. The findings of these research programs are reported by the OGIA annually and are being carried out in collaboration with CSIRO, Geoscience Australia, universities, other research institutions and petroleum tenure holders.

In 2011, the OGIA (formerly referred to as the Queensland Water Commission) implemented a range of technical investigations and assessments to support the development of the UWIR for the Surat CMA. The UWIR for the Surat CMA provides assessments on the impacts of water extraction by petroleum tenure holders on underground water in the Surat CMA, and specifies integrated management arrangements.

The investigations in support of the UWIR for the Surat CMA included:

- Compiling a current understanding of the hydrogeology of the area in and around the Surat CMA;
- Developing a regional groundwater flow model (the regional model) for making predictions of groundwater impacts from the petroleum and gas activities;
- Analysing uncertainty in model predictions;
- Undertaking a comprehensive survey of the relevant springs in the Surat CMA for their hydrogeological and ecological attributes; and
- Compiling an inventory of all existing and proposed monitoring bores and activities in the Surat CMA.

The UWIR for the Surat CMA was approved by the Department of Environment and Heritage Protection (DEHP) and took effect on 1 December 2012. The UWIR for the Surat CMA will be revised every three years (with the next revision due for public release in 2016) to incorporate new knowledge. Annual implementation reports will be prepared on monitoring results and emerging information.

OGIA is carrying out research to build new knowledge about the groundwater flow systems to support the revision of the UWIR. The research projects are being carried out in collaboration with CSIRO, Geoscience Australia, universities and petroleum tenure holders.

The following sections provide a summary of OGIA research projects being developed and implemented by the OGIA. The descriptions are largely taken directly from OGIA literature.

4.9.1 Condamine Connectivity Project

Although the impact on the Condamine Alluvium (CA) from depressurisation of the underlying Walloon Coal Measures (WCM) is expected to be relatively small, the alluvium is an essential resource that is heavily developed. Therefore improving understanding about interconnectivity between the formations is important.

Improving understanding of the connectivity between the CA and the WCM involves improving understanding of the geology of the contact zone between the formations, and the hydraulic properties of the contact zone. Multiple lines of investigation are being pursued including:

- Water level mapping;
- Aquifer pump testing;
- Geological mapping; and
- Synthesis (updated hydrogeological conceptualisation).

Santos GLNG is not required to contribute data to the project since the Condamine Alluvium is not located on or near (>50 km) GLNG tenures.

4.9.2 Walloon Connectivity Project

The Walloon Coal Measures will be extensively depressurised during gas production. The hydraulic properties and distribution of the overlying and underlying material are the primary factors affecting the extent to which associated aquifers will be affected. For this project, a similar approach is being used to that for the Condamine Connectivity Project. Due to the extent of the area, the project is focused at both regional and local scales. Local scale investigations are being carried out in collaboration with tenure holders.

Improving understanding of the connectivity between the gas bearing areas of the WCM and the overlying and underlying aquifers involves improving understanding of the geology and hydraulic properties of the aquitards. Because the aquitards cover such a large area, investigations are being carried out at both local and regional scales.

Santos GLNG contributes by providing available subsurface data to OGIA that is requested in relation to this research project, where such data are available.

4.9.3 Geological Modelling Project

A new geological model is being prepared as a basis for the later construction of the new groundwater flow model. The geological model is being developed principally by stratigraphic interpretation and correlation of downhole geophysical data (wireline logs) from petroleum and gas wells. Building upon existing approaches, a regionally consistent stratigraphic framework has been developed as the basis for correlation. Initially the data available from the bore holes is interpreted and then the framework is used to make a consistent and robust interpretation between these points across the extent of the model area.

Santos GLNG contributes by providing available subsurface data to OGIA that is requested in relation to this research project, where such data are available.

4.9.4 Modelling Methodology Project

A groundwater flow model for the Surat Cumulative Management Area needs to represent complex multilayered geology and the movement of groundwater in gaseous coal formations. Improved techniques for modelling are being identified and tested. Such areas for improvement and testing include dual phase flow modelling, regional versus local scale representation, and optimising the simplification of complex systems.

Santos GLNG contributes by providing available subsurface data to OGIA that is requested in relation to this research project, where such data are available.

4.9.5 Geological Structures Project

Geological structures, such as faults, have the potential to affect the flow of groundwater. The project will update the mapping of structures and assess their hydraulic characteristics.

Santos GLNG contributes by providing any available subsurface data to OGIA that is requested in relation to this research project, where such data are available.

4.9.6 Spring Knowledge Project

Improved understanding of the risk to springs requires improved understanding of spring function. Conceptual options for the hydrogeological setting of representative springs have been developed and field data is being collected to refine understandings. Spring monitoring methodologies are being reviewed and a field trial is currently being designed.

In parallel with other research projects, OGIA is carrying out the Spring Knowledge Project (SKP) to advance understanding in relation to springs. Major component subprojects are:

- Enhancing knowledge about the hydrogeological setting of springs;
- Improving the techniques for monitoring springs; and
- Identifying watercourse sections that are receiving a groundwater contribution.

The outcomes from the SKP will be used to inform the future assessments of risks to springs and the monitoring and management arrangements when the UWIR is reviewed in December 2015.

Santos GLNG contributes by providing relevant available data to OGIA that is requested in relation to this research project, where such data are available. More detail regarding the spring monitoring program that is directly financed by Santos GLNG is provided in Chapter 3 (EPBC Springs).

5.0 Managed Aquifer Recharge

5.1 Overview

Managed aquifer recharge (MAR) is the purposeful recharge (or injection) of water to aquifers for subsequent recovery. In the case of the proposed Santos GLNG MAR trial in Roma, the injected water comprises treated coal seam water.

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.

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 MAR and progress against each commitment.

Table 5-1: 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 pilot program and schedule for gas 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 January 2011.	Completed January 2011.
	Roma CSG Field Stage 2 – Investigations and Assessment.	Completed January 2011.	Completed January 2011.
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning.	Completed in Q1/Q2 2012.	Completed 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 Q4 2016.
	Roma CSG Field (The Bend) Stage 4 – Operation.	Due to commence Q3/Q4 2014.	Due to commence Q1 2017.
	Arcadia CSG Field Stage 1 – Desktop Study.	Completed September 2013.	Completed September 2013.
	All approved Injection Management Plans will be provided in an update to the CWMMP.	Ongoing.	Ongoing.

5.3 Status of Feasibility and Regulatory Approval

Santos GLNG is assessing the feasibility of implementation of MAR within the Roma field at the location of water treatment and gas compressor station Roma Hub Compressor Station 2 (HCS-02).

MAR in Roma would 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 construction, dust suppression and irrigation.

An application to the Queensland Government was sought to amend Environmental Authority (EA) conditions to permit the operation of MAR in the Roma field. This amendment was approved in 2014 following the submission including an Injection Management Plan (IMP) in support of the amendment application.

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 DEHP on 15 January 2014 was provided in the 2013 CWMMP Annual Report (Santos GLNG, 2014).

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

6.0 Hydraulic Fracturing

6.1 Overview

Hydraulic fracturing is employed in the petroleum industry to improve the production efficiency of 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 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 an 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 up to 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 well is put into production. The initial produced fluids (often referred to "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.

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 hydraulic fracturing and progress against conditions.

Table 6-1: Stage 2 CWMMP Rev 2 Commitments – Hydraulic Fracturing

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49e	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.	Complete Provided in Figure 6-1, Figure 6-2 and Table 6.2 of this Annual Report.
49f	Santos GLNG has agreed with the Department of the Environment to undertake additional Direct Toxicity Assessment that will include:	December 2013.	Ongoing, due for completion 2016.

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
	• an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with fraccing chemicals, and (iii) fraccing chemicals in freshwater; • assessing the risk of individual fraccing chemicals of concern; and • assessing contribution of fraccing chemicals to toxicity of fraccing fluids and flow-back waters (mixture toxicity). 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.		

6.3 Hydraulic Fracturing in 2015

As of December 2015, 51 wells within the Santos GLNG gas fields had been hydraulically fractured in 2015, a total of 152 hydraulic fracturing events/stages were completed within these 51 wells. The location and depth of the hydraulic fracturing stages are presented in Table 6-2.

The spatial distribution of wells that have been hydraulically fractured to the end of 2015 within the Santos GLNG gas fields are presented in Figure 6-1. Figure 6-2 contains the anticipated number of wells to be hydraulically fractured throughout the gas fields in 2016.

Table 6-2: Hydraulic Fracturing Locations and Perforation Details Completed in 2015

Well Name and Stage	Latitude (decimal) [WGS84]	Longitude (decimal) [WGS84]	Top of Perforation (mbgl)	Bottom of Perforation (mbgl)
BBW8	-26.44309	149.38316	497.8	797.5
BDH1	-26.47630	149.27251	535.1	796.7
BDH2	-26.47473	149.27538	540.5	812.3
BDH3	-26.47906	149.27136	536.2	805.3
FV13-09-2	-25.70473	149.11606	1940.4	2098.9
FV13-09-3	-25.70479	149.11600	1516.2	1760.2
FV13-09-5	-25.70490	149.11589	2113.8	2355.8
FV13-09-6	-25.70496	149.11583	2296.6	2327.4
FV13-14-1	-25.71681	149.10657	1386.6	1703.6
FV13-14-2	-25.71681	149.10648	1730.6	2030.3
FV13-14-4	-25.71681	149.10631	1062.1	1277.2
FV18-15-1	-25.79351	149.12773	1472.5	1849.9
FV18-15-5	-25.79365	149.12803	1574.3	1968.6
FV18-16-2	-25.79846	149.15030	1613.0	1927.9
FV18-16-3	-25.79850	149.15022	1674.7	1842.5
FV18-16-4	-25.79853	149.15015	1535.7	1717.0
FV18-16-5	-25.79857	149.15007	1777.4	1947.5
FV18-16-6	-25.79861	149.15000	1684.6	1824.5
FV18-16-7	-25.79856	149.14992	1119.9	1251.4
FV18-16-8	-25.79868	149.14985	1615.4	1789.7
MKY6	-25.23537	148.89511	605.1	690.1
MYF5	-26.40918	148.85720	405.4	630.0
MYF7	-26.40509	148.85131	392.0	624.2
RM02-38-1	-26.40412	149.06972	648.2	1078.3
RM02-38-2	-26.40406	149.06966	620.6	1130.1
RM02-38-3	-26.40401	149.06960	578.0	1052.9
RM02-38-4	-26.40396	149.06954	574.1	1062.5
RM08-14-1	-26.43950	149.04516	630.1	636.8
			748.1	749.6
			884.5	885.7
			935.3	938.9
			1038.5	1043.3
RM08-14-2	-26.43943	149.04513	723.0	725.1
			736.1	739.9
			748.9	752.4
			778.9	783.2
			864.9	867.9
			884.7	886.6
			1050.5	1053.9

Well Name and Stage	Latitude (decimal) [WGS84]	Longitude (decimal) [WGS84]	Top of Perforation (mbgl)	Bottom of Perforation (mbgl)
RM08-14-2	-26.43943	149.04513	1156.5	1160.6
RM08-14-3	-26.43936	149.04510	644.0	645.5
			651.3	653.9
			700.5	706.8
			734.3	739.0
			752.5	753.7
			872.6	874.0
			925.5	929.6
			1021.0	1027.2
RM08-14-4	-26.43929	149.04507	694.0	697.0
			707.0	711.2
			743.7	749.2
			805.7	808.7
			859.0	861.2
			959.0	965.7
			1050.2	1051.7
			1172.4	1179.1
RM08-16-1	-26.45044	149.03221	833.0	1386.7
RM08-16-2	-26.45039	149.03215	766.9	1169.7
RM08-16-3	-26.45034	149.03209	885.7	1247.9
RM08-16-4	-26.45028	149.03203	649.2	1011.9
RM09-04-1	-26.41089	149.06259	538.4	994.2
			569.0	575.7
			613.7	615.6
			682.4	683.9
			711.6	713.1
			736.0	737.5
			762.0	762.9
			892.5	898.4
			925.2	931.4
			974.3	979.4
			993.3	994.2
RM09-04-2	-26.411	149.063	522.5	523.5
			571.0	575.8
			641.5	642.6
			664.7	669.0
			772.6	773.5
			793.3	794.7
			815.8	817.5

Well Name and Stage	Latitude (decimal) [WGS84]	Longitude (decimal) [WGS84]	Top of Perforation (mbgl)	Bottom of Perforation (mbgl)
RM09-04-2	-26.411	149.063	876.2	878.8
			894.3	901.0
RM09-05-1	-26.414	149.083	438.7	445.4
			566.3	570.3
			589.0	591.6
			748.0	752.8
			772.8	774.8
			828.1	834.1
RM09-05-2	-26.414	149.083	480.1	486.7
			600.9	601.9
			620.7	627.4
			652.7	659.4
			791.7	792.9
			833.2	838.2
			920.7	917.4
			934.7	941.4
RM09-05-3	-26.414	149.083	641.8	648.5
			692.0	698.7
			720.0	724.9
			756.0	761.0
			799.0	802.0
			819.0	820.5
			833.1	839.8
			902.6	904.1
			950.3	952.2
			1036.7	1041.3
			1076.3	1077.5
			1122.2	1127.0
			1143.4	1147.6
RM09-05-4	-26.414	149.083	682.6	683.6
			760.2	766.9
			765.2	793.0
			815.4	816.4
			839.3	843.7
			923.8	928.2
			943.2	946.9
			975.5	982.2
			1009.1	1013.6
			1166.1	1167.8

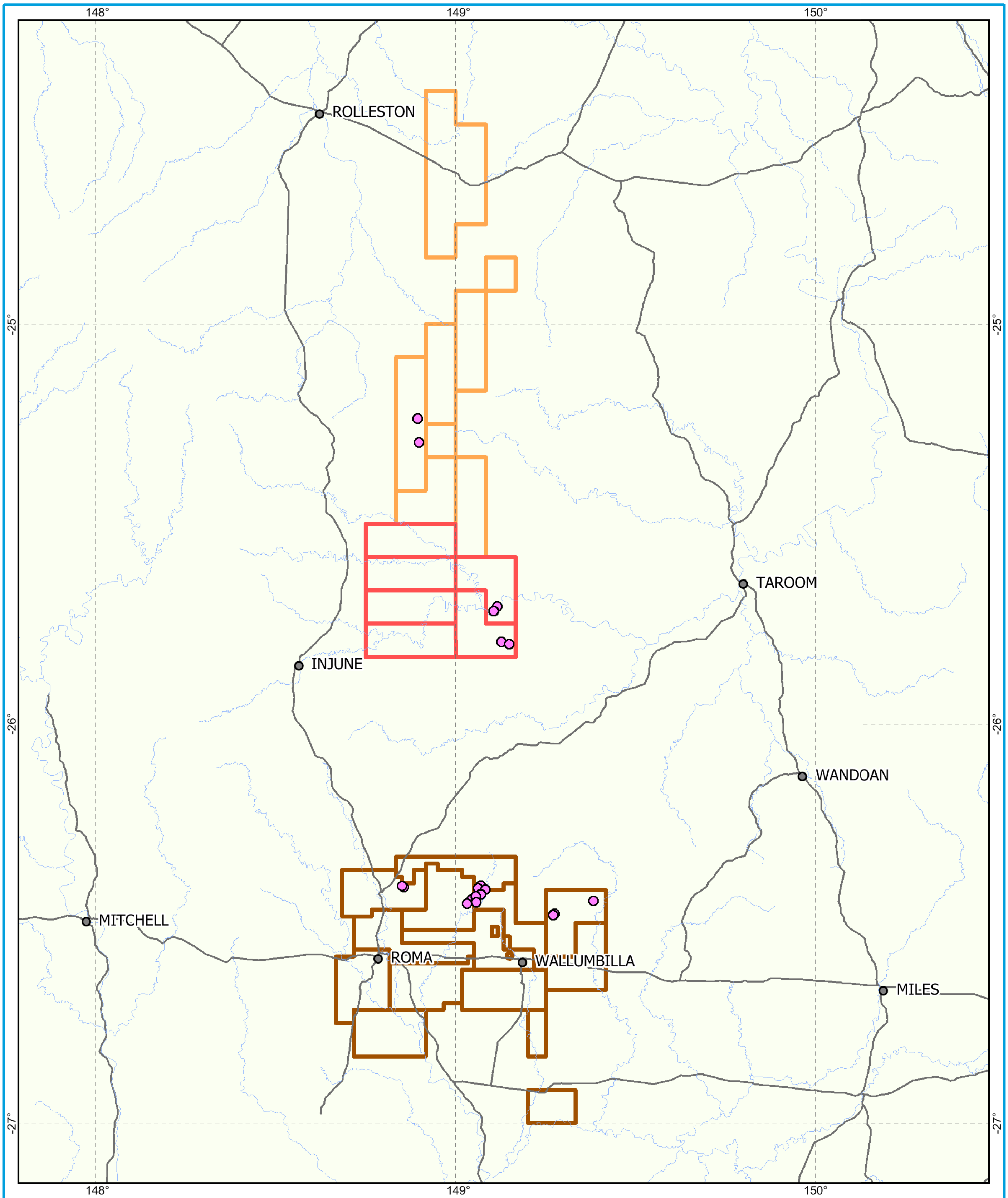
Well Name and Stage	Latitude (decimal) [WGS84]	Longitude (decimal) [WGS84]	Top of Perforation (mbgl)	Bottom of Perforation (mbgl)
RM09-05-4	-26.414	149.083	1230.1	1231.6
			1260.4	1264.0
			1287.6	1289.9
			1306.2	1311.7
RM09-09-1	-26.426	149.071	690.0	1009.9
RM09-09-2	-26.427	149.071	602.8	1132.7
RM09-09-3	-26.427	149.071	587.5	1093.1
RM09-09-4	-26.427	149.071	636.3	1171.9
RM09-14-1	-26.432	149.057	609.2	833.6
RM09-14-2	-26.432	149.057	641.9	1045.3
RM09-24-1	-26.446	149.058	770.7	773.7
			789.1	795.8
			828.6	835.3
			884.0	890.7
			941.5	948.2
			1087.8	1094.5
			1153.5	1154.3
			1197.0	1203.7
RM09-24-2	-26.446	149.058	788.7	789.7
			799.7	800.7
			872.6	874.1
			922.7	924.2
			973.2	974.7
			999.5	1000.3
			1062.4	1068.4
			1103.7	1104.9
			1126.7	1129.7
			1195.7	1197.2
			1216.7	1223.4
RM09-24-3	-26.446	149.058	492.1	498.3
			537.9	540.9
			555.0	556.5
			641.2	644.2
			703.4	704.9
SYH5	-25.295	148.899	674.7	740.8

mbgl – metres below ground level

6.4 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 Fracturing 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 fracturing fluids in the context of the natural ecotoxicity of coal seam gas water to surface water organisms.

The direct toxicity assessment for various waters and fluids commenced in December 2015, this involves testing representative coal seam waters from wells to be fractured and testing the hydraulic fracturing fluid and coal seam water as formulated for injection. Although the direct toxicity assessment has commenced, due to reservoir characteristics limiting the speed at which wells selected for the toxicity assessment can be pumped, the final sample required to complete the process has been delayed. Based on the delay in collecting the final sample and the extended laboratory turnaround times, the Direct Toxicity Assessment is scheduled to be completed by the end of 2016.



GLNG CSG WMMP ANNUAL REPORT 2015

Santos GLNG

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

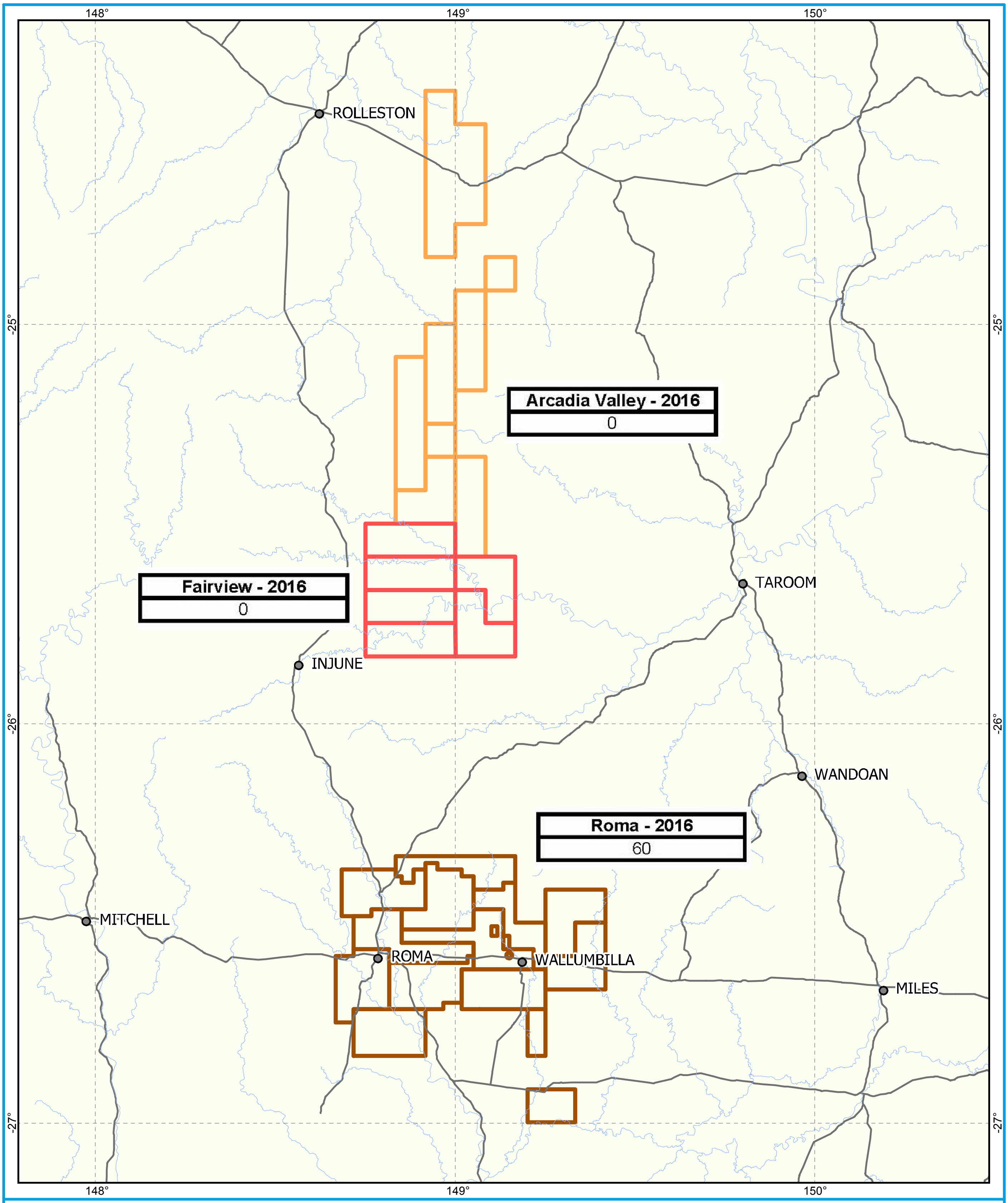
0 10 20 30 40 50 km

Date: March 2016, File No. GLNG 612a

GDA

FIGURE 6-1

Santos
GLNG Project



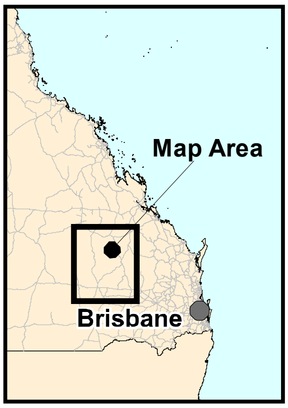
GLNG CSG WMMP ANNUAL REPORT 2015

Santos GLNG

State Controlled Roads

Hydrology

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 - 2016 60 — Number of Scheduled Hydraulic Fracturing Locations

0 10 20 30 40 50 km

Date: March 2016, File No. GLNG 612b

GDA

FIGURE 6-2

Santos GLNG Project

7.0 Surface Water Monitoring

7.1 Overview

The Fairview and Arcadia Valley fields are located within the Fitzroy Basin, whilst the Roma field is located in the upper catchment area of the Murray Darling Basin (MDB). The main water systems within the Fairview field are the Dawson River and its tributaries Baffle Creek and Hutton Creek. There are five creeks running through the Roma 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 field lies within both the Comet River and Dawson River catchments, where 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 catchment systems.

7.2 Coal Seam Water Monitoring and Management Plan Commitments

Table 7-1 provides an outline of the commitments made in the Stage 2 CWMMP Rev 2, specific to surface water monitoring and progress against each commitment.

Table 7-1: Stage 2 CWMMP Rev 2 Commitments – Surface Water Monitoring

Condition	Commitment	Target Completion Date Specified in Stage 2 CWMMP Rev 2	Status
49.g.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).	End of 2014.	Completed. Data acquisition ongoing.

7.2.1 Surface Water Threshold Values

The review of baseline data and the development of threshold values for Fairview and Roma fields was completed in February 2015. Methodology for threshold derivation included the selection of sites from each key watercourse, evaluation of high and low flow data and statistical analysis using the Environmental Protection (Water) Policy 2009 and associated Water Quality Objectives (WQO's) for regional comparison. The Surface Water Baseline Threshold Report is provided by URS (2015), refer to Appendix B.

A summary of the surface water monitoring program, including monitoring location, sub-catchment, relevant watercourses and period of record is also provided within the report. It is noted that the period of record may differ between the Baseline Threshold Report and Chapter 2 (Surface Water and Groundwater Baseline) due to surface water program establishment and decommissioning dates.

Ongoing collection of water quality sampling will be conducted within the Arcadia gas field until such time that threshold values have been established. The development of surface water threshold values for the Arcadia Valley gas field will be development at the time in which sufficient baseline data has been collected.

8.0 Brine Management

8.1 Overview

Brine is defined as the concentrated reverse osmosis waste stream (RO concentrate). Once RO concentrate reaches above 40,000 mg/L total dissolved solids (TDS), it is then defined by DEHP as 'brine'. Santos GLNG has the following mechanisms currently in place for RO concentrate management:

- **Fairview field:** Santos GLNG stores and manages RO concentrate production in brine containment ponds.
- **Roma field:** Santos GLNG stores and manages RO concentrate production in brine containment ponds.
- **Arcadia Valley field:** No RO concentrate will be produced in Arcadia Valley field within the scope of the Santos GLNG Stage 2 CWMMP Rev 2.

Further brine management options or expansion of current options may be required as gas fields develop, Santos GLNG is currently assessing options for the long-term management of RO concentrate and/or brine.

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 brine management and progress against each commitment.

Table 8-1: 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 Valley, Roma and Fairview gas fields as a state government requirement within the respective gas field's EA's. These will be provided in an update to the CWMMP.	December 2014.	March 2020 Due to an extension granted by the state government (DEHP) for provision of Brine Management Plans to December 2019.

8.3 Brine Management Progress

As stated in the 2014 CWMMP Annual Report there has been a significant reduction in water volumes (approximately 30%-50%) then originally predicted in the CWMMP Rev 2, for the Roma and Fairview gas fields. This has therefore significantly reduced estimated brine production volumes.

During 2015, the focus on brine management studies included maximising beneficial use options for CSG and proposed uses, as well as increased focus on fit for purpose use of water that meets relevant standards, understanding and capitalising on these opportunities as priority will minimise brine and solid salt production.

The outcomes of brine and salt management feasibility assessments are ongoing; however, based on current sanctioned Development Projects, Santos GLNG has constructed sufficient storage capacity in the Fairview field for brine management to 2025, and 2019 in the Roma field. The Arcadia Valley field is not estimated to start production until 2018 and therefore there will be no brine to manage during the scope of the Stage 2 CWMMP Rev 2.

Extension was previously granted by the state government (DEHP) for provision of Brine Management Plans for Roma field and Fairview and Arcadia Valley fields by December 2019.

9.0 Subsidence

9.1 Overview

Pressure reductions in the subsurface due to coal seam water production have the potential to cause subsidence within the coal seam and a risk of deformation at 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 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.

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

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 subsidence monitoring 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 Findings to Date

Stage 1 of the monitoring program comprised collection and interpretation of baseline ground motion conditions across the Surat and Bowen basins where gas field development activity is expected to occur at some point in the future. The findings were used to inform the Subsidence Management Plan.

Stage 2 of the InSAR monitoring program commenced in July 2012. An Interim report on the Stage 2 InSAR monitoring program was submitted to the DOTE in November 2013 as per the commitment made in the Stage 2 CWMMP Rev 2 and described the interim findings of Stage 2 of the monitoring program. Stage 2 was completed in April 2015.

Stage 3 of the current InSAR monitoring program commenced in April 2015. The first interim report for Stage 3 is due in April 2016.

To date, the results show a stability pattern over time for the whole Santos GLNG tenures. No direct correlation between ground deformation and exact locations of the gas activities is evident. The localised displacements measured over the Santos GLNG fields (accumulated values of up to 20 mm) are likely due to superficial processes. Such processes might include natural processes such as erosion, sediment deposition, and soil wetting/drying, as well as anthropogenic activity such as large civil construction projects and agricultural activities.

9.4 Ongoing Studies and Monitoring

InSAR image data acquisition for Stage 2 commenced in April 2015 and will run for 3 years. The data acquisition rate is every 48 days with periodic reporting scheduled for April 2016, March 2017 and February 2018 when Stage 3 of the data acquisition is programmed to stop.

Four Quarterly Reports have been delivered since the start of data acquisition in April 2015, up to December 2015. The next quarterly report is due in Q1 2016.

10.0 Reporting

10.1 Overview

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 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 DOTE within the first quarter of the following year.	31 March 2016.	Complete.
	Digital data can be provided to DOTE on request.	Ongoing.	Ongoing.
	Santos GLNG will publish the following reports on the internet (via the Santos Water Portal): ▪ Coal Seam Water Monitoring and Management Annual Report; ▪ Link to the latest Surat Cumulative Management Area (CMA); and Underground Water Impact Report (UWIR).	31 March 2016.	Complete.
	Santos GLNG will regularly publish data from the water monitoring network on the Santos Water Portal.	Ongoing.	Ongoing (last updated March 2016).
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. Updated CWMMP is due for submission four months after the revised UWIR as agreed with the DOTE in 2015.	In progress.

10.3 2015 Reporting

10.3.1 CWMMP Annual Report

The first Annual Report was submitted to the DOTE on 31 March 2014. The 2013 Annual Report included progress updates from October 2013 to December 2013 which incorporated the 2013 period since submission of Stage 2 CWMMP Rev 2. The 2014 Annual Report was previously submitted reporting on progress from the 1 January 2014 to the 31 December 2015.

This 2015 Annual Report has been developed to provide progress against commitments from 1 January 2015 to 31 December 2015 and will be made available on the Santos Water Portal as required by Conditions 49 and 53 of the EPBC approval by the 31 March 2016.

10.3.2 Digital Data Requests

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

10.3.3 Santos Water Portal

Updates to the water monitoring network were published on the Santos Water Portal, this included updated water level and water quality results for a range of groundwater bores and surface water monitoring locations. These were most recently updated in March 2016.

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

10.3.4 Future Reporting

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 quarterly basis with Q1 2016 data being uploaded in April 2016;
- Submission of the update to the CWMMP, this is due for submission four months after the revised UWIR as agreed with the DOTE in 2015; and
- Commencement of the Annual Report 2016 covering January 2016 to December 2016.

11.0 References

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

Hydrobiology Pty Ltd, 2013, *CSG Fraccing Fluid Ecotoxicology Work Plan June 2013*

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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, 2014, *Santos GLNG Coal Seam Water Monitoring and Management Annual Report.*

URS 2015, *Baseline Threshold Values for Surface Water Quality in Fairview and Roma Project Areas,* Report no. 42627494/R001/0.

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 3
	Installation of Early Warning Spring (EWS) monitoring network.	End 2016.	▶	Section 3
	Ground truthing of a selection of springs to assess the presence of EPBC listed species and EPBC communities.	On and off tenure springs baseline initiated as part of the JIP, to be reported April 2015.	●	Section 3
	Santos GLNG will assume responsibility of mitigation (if required) for on-tenure springs and those off-tenement springs as will be assigned by the Surat Underground Water Impact Report (UWIR)/DOTE.	Ongoing.	♦	Section 3
	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 GLNG is assessing the feasibility of programming 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 3

● 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.	Ongoing monitoring and data assessment.	▶	Section 4
	Contact Zone Program.	Ongoing after installation.	▶	Section 4
	Wallumbilla Fault Program.	Installation planned for 2014.	●	Section 4
	Aquifer Response.	Ongoing.	▶	Section 4
	Isotope and geochemical signature.	Ongoing.	▶	Section 4
	Pumping response observations and assessments.	Annually from 2014.	♦	Section 4
	The outcomes of the conventional oil and gas well and water bore risk assessment will be presented in an update to the CWMMP.	2014. Updated CWMMP is due for submission four months after the revised UWIR as agreed with DOTE in 2015.	▶	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
49c, 53a, 53 d)ii	**Aquifer Re-injection**			
	Santos GLNG has developed a Managed Aquifer Recharge (MAR) pilot program and schedule for gas field piloting of aquifer reinjection.			
	Fairview CSG Field Stage 1– Desktop Study.	Completed March 2012.	●	Section 5
	Roma CSG Field Stage 1– Desktop Study.	Completed January 2011.	●	Section 5
	Roma CSG Field Stage 2 – Investigations and Assessment.	Completed January 2011.	●	Section 5
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning.	Completed Q1/Q2 2012.	●	Section 5
	Roma CSG Field pilot trial (Hermitage) Stage 4 – Operation.	Completed Q4 2012.	●	Section 5
	Roma CSG Field (The Bend) Stage 3 – Construction and Commissioning.	Due for completion Q3 2014. Ongoing, due for completion 04 2016.	▶	Section 5
	Roma CSG Field (The Bend) Stage 4 – Operation.	Due to commence Q3/Q4 2014. Ongoing, due to commence Q1 2017.	▶	Section 5
	Arcadia Valley CSG Field Stage 1 – Desktop Study.	Completed September 2013.	●	Section 5
	All approved Injection Management Plans will be provided in an update to the CWMMP.	Ongoing.	♦	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
49e	**Hydraulic Fracturing**			
	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.	●	Section 6
49f	Santos GLNG has agreed with the DOTE to undertake additional Direct Toxicity Assessment that will include: • an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with hydraulic fracturing chemicals, and (iii) hydraulic fracturing chemicals in freshwater; • assessing the risk of individual hydraulic fracturing chemicals of concern; and • assessing contribution of hydraulic fracturing chemicals to toxicity of hydraulic fracturing fluids and flowback waters (mixture toxicity). 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 DOTE upon completion.	December 2013 Ongoing, due for completion 2016.	▶	Section 6

● 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, data acquisition ongoing.	▶	Section 2
	EPBC spring hydrogeological conceptual model.	Existing models submitted November 2013.	●	Section 3
	Atmospheric pressure monitoring – 1 installation (barrologger or other) at each EPBC spring complex or cluster of spring complexes.	Completed for on-tenure springs 2013.	●	Section 3
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 an update to the CWMMP.	End of 2014. Completed, data acquisition ongoing.	▶	Section 7
49.g.x)	**Brine Management Plans**			
	Provision of Brine Management Plans developed for Arcadia Valley, Roma and Fairview gas fields as a state government requirement within the respective gas field's environmental authorities (EA's). These will be provided in the next update to the CWMMP.	December 2014. The gas field Brine Management Plans will now be submitted to the DOTE in Santos GLNG Coal Seam Water Monitoring and Management Annual Report in 2019, due to an extension granted by the state government (DEHP) for submission of Brine Management Plans to December 2019.	▶	Section 8

● 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 2016 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): ▪ Coal Seam Water Monitoring and Management Annual Report; and ▪ Link to the latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR).	31 March 2016.	●	Section 10
	Santos GLNG will regularly publish data from the water monitoring network on the Santos Water Portal.	Ongoing	♦	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. Updated CWMMP is due for submission four months after the revised UWIR as agreed with the DOTE 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. Completed, data acquisition ongoing.	▶	Section 2
	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 Joint Industry Plan (JIP) provides a statistical methodology for groundwater level trend analysis.	●	Section 3
53.d.i.III	**Subsidence**			
	The Subsidence Management Plan provides a response plan into 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 – Surface Water Baseline Threshold Report

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Report

Coal Seam Water Monitoring and Management Plan

AUSTRALIA

Baseline Threshold Values for Surface Water Quality in Fairview and Roma Project Areas

17 February 2015
42627494/R001/0

Prepared for:
Santos

Prepared by URS Australia Pty Ltd

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ABBREVIATIONS

Abbreviation	Description
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
CSG	Coal seam gas
DO	Dissolved Oxygen
EC	Electrical Conductivity
EHP	Department of Environment and Heritage Protection
EIS	Environmental Impact Statement
EPBC	Environment Protection and Biodiversity Conservation
EPP Water	Environmental Protection (Water) Policy 2009
FPA	Fairview Project Area
LNG	Liquefied Natural Gas
MNES	Matters of National Environmental Significance
NTU	Nephelometric Turbidity Unit
QWQG	Queensland Water Quality Guidelines
RPA	Roma Project Area
TN	Total Nitrogen
TSS	Total Suspended Solids
URS	URS Australia Pty Ltd
WQO	Water quality objective

1 INTRODUCTION

1.1 Background

The Santos GLNG project will convert coal seam gas (CSG) to liquefied natural gas (LNG) for export to global markets. As part of the approval for this project, the Minister for the former Department of Sustainability, Environment, Water, Population and Communities (now Department of the Environment) granted approval under the Environment Protection and Biodiversity Act 1999, with various conditions that require the submission and approval of a Stage 1 and Stage 2 Coal Seam Water and Monitoring and Management Plan Report.

1.2 Project Scope

This report, which will form part of the latest update to the Santos GLNG Coal Seam Water Monitoring and Management Plan Stage 3 Report, provides threshold values for the surface waters within the Fairview and Roma Project Areas that are aimed to protect water quality, aquatic ecosystems and Matters of National Environmental Significance (MNES), as conditioned by Condition 49 (g) of the Environment Protection and Biodiversity Conservation (EPBC) Act Approval. The purpose of deriving threshold values is to specify levels at which management actions will be initiated to respond to escalating levels of risk to relevant MNES.

2 BACKGROUND INFORMATION

2.1 Legislation and Guidelines

2.1.1 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy 2009* (EPP Water) is an instrument of the Environmental Protection Act 1994 (EP Act). Amongst other functions, EPP Water governs the discharge of wastewater to land, surface water, and groundwater, aims to protect environmental values (EVs) and sets water quality objectives (WQOs) to provide guidance to protect EVs.

2.1.2 Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ 2000)

The Australian and New Zealand guidelines for fresh and marine water quality guidelines were developed in 2000 under the *National water quality management strategy* by the Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and provide a framework for assessing water quality by comparison with guidelines derived from local reference values. Guideline values were developed and classified on the following criteria:

- Level of environmental disturbance of surface waters (e.g. highly or slightly to moderately disturbed waters)
- Freshwater or saline surface water
- Waterbody elevation i.e. upland or lowland aquatic environments
- Biogeographic region such as southeast or tropical Australia.

The guidelines also state that “the old single number guidelines [1992; incorporated into current 2000 guidelines] are regarded as *guideline trigger values* that can be modified into regional, local or site specific guidelines by taking into account factors such as the variability of the particular ecosystem or environment, soil type, rainfall and level of exposure to contaminants. Trigger values are concentrations that, if exceeded, would indicate a *potential* environmental problem, and so ‘trigger’ a management response e.g. further investigation and subsequent refinement of the guidelines according to local conditions” (Volume 1, Chapter 2, p2-10). This report refers to both physicochemical and toxicant guideline values from ANZECC/ARMCANZ 2000.

2.1.3 Queensland Water Quality Guidelines

The Queensland Water Quality Guidelines (QWQG) (EHP 2009) provide a framework for assessing water quality in Queensland through the setting of WQOs to protect or enhance EVs for Queensland waters.

2.2 Surface Water Environment

2.2.1 Fairview Project Area (FPA)

The surface water environment in the FPA lies within the Upper Dawson River subcatchment that forms part of the Fitzroy River Basin. This environment comprises of three main watercourses, namely the Upper Dawson River, Hutton Creek and Baffle Creek. The reaches of the Dawson River that lie within the FPA are either semi-permanent (upstream of Dawson’s Bend) or permanent, being fed by springs at Dawson’s bend. The watercourses have been slightly to moderately impacted by historical and current landuse in the region, namely agriculture. Further details on the surface water environment of the Upper Dawson Catchment can be found in the Santos GLNG Gas Field Development Project EIS Appendix N (Surface Water Technical Report), August 2014.

2.2.2 Roma Project Area (RPA)

The surface water environment in the RPA comprises of the Upper Balonne tributaries that form part of the Balonne Condamine Basin. The main watercourses within the RPA include Yuleba Creek, Blyth Creek, Bungil Creek and Wallumbilla Creek which are ephemeral and therefore flow only after significant rain events. Like the watercourses in the Upper Dawson River catchment, the surface water environment is slightly to moderately impacted by historical and current landuses. Further details on the surface water environment of the Upper Dawson Catchment can be found in the Santos GLNG Gas Field Development Project EIS Appendix N (Surface Water Technical Report), August 2014.

2.3 Surface Water Monitoring

A summary of the Santos GLNG surface water monitoring locations within the FPA and RPA is provided in Table 2-1 below, including information on their location within each study-sub-catchment, relevant watercourses, and importantly the period of record and sample frequency.

Table 2-1 Santos GLNG monitoring locations by sub-catchment

Catchment	Sub-catchment	Watercourse	Gas field	Site ID	Location type (from Santos GLNG)	GIS coordinates		Period of record	Sample count *n*
						Latitude	Longitude		
Upper Dawson River	Upper Dawson – main channel (Headwaters to junction with Hutton Creek)	Dawson River	Arcadia	AS01	Perennial stream	-25.48722	148.83083	20/4/2010 - 5/12/2012	22
		Dawson River	Fairview	S9	Perennial stream	-25.38450	148.64880	9/5/2006 - 17/11/2011	16
		Dawson River	Fairview	S10	Perennial stream	-25.61900	148.99100	6/10/2006 - 17/11/2011	25
		Dawson River	Fairview	S13	Perennial stream	-25.58400	148.98100	10/9/2003 - 12/8/2012	157
	Upper Dawson – main channel (Hutton Creek to Taroom)	Dawson River	Scotia	DAW01	Perennial stream	-25.79776	149.55930	19/7/2012 - 31/10/2012	2
		Dawson River	Fairview	S1	Perennial stream	-25.72464	149.10405	11/9/2003 - 18/11/2011	23
		Dawson River	Fairview	S2	Perennial stream	-25.72900	149.09400	28/8/2009 - 16/3/2013	228
		Dawson River	Fairview	S3	Perennial stream	-25.72570	149.09200	23/4/2004 - 18/11/2011	20
		Dawson River	Fairview	S4	Perennial stream	-25.69233	149.21476	8/9/2003 - 19/3/2013	66
		Dawson River	Fairview	S5	Perennial stream	-25.74630	149.33140	25/5/2005 - 14/11/2011	15
		Dawson River	Fairview	S5a	Perennial stream	-25.79760	149.55770	29/5/2011	1
		Dawson River	Fairview	S14a	Perennial stream	-25.71667	149.11000	23/4/2004 - 22/5/2008	9
		Dawson River	Fairview	S18D	Surface water quality	-25.68308	149.15050	27/5/2012 - 5/6/2012	2
		Dawson River	Fairview	S18U	Surface water quality	-25.72869	149.09848	27/5/2012 - 5/6/2012	3
		Dawson River	Fairview	SC1	Spring	-25.72507	149.08765	3/11/2009 - 3/10/2012	17
		Juandah Creek/Dawson River junction	Fairview	SS2	Perennial stream	-25.66767	149.78749	20/9/2011 - 20/9/2011	1
		Dawson River	Fairview	TAR	Perennial stream	-25.63750	149.79010	11/11/2010 - 31/10/2012	5
	Baffle Creek	Baffle Creek	Fairview	S2a	Perennial stream	-25.58333	148.96000	9/9/2003	1
		Baffle Creek	Fairview	S2b	Perennial stream	-25.58333	148.96000	9/9/2003	1
		Baffle Creek	Fairview	S7	Perennial stream	-25.59440	148.81060	9/9/2003 - 16/11/2011	23
		Baffle Creek	Fairview	S8	Perennial stream	-25.58899	148.98215	10/9/2003 - 17/3/2013	215
		Baffle Creek	Fairview	S12	Perennial stream	-25.59397	148.81060	4/11/2009 - 17/3/2013	133

Catchment	Sub-catchment	Watercourse	Gas field	Site ID	Location type	GIS coordinates		Period of record	Sample
	Hutton Creek	Hutton Creek	Fairview	SW536	Spring	-25.71470	149.06513	12/5/2011	1
		Hutton Creek	Fairview	ES4	Ephemeral stream	-25.72605	148.98333	1/3/2013	1
		Hutton Creek	Fairview	I14	Perennial stream	-25.68991	148.96558	3/3/2009	1
		Hutton Creek	Fairview	I16	Perennial stream	-25.68400	148.93968	2/8/2007 - 3/3/2009	3
		Hutton Creek	Fairview	S6	Perennial stream	-25.72570	148.92100	19/4/2004 - 15/11/2011	21
		Hutton Creek	Fairview	S6a	Perennial stream	-25.73333	148.67667	10/9/2003	1
		Hutton Creek	Fairview	S11	Perennial stream	-25.77100	148.74800	5/10/2006 - 25/2/2013	35
		Hutton Creek	Fairview	S11a	Perennial stream	-25.80300	148.91070	11/9/2003 - 15/11/2011	15
		Hutton Creek	Fairview	S14	Perennial stream	-25.71372	149.07982	3/8/2007 - 1/8/2010	7
		Hutton Creek	Fairview	S15	Perennial stream	-25.78930	148.90955	28/11/2009 - 25/3/2013	398
		Hutton Creek	Fairview	S16	Perennial stream	-25.70687	148.97216	3/3/2009 - 28/3/2013	263
		Hutton Creek	Fairview	S17	Perennial stream	-25.70167	149.05092	27/12/2009 - 27/3/2013	205
		Fairview	Fairview	S19D	Surface water quality	-25.76135	148.77732	28/8/2012	1
		Fairview	Fairview	S19U	Surface water quality	-25.76133	148.77675	4/1/2010	1
		Hutton Creek	Fairview	SC3	Spring	-25.71961	149.02898	3/11/2009 - 22/2/2013	16
		Hutton Creek	Fairview	SC2	Spring	-25.71470	149.06513	3/11/2009 - 3/10/2012	21
	Juandah and Bungaban Creeks	Juandah Creek	Scotia	SS3	Perennial stream	-25.67973	149.80450	24/10/2011 - 18/4/2012	8
		Juandah Creek	Scotia	SS4	Perennial stream	-25.84193	149.82595	24/10/2011 - 14/3/2012	8
		Bungaban Creek	Scotia	SS5	Perennial stream	-25.82708	149.92210	24/10/2011 - 16/11/2011	4
		Juandah Creek	Scotia	SS6	Perennial stream	-25.68026	149.80511	18/7/2012	1
	Robinson Creek	Robinson Creek	Scotia	ROB01	Perennial stream	-25.49386	149.52100	18/7/2012 - 31/10/2012	2
		Robinson Creek	Scotia	ROB02	Perennial stream	-25.48985	149.64140	18/7/2012 - 1/11/2012	2
Lower Dawson River	Lower Dawson – main channel	Dawson River	Fairview	THEOW	Ephemeral stream	-24.93788	150.06728	11/11/2010 - 30/11/2010	4
Upper Balonne River tributaries	Upper Balonne – main channel	Balonne River	Roma	RS20	Perennial stream	-27.01900	149.37640	20/5/2010 - 7/4/2013	20

Catchment	Sub-catchment	Watercourse	Gas field	Site ID	Location type	GIS coordinates		Period of record	Sample
		Balonne River	Roma	RS24	Perennial stream	-27.01958	149.48298	8/7/2010 - 7/4/2013	23
	Upper Balonne – Yuleba Creek	Yuleba Creek	Roma	R019	Perennial stream	-26.88820	149.44810	20/5/2010 - 7/4/2013	31
		Yuleba Creek	Roma	R021	Perennial stream	-26.61110	149.38960	20/5/2010 - 7/4/2013	29
		Yuleba Creek	Roma	RES17	Ephemeral stream	-26.29230	149.35040	19/5/2010	1
	Upper Balonne – Wallumbilla Creek	Wallumbilla Creek	Roma	R014	Perennial stream	-26.92120	149.22410	18/5/2010 - 5/2/2013	18
		Wallumbilla Creek	Roma	RES15	Ephemeral stream	-26.69040	149.20550	20/5/2010	1
		Wallumbilla Creek	Roma	RES13	Ephemeral stream	-26.52120	149.12710	19/5/2010 - 5/7/2012	12
		Wallumbilla Creek	Roma	RS14	Perennial stream	-26.58580	149.18230	2/11/2010 - 10/3/2013	2
	Upper Balonne – Blyth Creek	Blyth Creek	Roma	BLCS1	Perennial stream	-26.36192	149.10934	14/11/2011 - 8/5/2012	23
		Blyth Creek	Roma	BLCS2	Perennial stream	-26.35953	149.10116	11/12/2011 - 2/2/2012	5
		Blyth Creek	Roma	BLCS3	Perennial stream	-26.38736	149.08925	19/12/2011 - 7/3/2012	17
		Blyth Creek	Roma	R011	Perennial stream	-26.72941	148.90181	28/4/2011 - 5/5/2012	10
		Blyth Creek	Roma	R025	Perennial stream	-26.43890	149.07755	28/4/2011 - 11/3/2012	7
		Blyth Creek	Roma	RES10	Ephemeral stream	-26.68250	148.90640	18/5/2010 - 1/9/2012	19
		Blyth Creek	Roma	RS7	Perennial stream	-26.71820	148.90350	18/5/2010	1
		Blyth Creek	Roma	RS11	Perennial stream	-26.44400	149.06220	19/5/2010 - 12/4/2012	11
		Appletree Creek	Roma	RS12	Perennial stream	-26.34390	149.12970	19/5/2010 - 5/10/2011	5
		Blyth Creek	Roma	RS25	Perennial stream	-26.46839	149.01429	2/11/2010 - 7/4/2013	5
	Upper Balonne – Bungil Creek	Bony Creek	Roma	RS23	Perennial stream	-26.83560	148.94860	18/5/2010 - 2/3/2013	14
		Bungil Creek	Roma	R001	Perennial stream	-26.57370	148.81440	17/5/2010 - 8/4/2013	23
		Bungil Creek	Roma	R002	Perennial stream	-26.51086	148.81182	11/4/2011 - 24/9/2012	18
		Bungil Creek	Roma	R012	Perennial stream	-26.89610	148.98140	18/5/2010 - 5/6/2012	21
		Bungeworgerai Creek	Roma	RES1	Ephemeral stream	-26.59050	148.69310	20/5/2010	1

Catchment	Sub-catchment	Watercourse	Gas field	Site ID	Location type	GIS coordinates		Period of record	Sample
		Bungil Creek	Roma	RES4	Ephemeral stream	-26.43200	148.79270	17/5/2010	1
		Bungil Creek	Roma	RES6	Ephemeral stream	-26.68880	148.83070	18/5/2010	1

3 THRESHOLD VALUE ASSESSMENT METHODOLOGY

3.1 Monitoring data selection

Water quality data used in this assessment was provided to URS directly by Santos GLNG. It has been assumed that the data had been previously subjected to appropriate quality assurance/ quality control procedures both during sample collection (in terms of sampling protocols) and initial data analysis, and is therefore suitable for interpretative use.

The key temporal and spatial considerations (in accordance with the QWQG 2009) that were made during the monitoring data selection process were as follows;

- Monitoring data was selected from each of the key watercourses within each of the project areas;
- Monitoring data that represented both upstream and downstream reaches of watercourses was selected wherever available;
- Monitoring sites were selected on the basis of the size of the monitoring data sets available (sites with larger data sets spanning longer time periods were preferred).
- Monitoring sites that had automatic gauge data for both electrical conductivity (EC) and stream flows were selected so as to allow for the derivation of EC threshold values for both low flow (baseflow) and high flow conditions.

The monitoring sites whose data were selected for derivation of baseline surface water threshold values are presented in Table 3-1.

3.2 Monitoring data analysis

The entire data set of selected monitoring sites obtained by automatic gauges was initially plotted to ascertain overall trends in water quality (using EC as a surrogate of water quality) in relation to stream flows, other temporal trends, and changes in water quality that could not be explained by changes in stream flow and were therefore deemed as landuse impacts. The overall data set was then manipulated by:

- Separating water quality data in terms of high flow and low (base) flow. High flow data was that which coincided with distinct peaks in stream discharge or stream water level. Conversely, intervening periods which normally coincided with the period of May to October, were deemed to represent low flow conditions. An example of this is shown in Figure 3-1 and Figure 3-2.
- Data of sections of the EC plots that represented obvious gauge error or was interpreted as impacts from unknown anthropogenic activity was not included in the baseline threshold value derivations.

Table 3-1 List of monitoring sites selected for baseline threshold value derivation

Project Area	Monitoring Site	Watercourse	Type	Sampling Method	No. Data Sets	Period
Fairview	S9 (U/S)	Dawson River	Semi-perennial	Grab	≥11*	May 2006- Apr 2013
	S2 (U/S)	Dawson River	Perennial	Gauge	26,011**	Apr 2009- Nov 2014
	S1 (D/S)	Dawson River	Perennial	Grab	≥11*	Nov 2003- Apr 2013
	S4 (D/S)	Dawson River	Perennial	Gauge	34,375**	Aug 2012- Nov 2014
	S5 (D/S)	Dawson River	Perennial	Grab	≥4*	May 2005- Apr 2013
	S11 (U/S)	Hutton Creek	Semi-perennial	Grab	≥19*	Oct 2006- Aug 2014
	S11A (U/S)	Hutton Creek	Semi-perennial	Grab	≥7*	Sep 2003- Apr 2013
	S15 (U/S)	Hutton Creek	Semi-perennial	Gauge	17,112**	Nov 2009- Nov 2014
	S6 (M/S)	Hutton Creek	Semi-perennial	Grab	≥6*	Apr 2004- Apr 2013
	S17 (D/S)	Hutton Creek	Semi-perennial	Gauge	28,460**	Aug 2009- Nov 2014
	S7 (U/S)	Baffle Creek	Semi-perennial	Grab	≥6*	Sep 2003- Apr 2013
Roma	RS25 (M/S)	Blyth Creek	Semi-perennial	Grab	≥10*	Nov 2010- June 2014
				Gauge	12,268**	Dec 2012- Nov 2014

Project Area	Monitoring Site	Watercourse	Type	Sampling Method	No. Data Sets	Period
	RO02 (U/S)	Bungil Creek	Ephemeral	Grab	≥5*	Apr 2011- Apr 2014
				Gauge	2,795**	Aug 2012- Nov 2014
	RO12 (D/S)	Bungil Creek	Ephemeral	Grab	≥2*	May 2010- Apr 2014
				Gauge	3,912**	Aug 2012- Nov 2014
	RO14 (D/S)	Wallumbilla Creek	Ephemeral	Grab	≥5*	May 2010- Apr 2014
				Gauge	25,565**	Jan 2009- Nov 2014
	RO19 (U/S)	Yuleba Creek	Ephemeral	Grab	≥13*	May 2010- Jun 2014
				Gauge	24,412**	Oct 2012- Nov 2014

**This number represents a full set of data for temperature, pH, EC, turbidity, DO, SS, TN, NH_3, B and Zn. This number does not represent the sampling frequency.*

***Represents the number of data sets consisting of EC and stream flow or level for selected high flow and low flow periods.*

Figure 3-1 Selected Stream flow and EC data used for EC threshold value calculations for waters at S2 (Dawson River) under low flow conditions

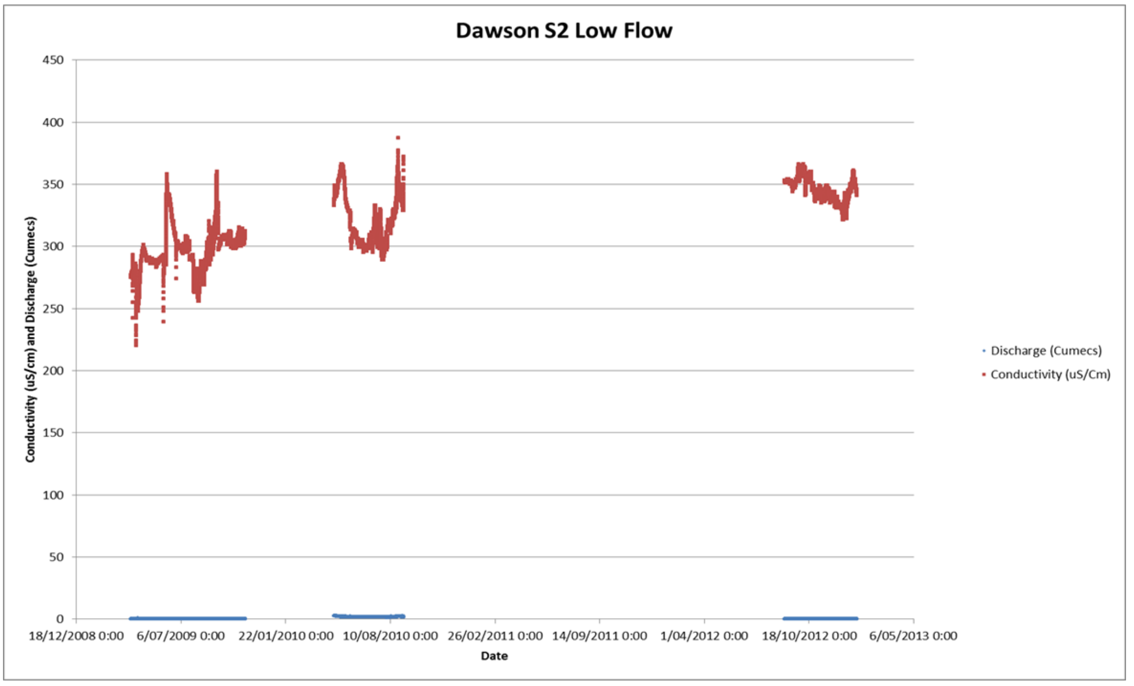
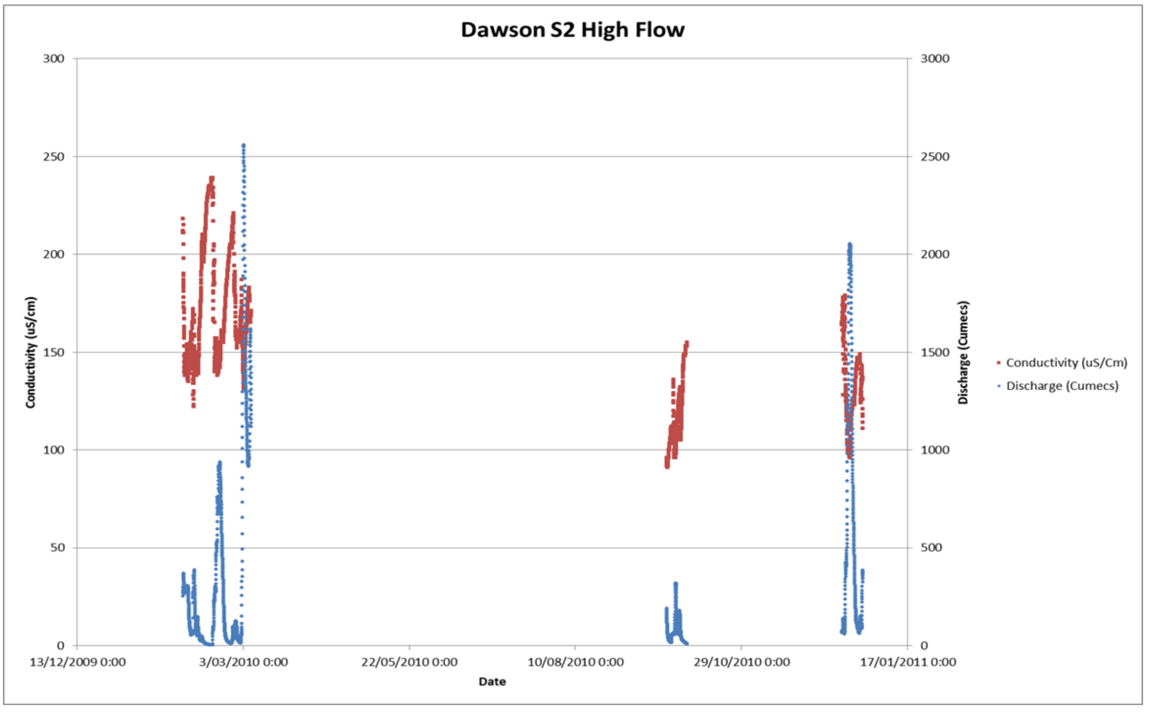


Figure 3-2 Selected Stream flow and EC data used for EC threshold value calculations for waters at S2 (Dawson River) under high flow conditions



4 BASELINE THRESHOLD VALUES

4.1 Fairview Project Area

4.1.1 Flow and EC Gauge Data

4.1.1.1 Dawson River

Monitoring Site S2

Results from the statistical low flow and high flow data for the Dawson River at monitoring site S2 is presented in Table 4-1.

Table 4-1 EC levels for low and high flow conditions at S2 (Dawson River)

S2 (Dawson River)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	23465	2546	23465	2546
Maximum	2.7	2557.4	387	239
Minimum	0.0	2.9	220	91
Median	0.1	90.6	310	151
Average	0.5	331.6	317	155
20th Percentile	0.1	21.5	292	125
80th Percentile	1.5	504.4	344	183
Standard Deviation	0.7	518.1	27	36

Both high flow and low flow water quality statistics were derived from a large data set. The high flow data was derived from three separate rain events spanning 12 months and two wet seasons, whereas low flow data was obtained between July 2009 and October 2012. The median for EC in the Dawson River at S2 under high flow (151 µS/cm) was significantly lower than that in low flow conditions (310 µS/cm), which were both lower than the WQOs set in EPP Water for the Upper Dawson Catchment; the EC WQOs for the protection of aquatic ecosystems in the moderately disturbed waters of the Upper Dawson River is 210 µS/cm and 370 µS/cm for high flow and low flow conditions, respectively.

Monitoring Site S4

Results from the statistical analysis of low flow and high flow data for the Dawson River at monitoring site S2 is presented in Table 4-2.

Table 4-2 EC levels for low and high flow conditions at S4 (Dawson River)

S4 (Dawson River)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	33846	529	33846	529
Maximum	0.9	108.3	442	388
Minimum	0.2	1.2	248	145
Median	0.3	6.8	333	195
Average	0.3	13.9	333	201
20th Percentile	0.3	3.7	280	184
80th Percentile	0.4	15.3	383	213
Standard Deviation	0.1	20.8	47	31

The shaded cells indicate EC levels that exceed the WQO for the protection of aquatic ecosystems in the Upper Dawson waters (EPP Water) (370 µS/cm for low flow conditions and 210 µS/cm for high flow conditions).

Both high flow and low flow water quality statistics were derived from a large data set. The high flow data was derived from three separate rain events spanning over 12 months and includes two wet seasons (January 2013 to April 2014), whereas low flow data was obtained between July 2012 and October 2014. The median EC value in the Dawson River at S4 under high flow (195 µS/cm) was significantly lower than in low flow conditions (333 µS/cm), which were both lower than the WQOs set in EPP Water for the Upper Dawson Catchment; the EC WQOs for the protection of aquatic ecosystems in the moderately disturbed waters of the Upper Dawson River is 210 µS/cm and 370 µS/cm for high flow and low flow conditions, respectively.

Dawson River EC Threshold Values

Given that median EC values for the Dawson River (at sampling sites S2 and S4) were lower than the EPP Water WQOs for the Upper Dawson River, the EPP Water WQOs have been adopted as EC threshold values for this river (i.e. 210 µS/cm and 370 µS/cm for high flow and low flow conditions, respectively).

4.1.1.2 Hutton Creek

Monitoring Site S15

Results from the statistical analysis of low flow and high flow data for Hutton Creek at monitoring site S15 is presented in Table 4-3.

Table 4-3 EC levels for low and high flow conditions at S15 (Hutton Creek)

S15 (Hutton Creek)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	14789	2323	14789	2323
Maximum	2.0	852	905	385
Minimum	0.2	0	331	97
Median	0.7	26	614	240
Average	0.6	98	621	239
20th Percentile	0.2	1	375	177
80th Percentile	0.8	161	677	296
Standard Deviation	0.3	156	106	64

The shaded cells indicate EC levels that exceed the WQO for the protection of aquatic ecosystems in the Upper Dawson waters (EPP Water) (370 µS/cm for low flow conditions and 210 µS/cm for high flow conditions).

Both high flow and low flow water quality statistics for monitoring site S15 were derived from a large data set. The high flow data was derived from three separate rain events spanning over 12 months and includes two wet seasons (February 2010 to April 2011), whereas low flow data was obtained between May 2010 and October 2011. The median EC value in Hutton Creek at S15 under high flow (240 µS/cm) was significantly lower than that in low flow conditions (614 µS/cm). However, the median values of monitoring data at S15 were significantly higher than the WQOs set in EPP Water for the Upper Dawson Catchment; the EC WQOs for the protection of aquatic ecosystems in the moderately disturbed waters of the Upper Dawson River is 210 µS/cm and 370 µS/cm for high flow and low flow conditions, respectively. This may mean that monitoring site S15, which lies within the FPA, is either impacted by landuse activities, or that local baseline threshold values for EC in Hutton Creek may need to be derived. Further analysis of the threshold value for EC in Hutton Creek is provided in Section 4.1.2.1 below.

Monitoring Point S17

Results from the statistical analysis of low flow and high flow data for Hutton Creek at monitoring site S17 is presented in Table 4-4.

Table 4-4 EC levels for waters at S17 (Hutton Creek) under low and high flow conditions

S17 (Hutton Creek)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	26546	1914	26546	1914
Maximum	11.2	2013.1	496	256
Minimum	0.0	2.2	357	68
Median	0.0	34.0	413	131
Average	0.1	195.1	423	134
20th Percentile	0.0	10.1	379	97
80th Percentile	0.3	260.9	479	173
Standard Deviation	0.3	369.6	44	36

The shaded cells indicate EC levels that exceed the WQO for the protection of aquatic ecosystems in the Upper Dawson waters (EPP Water) (370 µS/cm for low flow conditions and 210 µS/cm for high flow conditions).

Both high flow and low flow water quality statistics for monitoring site S17 were derived from a large data set. The high flow data was derived from three separate rain events spanning over 12 months and includes two wet seasons (October 2010 to February 2012), whereas low flow data was obtained between August 2009 and October 2013. The median for EC in Hutton Creek at S17 under high flow (131 µS/cm) was significantly lower than that in low flow conditions (413 µS/cm). The median values of EC measured at S17 under high flow conditions were significantly lower than the WQOs set in EPP Water for the Upper Dawson Catchment (210 µS/cm). In contrast, the median for EC in Hutton Creek under low flow conditions measured at site S17 exceeded the corresponding EC WQOs for low flow conditions (370 µS/cm). This may mean that the waters in Hutton Creek at monitoring site S17, which lies within the FPA, is either impacted by landuse activities such as cattle grazing, or that local baseline threshold values for EC in Hutton Creek under low flow conditions may need to be derived. Further analysis of the threshold value for EC in Hutton Creek is provided in Section 4.1.2.1 below.

4.1.2 Grab Sampling Data

Results from the statistical analysis of grab sampling data for the Dawson River, Hutton Creek and Baffle Creek is presented in Table 4-5.

Table 4-5 Water quality in the Dawson River, Hutton Creek and Baffle Creek measured by grab sampling between 2003 and 2013

Site	Stream	Parameter	Ambient Temp - Field	pH - Field	EC - Field	Turbidity - Field	DO - Field	Suspended Solids	Total Nitrogen	NH_3-N	Boron (total)	Zinc (dissolved)
		Unit	°C	pH Unit	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Published WQO*			NA	6.5-8.5	low flow- 370 high flow- 210	50	7-9	30	0.62	0.02	0.37	0.008
S11	Hutton Creek (U/S)	Count	9	28	23	19	22	44	39	40	39	40
		Median	18.3	7.5	379	12	7.85	14	0.5	0.03	0.025	0.0025
		20th %ile	15.48	7.2	359	1.2	4.996	6.6	0.4	0.005	0.025	0.0025
		80th %ile	24.94	8.0	596	38	8.592	44.2	0.9	0.04	0.06	0.0086
S11A	Hutton Creek (U/S)	Count	7	11	10	8	7	9	9	9	10	9
		Median	22.5	7.2	591	48	7.3	61	0.84	0.017	0.0305	0.01
		20th %ile	14.56	6.8	155	21	4.82	23	0.63	0.005	0.025	0.0052
		80th %ile	25.56	7.6	664	168	8.4	368	1.42	0.0402	0.0438	0.0208
S6	Hutton Creek (M/S)	Count	12	11	15	6	11	10	14	10	13	11
		Median	22.6	7.2	358	23	5.6	61	0.9	0.0135	0.044	0.0025
		20th %ile	14.18	6.7	179	9.5	5	5.8	0.63	0.005	0.025	0.0025
		80th %ile	23.2	7.4	465	116	7.5	128.4	1.31	0.0478	0.069	0.014
S7	Baffle Creek (U/S)	Count	13	12	16	6	12	12	15	12	16	12
		Median	24	7.2	155	64	8.75	36	0.81	0.01	0.025	0.0185
		20th %ile	16.6	6.7	134	17	7.2	15.6	0.58	0.005	0.025	0.0044
		80th %ile	31.34	7.8	196	101	9.776	73.6	1.02	0.0432	0.046	0.0248
S9	Dawson River (U/S)	Count	9	8	11	6	8	11	11	11	11	11
		Median	20.6	6.7	140	74	7	33	0.9	0.03	0.025	0.011
		20th %ile	13.28	6.5	84	22	2.32	16	0.48	0.01	0.025	0.0025
		80th %ile	28.36	7.6	163	94	10.14	67	2.5	0.4	0.038	0.018
S5	Dawson River (D/S)	Count	7	6	10	4	7	9	10	9	9	9
		Median	19.8	7.4	346	11.7	8.1	10	0.34	0.005	0.025	0.004
		20th %ile	12.44	7.1	274	6.04	6.2	5.6	0.18	0.005	0.023	0.0025
		80th %ile	22.92	7.7	520	118	12.2	23	0.56	0.0174	0.0624	0.0082

Site	Stream	Parameter	Ambient Temp - Field	pH - Field	EC - Field	Turbidity - Field	DO - Field	Suspended Solids	Total Nitrogen	NH_3-N	Boron (total)	Zinc (dissolved)
		Unit	°C	pH Unit	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
S1	Dawson River (D/S)	Count	11	11	16	5	12	12	15	11	15	12
		Median	21.2	6.9	267	9.5	6.6	11	0.37	0.005	0.025	0.0085
		20th %ile	16.7	6.7	228	4.4	5.1	5.4	0.15	0.005	0.025	0.0025
		80th %ile	24.6	7	382	93	7.72	29.8	0.54	0.02	0.054	0.0164

**WQOs for the protection of the aquatic ecosystem in the moderately disturbed waters of the Upper Dawson River Catchment are found in EPP Water, with the exception of those for boron and zinc- these are derived from the ANZECC (2000) guidelines for the 95% protection of aquatic ecosystems.*

Cells shaded in gold depict parameter values that exceed their corresponding WQOs. Only medians were assessed in accordance with the QWQG (2009).

4.1.2.1 Electrical Conductivity

Median levels of EC sampled in Hutton Creek at three different monitoring locations were found to exceed the WQO for the Upper Dawson waters (370 µS/cm). The results for EC levels in Hutton Creek obtained by grab sampling are consistent with those obtained by automatic flow gauges. It is important to note that the grab sampling data did not include data on stream flows at the time of sampling, thereby precluding any assessments with regards to EC levels and flows in Hutton Creek. Furthermore, whilst the grab sampling data point to elevated EC levels in Hutton Creek, the number of grab samples taken (9, 7 and 12 for S11, S11a and S6, respectively), are insufficient for the derivation of robust EC baseline threshold values.

EC levels in Baffle Creek and Dawson River measured by grab sampling were below the EC WQOs for the Upper Dawson River. The results for the Dawson River taken at monitoring points S9, S5 and S1 were consistent with those obtained by automatic flow gauges taken at sites S2 and S4.

The large amounts of data collected by automatic gauges at S15 and S17 allow for the derivation of threshold values with a high degree of confidence, which strongly suggest that the EC levels in Hutton Creek are indeed elevated above the WQOs for the Upper Dawson waters set in the EPP Water. Whether an interim local baseline threshold values for EC in Hutton Creek is required was verified using the EC 80th percentiles as follows;

- Average 80th percentile for EC (low flow) = (677[1] +479[2])/2

  = 578 µS/cm
- Standard deviation = 140 µS/cm

Given that the average of the 80th percentile for EC levels ± two times the standard deviation [578 – (140 x 2) equals 298 µS/cm] is not greater than the regional guideline value for EC of 370 µS/cm, then a local baseline threshold value for Hutton Creek should not be adopted.

Adoption of sub-regional WQOs set out for the Upper Dawson River catchment is recommended for both the Dawson and Hutton Rivers (210 µS/cm for high flow conditions and 370 µS/cm for low flow conditions).

4.1.2.2 pH

Medians of pH of waters sampled from numerous monitoring points on the Dawson River, Hutton Creek and Baffle Creek were all within the WQO of 6.5 to 8.5 for the Upper Dawson catchment. The published sub-regional WQO of pH 6.5 to 8.5 has therefore been adopted as the baseline threshold value for pH for surface water in these watercourses.

4.1.2.3 Turbidity

The surface water in Baffle Creek (at location S7) and Dawson River (at location S9) had median turbidity levels that exceeded the 50 Nephelometric Turbidity Unit (NTU) WQO for the Upper Dawson catchment. Both data sets consisted of only six separate sampling events;

[1] 80th percentile low flow EC value for automatic gauging station S15.
[2] 80th percentile low flow EC value for automatic gauging station S17.

which is insufficient to ascertain whether these waters have a baseline turbidity level that is higher than the stated WQO. The surface water sampled at all other sites was below the threshold limit for turbidity. The published WQO of 50 NTU has therefore been adopted as the baseline threshold value for turbidity in Baffle Creek and Dawson River.

4.1.2.4 Dissolved Oxygen

The median levels of dissolved oxygen for surface water sampled in the Dawson River, Baffle Creek and Hutton Creek were compliant with the relevant WQO of 85% to 110% DO content. The only exception was the surface water sampled at monitoring site S6 which had a median DO level of 5.6 mg/L which was derived from only 11 separate measurements. The adopted baseline threshold value for DO in these watercourses is therefore 7 and 9 mg/L.

4.1.2.5 Suspended Solids

Median concentrations of total suspended solids (TSS) at both monitoring locations on Hutton Creek are significantly higher than the Upper Dawson River Catchment WQO for the protection of aquatic ecosystems. Waters sampled at both monitoring site S11a and S6 have identical median TSS levels of 61 mg/L, a value derived from a total of 19 different sample events (nine events for S11a and 10 events for S6). Therefore the adopted baseline threshold value for TSS in Hutton Creek is 61 mg/L.

In contrast, the median TSS concentration in Baffle Creek (S7 - 36 mg/L) and the upstream site on the Dawson River (S9 - 33mg/L) are higher than the sub-regional WQO of 30 mg/L. Whilst this data may indicate elevated baseline threshold values for TSS in Baffle Creek and the upstream waters of the Dawson River (at S9), there is insufficient data at this stage to warrant the adoption of a local baseline threshold value therefore the Upper Dawson WQO for TSS (30 mg/L) will be adopted.

4.1.2.6 Total Nitrogen

Median levels of TN in Hutton Creek at grab monitoring sites S11a and S6 are significantly higher than the Upper Dawson WQO for the protection of aquatic systems (0.62 mg/L). The median TN of 0.84 mg/L (n=9) at S11a and 0.9 mg/L (n=14) at S6 strongly indicate that local baseline threshold values for TN will need to be adopted. In accordance with the QWQG (2009) there was a significant difference in the TN concentration in Hutton Creek when compared with the published WQO for surface waters in the Upper Dawson, as follows;

- Average 80th percentile for TN = (0.9[3] +1.42[4] +1.31[5])/3

  = 1.21 mg/L

- Standard deviation = 0.27 mg/L

[3] 80th percentile low flow EC value for automatic gauging station S11.
[4] 80th percentile low flow EC value for automatic gauging station S11A.
[5] 80th percentile low flow EC value for automatic gauging station S6.

Given that the average of the 80th percentile for TN concentrations ± two times the standard deviation of the average [1.21 – (0.27 x 2) equals 0.67 mg/L] is greater than the EPP Water WQO for TN of 0.62 mg/L, then a local baseline threshold value for Hutton Creek of 1.21 mg/L for TN should be adopted.

The median value for TN in Baffle Creek (S7) also exceeded the Upper Dawson WQO for the protection of aquatic ecosystems, however this is based on a data set size that is considered to be inadequate to firmly conclude whether a local baseline threshold value for TN in Baffle Creek is required. The adopted TN threshold value for Baffle Creek will therefore be 0.62 mg/L, in-line with the sub-regional WQO.

Medians and 80th percentiles of TN in the surface waters in Dawson River at monitoring sites S5 and S1 were below the Upper Dawson WQO. However, surface water at the upstream site of S9 was found to contain elevated levels of TN, such that the median TN level (0.9 mg/L) was significantly higher than the corresponding WQO (0.62 mg/L). Assessment of the average of the 80th percentiles ± 2 x standard deviation of the TN levels measured at S5, S1 and S9 indicated that the adoption of a local baseline threshold value for TN in the Dawson River was not warranted. Therefore the TN baseline threshold value for the Dawson River is 0.62 mg/L.

4.1.2.7 Ammonia

The median levels for ammonia measured in the Hutton Creek were below the Upper Dawson WQO for sites S6 and S11a, but exceeding the WQO at site S11. However, the 80th percentile for ammonia measured at all these three sites exceeded the WQO of 0.02 mg/L. In accordance with the QWQG (2009) there was a significant difference in the ammonia concentration in Hutton Creek when compared with the published WQO for surface waters in the Upper Dawson, as follows;

- Average 80th percentile for ammonia = (0.04[6] +0.0402[7] +0.0478[8])/3

  =0.0427 mg/L
- Standard deviation =0.004 mg/L

Given that the average of the 80th percentile for ammonia concentrations ± two times the standard deviation of the average [0.0427 – (0.004 x 2) equals 0.0347 mg/L] is greater than the EPP Water WQO for ammonia of 0.02 mg/L, then a local baseline threshold value for Hutton Creek of 0.0427 mg/L for ammonia should be adopted.

The median value for ammonia in Baffle Creek (S7) did not exceed the Upper Dawson WQO for the protection of aquatic ecosystems. This median is based on a set of 14 different sampling events, a data set that is considered to be inadequate in size to allow for the adoption of a local baseline threshold value for Baffle Creek. Until further data becomes available, the ammonia threshold value for Baffle Creek will therefore be 0.02 mg/L.

[6] 80th percentile low flow EC value for automatic gauging station S11.
[7] 80th percentile low flow EC value for automatic gauging station S11A.
[8] 80th percentile low flow EC value for automatic gauging station S6.

Similar to the results for TN, medians and 80th percentiles of ammonia in the surface waters in Dawson River at monitoring sites S5 and S1 were compliant with the Upper Dawson WQO. However, surface water at the upstream site of S9 was found to contain elevated levels of ammonia, such that the median ammonia level (0.03 mg/L) was significantly higher than the corresponding WQO. Assessment of the average of the 80th percentiles ± 2 x standard deviation of the ammonia levels measured at S5, S1 and S9 indicated that the adoption of a local baseline threshold value for ammonia in the Dawson River was not warranted. Therefore the ammonia baseline threshold value for the Dawson River is 0.02 mg/L.

4.1.2.8 Boron

Surface water sampled in the Dawson River, Hutton Creek and Baffle Creek all had levels of boron that were well below the WQO for the protection of aquatic ecosystems of 0.37 mg/L, therefore this concentration is the adopted boron baseline threshold vale for the surface water environment within the FPA.

4.1.2.9 Zinc

Surface waters monitored in Hutton Creek for levels of total zinc indicated median concentrations that were below the WQO of 0.008 mg/L, with the exception of site S11a. The 80th percentiles for these waters were all above the WQO, however, assessment of the average of the 80th percentiles ± 2 x standard deviation of the total levels of zinc measured at S11, S11a and S6 indicated that the adoption of a local baseline threshold value for total zinc in Hutton Creek was not warranted. Furthermore, soluble levels of zinc in Hutton Creek were well below the WQO. Therefore the zinc baseline threshold value for Hutton Creek is 0.008 mg/L (the sub-regional WQO).

Median and 80th percentile of total zinc levels in Baffle Creek (S7) were also in exceedance of the WQO. The data set comprised only of 12 separate sampling events, whereas soluble zinc was measured only once; therefore insufficient data is available to ascertain whether a local baseline threshold value is warranted. A baseline threshold value of 0.008 mg/L for zinc in Baffle Creek (the sub-regional WQO) should therefore be adopted.

4.2 Roma Project Area

4.2.1 Flow and EC Gauge Data

4.2.1.1 Blyth Creek at Monitoring Point RS25

Results from the statistical analysis of low flow and high flow data for Blyth Creek at monitoring site RS25 is presented in Table 4-6.

Both high flow and low flow water quality statistics were derived from a large data set. The median for EC in Blyth Creek at RS25 under high flow (592 µS/cm) was significantly lower than that in low flow conditions (6456 µS/cm), which were both significantly higher than the guideline value (350 µS/cm) for upland freshwater streams for south-east Australia set in the ANZECC/ARMCANZ (2000) guidelines.

Given that Blyth Creek is an ephemeral watercourse, EC levels during no-flow conditions reflect deteriorating water quality in isolated pools; this data should therefore not be considered when assessing baseline EC threshold values for Blyth Creek. The 80th percentile value for EC in Blyth Creek was 676 µS/cm, significantly higher than the ANZECC/ARMCANZ (2000) guideline value for the protection of aquatic ecosystems. A concentration of 676 µS/cm should therefore be adopted as an interim EC baseline threshold value for Blyth Creek.

Table 4-6 EC values for water at RS25 (Blyth Creek) under low and high flow conditions

RS25 (Blyth Creek)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	12240	229	12039	229
Maximum	0.2	1.5	12187	11397
Minimum	0.0	0.0	3100	382
Median	0.0	0.4	6456	592
Average	0.0	0.5	6855	1209
20th Percentile	0.0	0.3	4674	458
80th Percentile	0.0	0.6	9171	676
Standard Deviation	0.0	0.2	2325	229

The shaded cells indicate EC levels that exceed the guideline value (350 µS/cm) for upland freshwater streams for south-east Australia set in the ANZECC/ARMCANZ (2000) guidelines.

4.2.1.2 Bungil Creek (Bungil Creek at Monitoring Site RO12

Results from the statistical analysis of low flow and high flow data for Blyth Creek at monitoring site RO12 is presented in Table 4-7.

Table 4-7 EC levels for water at RO12 (Bungil Creek) under low and high flow conditions

RO12 (Bungil Creek)	Water Level m		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	3504	408	3504	408
Maximum	0.5	3.8	395	232
Minimum	0.1	0.5	331	76
Median	0.3	2.0	350	171
Average	0.3	2.1	352	170
20th Percentile	0.2	1.1	339	144
80th Percentile	0.4	3.3	357	200
Standard Deviation	0.1	1.0	15	36

The shaded cells indicate EC levels that exceed the guideline value (350 µS/cm) for upland freshwater streams for south-east Australia set in the ANZECC/ARMCANZ (2000) guidelines.

Both high flow and low flow water quality statistics were derived from a large data set. The high flow data was derived from two separate rain events spanning over three months during the 2014 wet season, whereas low flow data was obtained between April 2014 and July 2014. The median for EC in Bungil Creek at R012 under high flow (171 µS/cm) was significantly lower than that in low flow conditions (350 µS/cm), which were compliant with the regional guideline. Therefore the EC baseline threshold value for Bungil Creek is 350 µS/cm.

4.2.1.3 *Bungil Creek at Monitoring Point R002*

Results from the statistical analysis of low flow and high flow data for Bungil Creek at monitoring site R002 is presented in Table 4-8.

Table 4-8 EC levels for monitoring point R002 (Bungil Creek) under low flow and high flow conditions

R002 (Bungil Creek)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	2666	129	2666	129
Maximum	0.0	22.2	2304	257
Minimum	0.0	1.0	1131	33
Median	0.0	5.6	1902	99
Average	0.0	6.4	1882	100
20th Percentile	0.0	2.1	1735	58
80th Percentile	0.0	8.8	2013	121
Standard Deviation	0.0	4.8	168	46

The shaded cells indicate EC levels that exceed the guideline value (350 µS/cm) for upland freshwater streams for south-east Australia set in the ANZECC/ARMCANZ (2000) guidelines. The median for EC in Bungil Creek at R002 under high flow (99 µS/cm) was significantly lower than that in low/no flow conditions (1902 µS/cm). The median and 80th percentile values for EC measured at this monitoring point on Bungil Creek were significantly lower than the regional EC guideline value. Given that EC levels measured during no flow conditions probably reflect deteriorating water quality in isolated pools, this data was not considered when assessing baseline EC threshold values for Bungil Creek. The regional EC guideline value of 350 µS/cm will be adopted as EC baseline threshold value for Bungil Creek at R002.

4.2.1.4 *Wallumbillla Creek at Monitoring Point R014*

Results from the statistical analysis of low flow and high flow data for Wallumbilla Creek at monitoring site R014 is presented in Table 4-9.

Table 4-9 EC levels for waters at R014 (Wallumbilla Creek) under low and high flow conditions

R014 (Wallumbilla Creek)	Water Level m		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	23584	1981	23584	1981
Maximum	4.3	7.6	961	699
Minimum	0.1	0.4	118	91
Median	0.5	2.5	522	395
Average	0.5	3.1	554	390
20th Percentile	0.2	1.4	377	197
80th Percentile	0.6	5.0	773	574
Standard Deviation	0.3	1.9	186	175

The shaded cells indicate EC levels that exceed the guideline value (350 µS/cm) for upland freshwater streams for south-east Australia set in the ANZECC/ARMCANZ (2000) guidelines.

Both high flow and low flow water quality statistics for Wallumbilla Creek were derived from a large data set. The high flow data was derived from four separate rain events spanning over two years from January 2010 to April 2012, whereas low flow data was obtained between January 2010 and July 2014. The median for EC in Wallumbilla Creek at R014 under high flow (395 µS/cm) was significantly lower than that in low flow conditions (522 µS/cm), which were both significantly higher than the regional guideline value of 350 µS/cm. The 80th percentile values for EC in Wallumbilla Creek under low flow and high flow conditions were 773 µS/cm and 574 µS/cm, respectively.

Given that the 80th percentile values for EC appear to be significantly different to the regional guideline of 350 µS/cm, a baseline EC threshold value of 773 µS/cm should be adopted for Wallumbilla Creek.

4.2.1.5 Yuleba Creek at Monitoring Point RO19

Results from the statistical analysis of low flow and high flow data for Yuleba Creek at monitoring site R019 is presented in Table 4-10.

Both high flow and low flow water quality statistics for Yuleba Creek were derived from a large data set. The high flow data was derived from two separate rain events spanning over twelve months from February 2013 to April 2014, whereas low flow data was obtained between May 2012 and November 2014. The median for EC in Yuleba Creek at RO19 under high flow (141 µS/cm) was significantly lower than that in low flow conditions (867 µS/cm). The measured EC level at low/no flow conditions was significantly higher than the regional guideline value of 350 µS/cm. Given that EC levels measured during no-flow conditions probably reflect deteriorating water quality in isolated pools, this data was not considered when assessing baseline EC threshold values for Yuleba Creek. The regional EC guideline value of 350 µS/cm will be adopted as EC baseline threshold value for Yuleba Creek at RO19.

Table 4-10 EC levels for waters at R019 (Yuleba Creek) under low and high flow conditions

R019 (Yuleba Creek)	Discharge Cumecs		Conductivity µS/cm	
	Low Flow	High Flow	Low Flow	High Flow
Number of data points	23904	508	23904	508
Maximum	0.1	43.7	1298	426
Minimum	0.0	0.6	322	73
Median	0.0	1.9	867	141
Average	0.0	9.1	804	148
20th Percentile	0.0	1.1	635	91
80th Percentile	0.0	20.2	980	184
Standard Deviation	0.0	12.1	225	55

The shaded cells indicate EC levels that exceed the guideline value (350 µS/cm) for upland freshwater streams for south-east Australia set in the ANZECC/ARMCANZ (2000) guidelines.

4.2.2 Grab Sampling Data

Results from the statistical analysis of grab sampling data for the Blyth Creek, Bungil Creek, Wallumbilla Creek and Yuleba Creek are presented in Table 4-11.

Table 4-11 Water quality in Blyth Creek, Bungil Creek, Wallumbilla Creek and Yuleba Creek measured by grab sampling between 2010 and 2014

Site	Site Description	Parameter	Field Ambient Temp	pH - Field	EC - Field	Turbidity - Field	DO - Field	Suspended Solids	Total Nitrogen as N	Ammonia as N	Boron	Zinc
		Unit	°C	pH Unit	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline Value				6.5-7.5	350	25	7-9	na	0.25	0.9	0.37	0.008
RS25	Blyth Creek (M/S)	Count	10	12	10	12	12	25	25	25	13	13
		Median	23.1	8.3	3428	49.1	8.9	94	2.2	0.02	0.24	0.0025
		20th %ile	18.9	7.6	1086	29.6	6.9	32	0.96	0.005	0.108	0.0025
		80th %ile	28.9	8.6	4890	71.9	10.0	1612	3.2	0.03	0.352	0.0058
R012	Bungil Creek (D/S)	Count	6	2	4	11	9	19	19	18	18	19
		Median	19.2	7.1	818	87.1	8.5	51	0.9	0.04	0.06	0.006
		20th %ile	14.4	6.6	485	25	4.6	25.8	0.56	0.024	0.025	0.0025
		80th %ile	22.6	7.6	1110	454	11.9	202.2	1.44	0.066	0.08	0.0178
RO02	Bungil Creek (U/S)	Count	1	13	5	9	9	18	19	18	19	19
		Median	27.4	7.9	1373	56.9	10.1	19	0.4	0.03	0.09	0.006
		20th %ile	27.4	7.19	1256	31.24	6.302	9.4	0.3	0.014	0.08	0.0025
		80th %ile	27.4	8.13	1763.6	142.5	10.6	29.6	0.76	0.056	0.124	0.0088
R014	Wallumbilla Creek (D/S)	Count	5	12	5	11	8	16	16	16	16	16
		Median	24	7.2	187	142	4.8	82.5	1.2	0.03	0.025	0.016
		20th %ile	21.2	7.1	151	116	2.2	44	1	0.02	0.025	0.008
		80th %ile	27.1	7.7	266	533	6.5	136	1.9	0.06	0.025	0.024
R019	Yuleba Creek (U/S)	Count	13	22	13	15	16	31	31	31	24	24
		Median	22	7.4	244	287	5.1	167	1.3	0.05	0.025	0.017
		20th %ile	16.6	6.9	164	100.2	3.8	44	0.9	0.02	0.025	0.006
		80th %ile	25.3	7.7	403	562.6	6.9	390	1.9	0.08	0.06	0.0264

**Guideline values for the protection of the aquatic ecosystem in the moderately disturbed waters of the Condamine-Balonne Basin are found in the ANZECC (2000) guidelines.*

Cells shaded in gold depict parameter values that exceed their corresponding WQOs. Only medians were assessed in accordance with the QWQG (2009).

4.2.2.1 Electrical Conductivity

Median levels of EC sampled in Blyth Creek and Bungil Creek were found to exceed the regional guideline value of 350 µS/cm (ANZECC/ARMCANZ 2000). The results for EC levels in Bungil Creek (but not for those in Blyth Creek), obtained by grab sampling are consistent with those obtained by automatic flow gauges. It is important to note that the grab sampling data did not include data on stream flows at the time of sampling, thereby precluding any assessments with regards to EC levels and flows in Blyth and Bungil Creek. Furthermore, whilst the grab sampling data point to elevated EC levels in these watercourses, the number of grab samples taken for Blyth Creek (n=10) and Bungil Creek (n = 4 and 5 for R012 and R002, respectively), are insufficient for the derivation of robust EC baseline threshold values. The large amounts of data taken by automatic gauges at these locations (RS25, R012 and R002) allow for the derivation of threshold values with a high degree of confidence. This gauge data strongly suggest that the EC levels in Blyth Creek and are indeed elevated above the regional guideline value of 350 µS/cm (ANZECC/ARMCANZ 2000).

Median EC levels in Wallumbilla Creek and Yuleba Creek measured by grab sampling were below the EC regional guideline of 350 µS/cm. However, EC gauge data for Wallumbilla Creek show levels higher than the regional guideline; a local guideline value has therefore been set.

4.2.2.2 pH

Medians of pH of waters sampled from Bungil Creek, Wallumbilla Creek and Yuleba Creek were all within the regional pH guideline range of 6.5 to 7.5. The median pH for Blyth Creek was pH 8.3, which was derived from a statistical set of 12 samples. The baseline threshold value for pH for surface water in Bungil Creek, Blyth Creek, Wallumbilla Creek and Yuleba Creek is therefore pH 6.5 to 7.5. There is insufficient data available to ascertain whether a local pH guideline is required for Blyth Creek.

4.2.2.3 Turbidity

The surface water of Blyth Creek, Bungil Creek, Wallumbilla Creek and Yuleba creek were all found to have median turbidity levels greater than the regional guideline of 25 NTU. Assessment of the average of the 80^{th} percentiles ± 2 x standard deviation of the turbidity levels measured in these watercourses indicated that whilst there is a strong possibility that a local baseline threshold value for turbidity in the watercourses of the RPA may be warranted, there is insufficient data to confirm this. The standard deviation of 229 NTU around a mean of 353 NTU indicates a very wide spread of turbidity values, possibly reflecting the differences in stream flows when this data was acquired..

The regional guideline value of 25 NTU has been adopted as the threshold value for turbidity in the RPA.

4.2.2.4 *Dissolved Oxygen*

The median levels of dissolved oxygen for surface water sampled in Bungil Creek were compliant with the relevant guideline of 7 to 9 mg/L DO. However, surface waters sampled from Wallumbilla Creek, Yuleba Creek and from one sampling point on Bungil Creek, all had median DO concentrations that were not compliant with the guideline value.

The regional guideline value of 7 to 9 mg/L has been adopted as the threshold value for DO in the RPA.

4.2.2.5 *Suspended Solids*

There are no guideline values for TSS for the watercourses in the RPA. The baseline threshold values for these watercourses are therefore derived from the 80th percentile levels of grab sampling data (See Table 4-11).

4.2.2.6 *Total Nitrogen*

Median levels of TN in Blyth Creek, Bungil Creek, Wallumbilla Creek and Yuleba Creek for waters grab sampled at monitoring sites depicted in Table 4-11 are significantly higher than the regional guideline value for the protection of aquatic systems (0.25 mg/L). These results strongly indicate that a local baseline threshold values for TN will need to be adopted. In accordance with the QWQG (2009), the local baseline threshold value for TN was calculated as follows;

- Average 80th percentile for TN = (3.2[9] +1.44[10] +0.76[11] + 1.9[12] + 1.9[13])/5

  = 1.84 mg/L
- Standard deviation = 0.52 mg/L

Given that the average of the 80th percentile for TN concentrations ± two times the standard deviation of the average [1.84 – (0.52 x 2) equals 0.8 mg/L] is greater than the regional guideline for TN of 0.25 mg/L, then a local baseline threshold value for the watercourses in the RPA of 1.84 mg/L for TN should be adopted.

4.2.2.7 *Ammonia*

The median levels for ammonia measured in Blyth Creek, Bungil Creek, Wallumbilla Creek and Yuleba Creek were all below the regional guideline for ammonia of 0.9 mg/L. However, the 80th percentile levels of ammonia measured in these watercourses was much less than the regional guideline. Therefore it is prudent to use a local baseline threshold value for ammonia which is derived as follows;

- Average 80th percentile for ammonia = (0.03[9] +0.066[10] +0.056[11] + 0.06[12] + 0.08[13])/5

  = 0.058 mg/L

[9] 80th percentile low flow EC value for automatic gauging station RS25.
[10] 80th percentile low flow EC value for automatic gauging station R012.
[11] 80th percentile low flow EC value for automatic gauging station R002.
[12] 80th percentile low flow EC value for automatic gauging station R014.
[13] 80th percentile low flow EC value for automatic gauging station R019.

- Standard deviation = 0.018 mg/L

A local baseline threshold value for the watercourses in the RPA of 0.058 mg/L for ammonia should be adopted.

4.2.2.8 *Boron*

Surface water sampled in Blyth Creek, Bungil Creek, Wallumbilla Creek and Yuleba Creek all had levels of boron that were well within the guideline the protection of aquatic ecosystems of 0.37 mg/L. This concentration of boron is the adopted boron baseline threshold value for the surface water environment within the RPA.

4.2.2.9 *Zinc*

Surface waters in Wallumbilla Creek and Yuleba Creek, but not those of Blyth Creek and Bungil Creek, had median levels of total zinc that were higher than the regional guideline for the protection of aquatic ecosystems of 0.008 mg/L. However, median levels of dissolved zinc were found to be compliant with the regional guideline, which is adopted as the baseline threshold value for zinc in surface waters of the RPA.

5 SUMMARY OF RESULTS

The baseline threshold values for surface waters within the FPA and RPA are shown in Table 5-1. The values found in cells shaded in green indicate locally derived threshold values. All other values correspond to the sub-regional WQOs (for Upper Dawson River catchment as per EPP Water) and regional guideline values (ANZECC/ARMCANZ 2000).

Table 5-1 Baseline Threshold Values for Fairview and Roma Project Areas Surface Waters

		Fairview Project Area			Roma Project Area			
Parameter	Units	Dawson River	Hutton Creek	Baffle Creek	Blyth Creek	Bungil Creek	Wallum-billa Creek	Yuleba Creek
EC (High Flow)	µS/cm	210	210	210	676	350	773	350
EC (Low Flow)		370	370	370				
pH		6.5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 7.5	6.5 - 7.5	6.5 - 7.5	6.5 - 7.5
Turbidity	NTU	50	50	50	25	25	25	25
TSS	mg/L	30	30	30	1612	202	136	390
DO	mg/L				7-9	7-9	7-9	7-9
TN	mg/L	0.62	1.21	0.62	1.84	1.84	1.84	1.84
Ammonia-N	mg/L	0.02	0.0427	0.02	0.058	0.058	0.058	0.058
Boron	mg/L	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Zinc (dissolved)	mg/L	0.008	0.008	0.008	0.008	0.008	0.008	0.008

Note:
The values found in cells shaded in green indicate locally derived threshold values. All other values correspond to the sub-regional WQOs (for Upper Dawson River catchment as per EPP Water) and regional guideline values (ANZECC/ARMCANZ 2000).

6 REFERENCES

ANZECC/ARMCANZ 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, October 2000, Canberra.

EHP 2009. Queensland Water Quality Guidelines, Version 3, Department of Environment and Heritage Protection, Queensland Government, re-published July 2013.

EHP 2011. Environmental Protection (Water) Policy 2009. Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment.

URS 2014. Santos GLNG Gas Field Development Project EIS Appendix N (Surface Water Technical Report)

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