



Santos NSW (Eastern) Pty Ltd

**Energy NSW Coal Seam Gas Exploration and
Appraisal**

Produced Water Management Plan

PEL238 PAL2 PPL3

10 February 2014

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1. Introduction

1.1. Purpose and scope

This Produced Water Management Plan (PWMP) has been developed in accordance with the requirements of condition 14 of Petroleum Exploration Licence (PEL) 238. It is designed to provide information about how Santos NSW (Eastern) Pty Ltd (Santos) will manage produced water resulting from the operation of its coal seam gas (CSG) Exploration and Appraisal Program activities in the Narrabri area that includes land within PEL238, Petroleum Assessment Lease (PAL) 2 and Petroleum Production Lease (PPL) 3. It also covers the management of the remaining produced water associated with the previous operation of CSG activities in PAL2 and PEL238.

This PWMP supersedes the previous PWMP dated December 2012 that was approved by the NSW Department of Trade and Investment on 19 March 2013.

In accordance with condition 14 of PEL 238, this PWMP has been prepared in consultation with the NSW Office of Water and the NSW Environment Protection Authority and will be submitted to the NSW Office of Coal Seam Gas (CSG) for approval by the Minister administering the *Petroleum (Onshore) Act 1991*.

1.2. PWMP summary table

Table 1 summarises the content requirements of condition 14 of PEL238 and where this information is provided in this PWMP.

Table 1: Content of Produced Water Management Plan

PWMP requirement under condition 14 of PEL238	Section Reference
Expected sources and estimated quantities of produced water	Section 2
Proposed containment measures	Section 3
Proposed treatment measures	Section 4
Proposed beneficial reuse or disposal methods	Section 4
Controls to be implemented to prevent and/or minimise pollution	Section 3
Record keeping for the quality, quantity, transport and disposal of produced water	Section 5
Staging process for implementation of the PWMP	Section 1.5

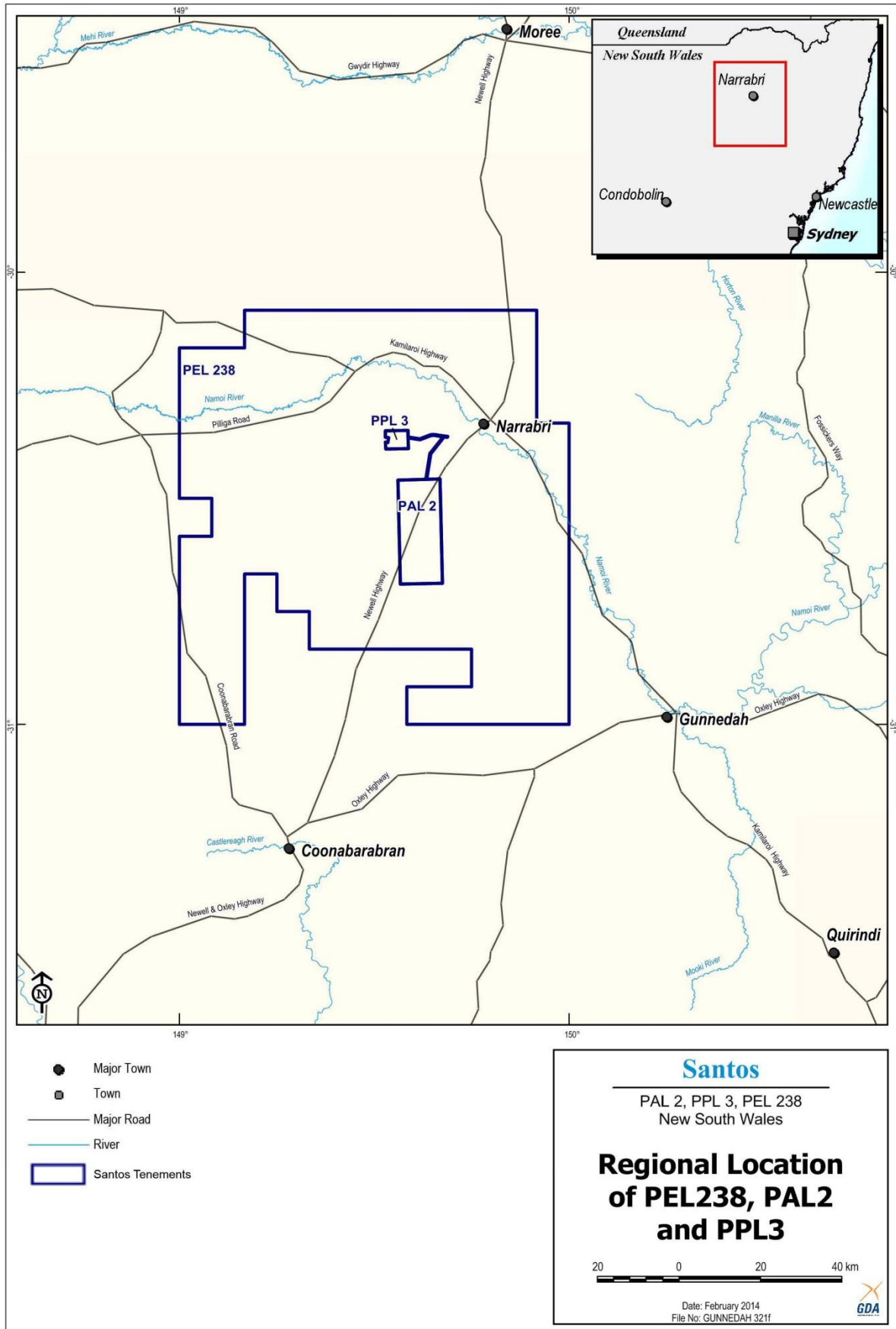
1.3. Background

Santos is an Australian energy company that has been supplying natural gas to New South Wales from South Australia for almost 40 years. Santos has been safely and sustainably extracting coal seam gas in Queensland for more than 20 years. Santos' operations in NSW are focussed on the development of natural gas from coal seams in the Narrabri area in north-west NSW.

Santos began exploring for coal seam gas in NSW in 2008, completing seismic surveys and drilling core holes to assist in the assessment of the geology of the area. In November 2011, Santos completed its acquisition of Eastern Star Gas' (ESG) acreage and operations near Narrabri, including six completed pilots in and around the Pilliga.

Santos has commenced its CSG Exploration and Appraisal Program in the Narrabri area within PEL238, PAL2 and PPL3 (herein referred to as the program). Figure 1 shows the regional location of PEL 238, PAL 2 and PPL3.

Figure 1: Regional location of PEL 238, PAL 2 and PPL3



The program includes recommencing the operation of a number of existing pilot wells, drilling and operating new pilot wells and constructing and operating water and gas management facilities to support the program. Appraisal activities, including pilot testing, surface infrastructure operation and water and gas management, will occur for up to three years.

The program activities are necessary for the ongoing exploration, appraisal and evaluation of the CSG hydrocarbon potential in PEL 238, PAL 2 and PPL3. The program will assist in gaining further knowledge of coal fines, gas composition and flow rates, the deliverability of the reservoir and investigating well design, drilling and completion technologies. This information is essential to determine whether a commercial gas production project is viable within the Narrabri area and would be used to assist in the development planning of such a project.

1.4. Existing approvals

The program activities are subject to regulation and approval by the New South Wales and Australian Governments. Table 2 provides a summary of the relevant activity approvals and corresponding legislation. The activity description includes the associated produced water management infrastructure to be constructed and operated. Figure 2 provides a layout of the existing and future exploration and appraisal infrastructure.

In June 2013 Santos referred the program to the Australian Government for assessment under the *Environment Protection and Biodiversity Conservation Act 1999* in relation to matters of national environmental significance. This included an assessment as to whether the activity, as a coal seam gas development, will have or is likely to have, a significant impact on water resources. Santos provided detailed information on the production and management of produced water to the Government during its assessment.

On 1 October 2013 the Minister for the Environment decided that the action was not a controlled action if the activity is undertaken in accordance with particular stated measures.

Table 2: Summary and status of relevant State and Commonwealth Approvals

Regulator	Activity	Approval Pathway	Status (1 February 2014)
Australian Government	Santos Energy NSW CSG Exploration & Appraisal Program	<i>Environment Protection and Biodiversity Conservation Act 1999</i>	Decision: Not Controlled Action – Particular Manner
NSW Dept. Primary Industries	Bibbiewindi Pond 2 and 3 water management infrastructure	EP&A Act Part 5	Approved
NSW Dept. Primary Industries	Bibbiewindi Multi-Lateral Pilot (drilling of 12 wells and operation of pilot)	EP&A Act Part 5	Approved
NSW Dept. Primary Industries	Bibbiewindi West Pilot (drilling of 5 wells and operation of pilot)	EP&A Act Part 5	Approved
NSW Dept. Primary Industries	Dewhurst 13-18 (drilling and operation of Dewhurst 13-18H pilot (previously known as the Dewhurst 8 Lateral Production Pilot))	EP&A Act Part 5	Approved
NSW Office of Coal Seam Gas	Dewhurst 22-25 Pilot (drilling four appraisal wells, converting existing core hole to appraisal well and operation)	EP&A Act Part 5	Approved

Regulator	Activity	Approval Pathway	Status (1 February 2014)
NSW Office of Coal Seam Gas	Dewhurst 26-29 Pilot (drilling of four appraisal wells and operation)	EP&A Act Part 5	Approved
NSW Office of Coal Seam Gas	Dewhurst Northern Water and Gas Flow Lines (22.8 kilometres (km) long water and gas flow lines)	EP&A Act Part 5	Approved
NSW Office of Coal Seam Gas	Dewhurst Southern Water and Gas Flow Lines (4.5 km long water and gas flow lines)	EP&A Act Part 5	Approved
NSW Dept of Trade and Investment	Leewood Produced Water and Brine Management Project that includes: Construction and operation of two 300 ML each storage ponds and associated infrastructure) Construction and operation of a 5ML produced water tank at the Bibblewindi Water Transfer Facility (Bibblewindi Water Transfer Tank) to facilitate the transfer of produced water from the pilot wells to the Leewood Produced Water Facility. Construction and operation of the Leewood Water Pipeline which will transfer produced water from the Bibblewindi Water Transfer Facility to the Leewood Produced Water Facility.	EP&A Act Part 5	Approved
NSW Dept of Trade and Investment	Tintsville Pilot (construction and operation of Tintsville 2-7 pilot)	EP&A Act Part 5	Approved
NSW Dept of Trade and Investment	Tintsville Pilot (construction and operation of gas and water management infrastructure).	EP&A Act Part 5	Approved
NSW Office of Coal Seam Gas	Tintsville 2-7 Pilot (reoperation of existing pilot, construction and operation of flare)	EP&A Act Part 5	Approved
NSW Minister for Planning	Wilga Park Power Station modification (installation of riser on existing gas line at Leewood property and minor administrative changes)	EP&A Act Part 3A	Under assessment
NSW Minister for Planning	Bibblewindi Multi-Lateral Pilot (drilling two new wells and recommencing operation)	EP&A Act Part 4	Under assessment
NSW Minister for Planning	Dewhurst Pilot Expansion (drilling additional laterals from within existing Dewhurst 13-18 wells, drilling two additional wells Dewhurst 30-31 at the Dewhurst 26-29 pilot & operation)	EP&A Act Part 4	Under assessment
NSW Office of Water	Water allocation and licensing requirements to support the construction and operation of the above activities, including a water allocation, Water Supply Works and Water Access Licence	<i>Water Management Act 2000, Water Act 1912</i>	Approved on a project by project basis
Environment Protection Authority	Environment Protection Licence for coal seam gas exploration, assessment and production	<i>Protection of the Environment Operations Act 1997</i>	Under assessment

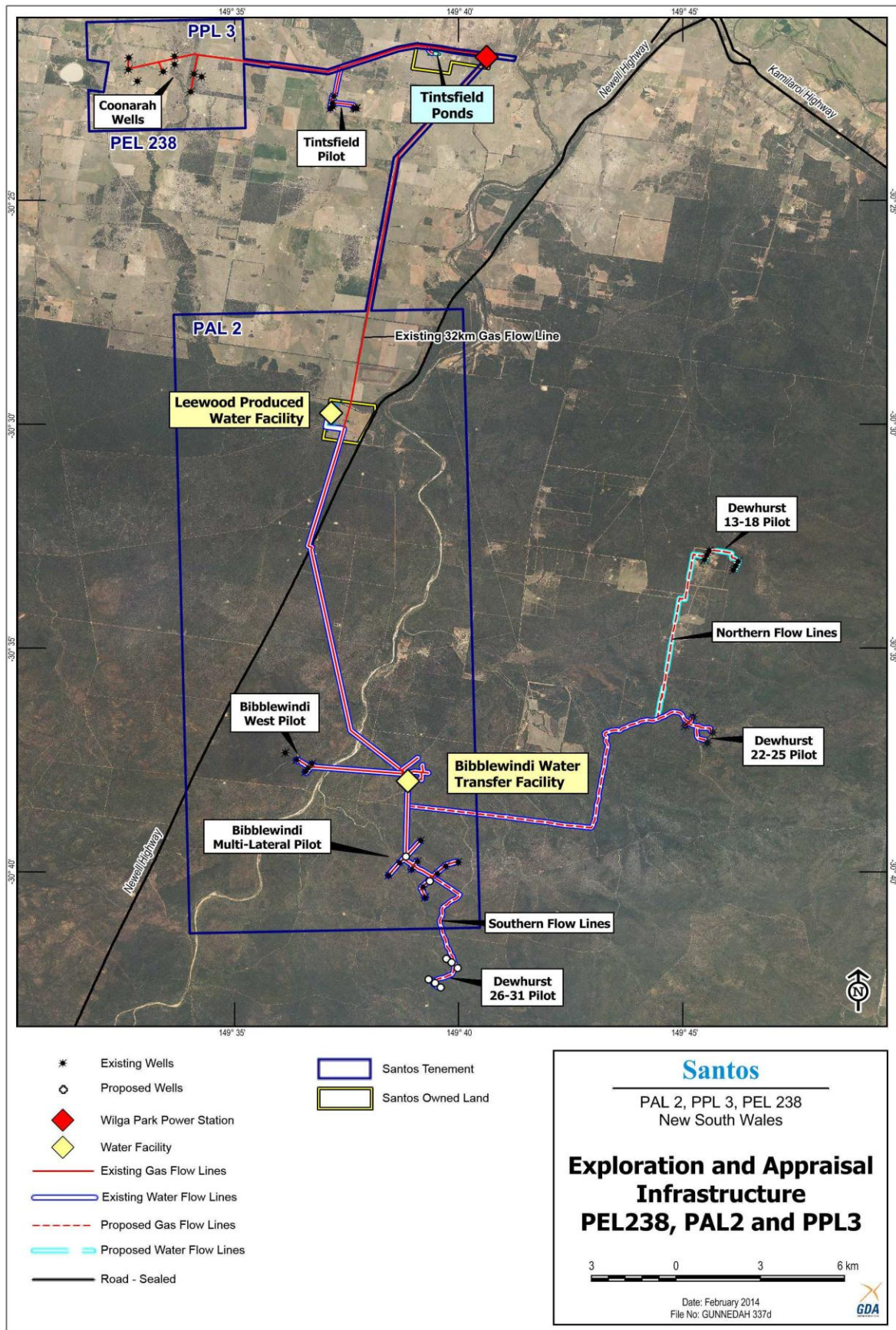
EP&A Act *Environmental Planning and Assessment Act 1979* (NSW)

1.5. Implementation of this Plan

This PWMP applies to the management of produced water produced during the exploration and appraisal activities. It includes information on options being investigated for the treatment and reuse of the produced water (section 4). Treatment and reuse of produced water will be in accordance with legislative requirements, including impact assessment and approval processes where this is required. If further legislative impact assessment processes are required to treat and use produced water, this PWMP will be updated in accordance with the outcomes of this process.

Santos will complete an evaluation of treatment and management options for produced water associated with any commercial gas production project during the impact assessment process for such a project. As noted above, the data collected from the exploration and appraisal program will provide critical information (water quality, yield and rates) to assist in defining the water production curves and required design of water management systems for a commercial gas production project. Produced water management infrastructure would be upgraded and/or designed and constructed in accordance with the project approval and this PWMP would be updated at that stage to reflect the arrangements for produced water management to be implemented.

Figure 2: Exploration and Appraisal Pilots and Infrastructure



2. Characterisation of Produced Water

2.1. Produced water source

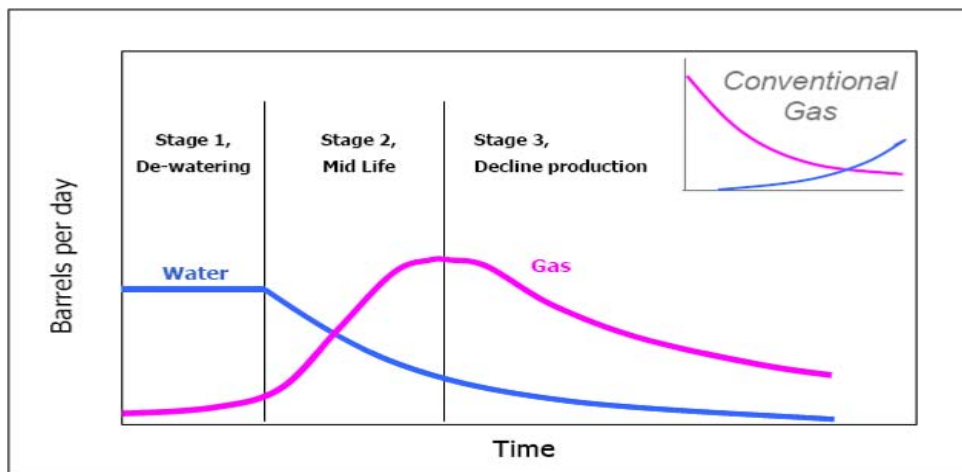
CSG development will primarily target gas reserves associated with Early Permian coal seams of the Maules Creek Formation, located at depth in the northern portion of the Gunnedah Basin.

The primary target seams (Bohena, Parkes, Namoi and Rutley seams) of the early Permian Maules Creek Formation occupy the basal part of the Bohena Trough within the northern part of the Gunnedah Basin. The coal seams are generally moderately transmissive, exhibiting higher hydraulic conductivity than the adjacent units. However, these units are not utilised for water supply due to the depth and presence of the alluvium and Pilliga Sandstone closer to the ground surface. The coal seams are typically characterised by poor (saline) water quality.

Overlying the target seams are approximately 600 - 800 metres (m) of Permian and Triassic strata. Jurassic-age strata belonging to the Surat Basin, a south eastern extension of the Great Artesian Basin, overly the Permo-Triassic strata and are themselves overlain in part by more recent consolidated and unconsolidated alluvial sediments.

Gas trapped in coal is adsorbed onto the coal surface in cleats and joints or micro pores and held in place by reservoir and water pressures. To extract the gas it is necessary to reduce the pressure by first removing water (known as produced water). Typically, water production is higher earlier in the life of a CSG field and declines as gas production increases as demonstrated in Figure 3

Figure 3: Stages of Produced Water and CSG Production



2.2. Produced water quantity

Details of the estimated quantity of produced water associated with the operation of the pilots for the exploration and appraisal program is provided in Table 3. These estimates are based on the operation of each pilot for a three year period and are based on data collected during the previous operation of pilot wells within the Narrabri area.

Table 3: Estimated volume of produced water for the Exploration and Appraisal program

Pilot	Total Extraction over operation of pilot – based on average extraction rates (ML)	Maximum Extraction (ML/day)	Average Extraction (ML/day)
Dewhurst 13-18 Pilot	331.1	0.40	0.30
Dewhurst 22-25 Pilot	285.1	0.27	0.26
Dewhurst 26-31 Pilot	413.8	0.45	0.38
Bibblewindi Multi-lateral Pilot	285.1	0.58	0.26

Pilot	Total Extraction over operation of pilot – based on average extraction rates (ML)	Maximum Extraction (ML/day)	Average Extraction (ML/day)
Biblewindi West Pilot	93	0.21	0.09
Tintsville 2-7 Pilot	25.2	0.04	0.02

Simulations prepared indicate that peak produced water extraction for the exploration and appraisal program will be approximately 1.3ML/day. This estimation is contingent on the timing for commencement of pilot activities and may change depending on timing of approvals and other operational considerations.

The volume of water generated during the production phase is determined by the properties of the coal and the depressurisation targets that must be achieved to facilitate gas production. There is limited ability to reduce depressurisation targets (and associated water production) during appraisal testing as this impacts gas flow and volumes extracted and therefore reduces the information that can be gained during the testing period.

There is produced water remaining from the previous operation of CSG activities in PAL2 and PEL238 (prior to Santos’ acquisition). This remaining produced water will be managed in accordance with this PWMP. The volumes and quality field measurements of material held in each facility are included in the table below.

Storage name	Volume (ML) (3 February 2014)	Water quality field measurements (January 2014)		
		pH	Temperature (C)	Total Dissolved Solids (mg/L)
Biblewindi Water Transfer Facility (Pond 3)	96	9.35	36.6	33020
Tintsville Ponds (Pond 2)	47	9.51	30.2	34320

2.3. Produced water quality

The quality of produced water is primarily dependent upon the geology of the area in which CSG wells are located and consequently, variability between wells can be high. Evidence suggests that the produced water quality from a single well is generally within a consistent range with fluctuations in the order of 20% (+/-) over the lifetime of a well.

Table 4 provides the average concentrations for produced water quality. The information is based on historical water quality monitoring data collected from wells and ponds within the Narrabri area.

Table 4: Produced water quality

Parameter	Units	Produced Water <i>Average concentration</i>
Total Dissolved Solids (TDS)	mg/L	21,000
Temperature	°C	15 - 30
pH		8.33
Total Suspended Solids (TSS)	mg/L	30
Turbidity	NTU	50
Carbonate (CO ₃)	mg/L as CaCO ₃	670
Bicarbonate (HCO ₃)	mg/L as CaCO ₃	10,100
Chloride (Cl)	mg/L	2,000
Sodium (Na)	mg/L	6,200
Sulphate (SO ₄)	mg/L	4
Calcium (Ca)	mg/L	7
Magnesium (Mg)	mg/L	4.0
Potassium (K)	mg/L	45
Strontium (Sr)	mg/L	1.3
Barium (Ba)	mg/L	13
Fluoride (F)	mg/L	5.8
Silica (SiO ₂)	mg/L	23
Boron (B)	mg/L	0.87
Iron (Fe, dissolved)	mg/L	0.28
Cyanide (Total)	mg/L	0.004
Manganese (Total)	mg/L	0.009
Aluminium (Total)	mg/L	0.10
Phosphorus (Total)	mg/L	0.14
Ammonia	mg/L as N	13
Nitrate	mg/L as N	0.10
Nitrogen (Total)	mg/L	14
Copper (Total)	mg/L	0.022
Zinc (Total)	mg/L	0.023
Arsenic (Total)	mg/L	0.010
Chromium (Total)	mg/L	0.006
Hexavalent Chromium	mg/L	<0.05
Cadmium (Total)	mg/L	0.0053
Mercury (Total)	mg/L	0.00071
Molybdenum (Total)	mg/L	0.00064
Nickel (Total)	mg/L	0.0013
Antimony (Total)	mg/L	0.00012
Selenium (Total)	mg/L	0.0150
Uranium (Total)	mg/L	0.0001
Lead (Total)	mg/L	0.0037

3. Produced Water Management

Produced water management for the exploration and appraisal activities involves the development of local and regional gathering, storage and transfer systems. Extensive impact assessment and approval of the construction and operation of the produced water management infrastructure has been undertaken in accordance with legislative requirements. Detailed information on the design, construction and operation of the produced water management infrastructure is provided within the application material provided to regulators as part of the assessment and approval of each project. Table 2 provides a summary and status of the relevant assessment and approval processes and Figure 2 provides a map of the location of the infrastructure. The construction and operation of the infrastructure is subject to many conditions contained within the relevant approvals.

An outline of the produced water management infrastructure and methodology is set out below. In addition, Figure 4 provides a diagrammatic overview of the infrastructure.

Santos is currently investigating the economic and technical feasibility of treating the produced water from exploration and appraisal activities by reverse osmosis or other methods. The options under evaluation for produced water treatment and reuse are provided in section 4. The implementation of treatment and/or reuse of produced water from exploration and appraisal activities will be subject to any regulatory and impact assessment requirements in accordance with relevant legislation.

Produced water will be transported to an appropriately licensed facility for treatment or disposal if Santos decides not to treat and/or reuse produced water in its operations.

3.1. Produced water gathering and transfer

A description of the produced water gathering and transfer infrastructure and processes is provided here. Produced water remaining from previous operations will also be managed in this way. Refer to Figure 4 for a diagrammatic overview and Table 5 contains a Summary of Produced Water Storage Facilities.

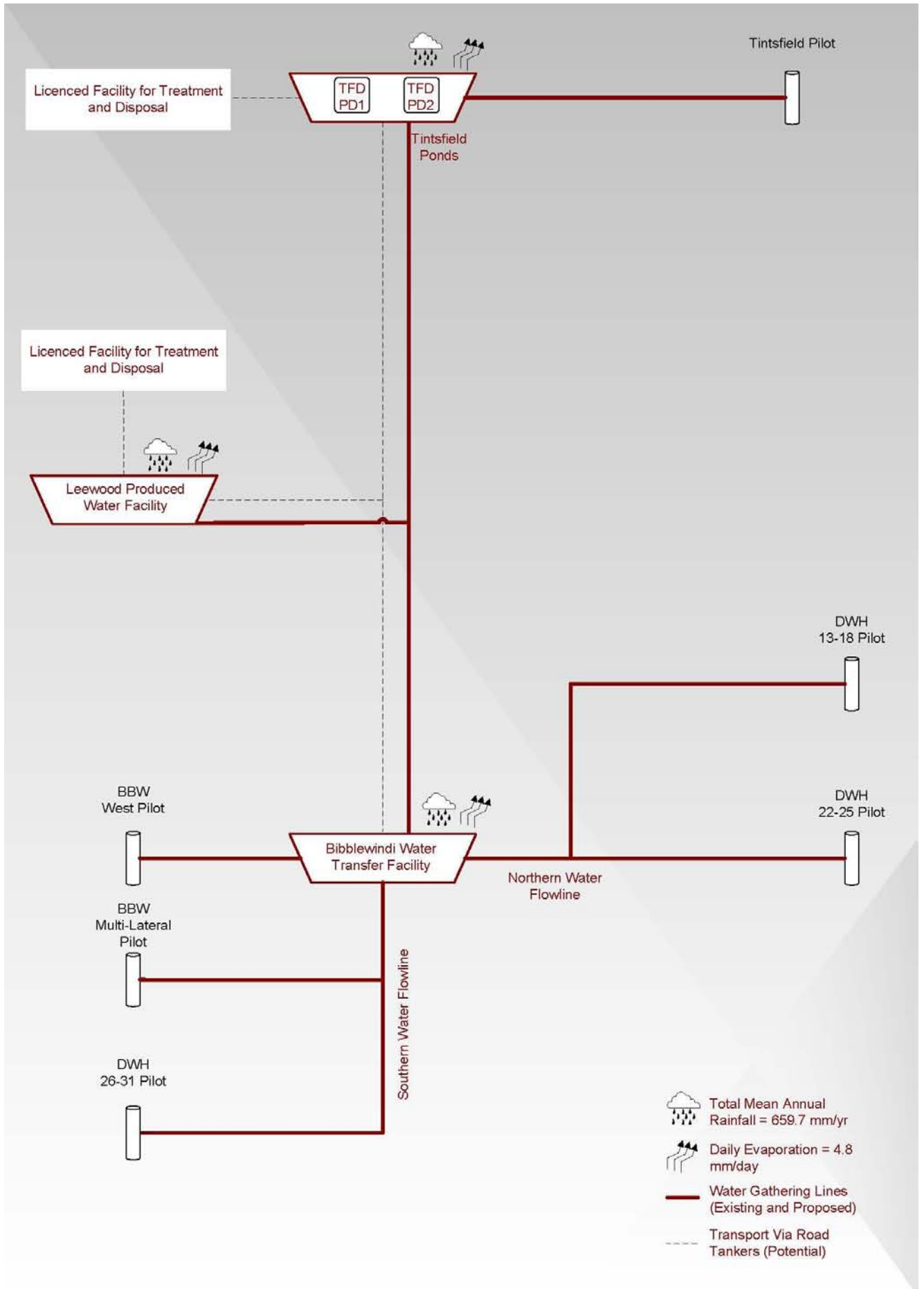
At each pilot produced water will be pumped from the separator at each well head through the water gathering lines to a centralised balance tank for that pilot (where installed). Produced water is then pumped from the balance tank (or directly from the pilot well where no balance tank is installed) to the Bibblewindi Water Transfer Facility or Tintsville Ponds via water flow lines.

The Bibblewindi Water Transfer Facility, including the 5ML balance tank and Bibblewindi Ponds 2 and 3, will be used to store and balance produced water received from pilots prior to its transfer to the Leewood Produced Water Facility (under construction, first pond expected to be operational March 2014) or the Tintsville Ponds (Pond 1 and Pond 2) located on Santos owned land adjacent to the Wilga Park Power Station.

Depending on operational requirements, produced water may be transferred between the three facilities (i.e. Bibblewindi Water Transfer Facility, the Leewood Produced Water Facility and the Tintsville Ponds) by pipeline or road transport.

The flowlines to be used for the transfer of produced water and brine includes the Dewhurst Northern and Dewhurst Southern Water Flowlines, the existing water flowlines from Bibblewindi West and Bibblewindi Multi-Lateral pilots to the Bibblewindi Water Transfer Facility, the existing flowlines from the Tintsville Pilot to the Tintsville Pond, the Leewood Water Pipeline (under construction) and the gas pipeline from Bibblewindi Water Transfer Facility to the Tintsville Ponds (with offtake at Leewood Produced Water Facility, subject to Part 3A modification approval, under assessment) and associated infrastructure.

Figure 4: Diagrammatic overview of produced water infrastructure



3.2. Produced water storage facilities

Refer to Figure 4 for a schematic overview of the produced water infrastructure.

A summary of the approved produced water storage facilities is presented in Table 5. The table includes information on storage volumes of each facility and controls to prevent and minimise pollution including pond liners and monitoring equipment installed.

3.3. Overview of infrastructure monitoring

An infrastructure monitoring program is implemented across the Produced water and brine storage facilities and gathering and transfer infrastructure. A summary of the infrastructure monitoring measures and their frequency for each storage is included in Table 5.

In addition to the monitoring outlined for the Leewood Produced Water Management Facility, the ponds will be subject to the surveillance requirements for prescribed dams, including the preparation of a Surveillance Report. This report requires inspection and reporting of the condition of the ponds including embankment slopes, crest and spillway, presence of any erosion, vegetation, seepage and monitoring instrumentation.

The design, construction and operation of the High Density Poly-Ethylene (HDPE) flowlines is undertaken in accordance with the Australian Pipeline Industry Association's *Code of Practice for Upstream Polyethylene Gathering Networks - CSG Industry* (March 2013). This includes detailed quality control measure requirements to ensure the integrity during the construction process. After construction and prior to commissioning, the entire flowline is required to be pressure tested and once operating, ongoing pressure monitoring using remote telemetry occurs.

Pipeline integrity management procedures are maintained to ensure flowline infrastructure remains fit for purpose at all times by implementing a systematic approach to operation, maintenance, testing and inspection activities. Periodic inspections are carried out to identify actual or potential problems that could affect the integrity of the pipeline and any maintenance required is carried out in a timely manner.

Santos also undertakes an extensive regional groundwater monitoring program to monitor groundwater in the region of its operations. This program is the subject of the Groundwater Monitoring and Modelling Plan prepared in relation to exploration and appraisal activities and approved by the NSW Office of CSG in July 2013.

In relation to the operation of the produced water storage facilities, in the event that an elevated water level, in excess of a pre-defined trigger level (such as the MOL), is recorded, operators will respond in accordance with responses set out in the Trigger Action and Response Plan (TARP).

TARPs set out the actions to be undertaken in response to situations outside of normal operating conditions. The TARP's objective is to minimise and manage any risks to human safety, the environment, property and operations. The TARP also includes directions on internal and external reporting and notification procedures in accordance with legislative requirements. Actions that will be considered in the event that the maximum operating level is exceeded include 'shutting in' wells to cease the production of produced water, reducing the water levels through transferring water to other produced water storages and removing water for treatment / disposal at an appropriately licensed facility.

In addition, a Dam Safety Emergency Plan has been provided to the NSW Dam Safety Committee in accordance with the requirements of the *Dams Safety Act 1978*. The plan provides emergency response procedures for the management of the Leewood ponds in the event of an imminent or actual uncontrolled release from the ponds.

Table 5 Summary of Produced Water Storage Facilities

Facility name	Storage name	Full Supply Level Volume (ML)	Maximum Operating Level Volume (ML)	Controls to prevent and minimise pollution			
				Lining system	Facility monitoring (when storage contains produced water)		Shallow groundwater monitoring around storage
					Monitoring aspect	Frequency	
Biblewindi Produced Water Transfer Facility	Biblewindi Transfer Tank	4	3.75	Galvanised steel panel tank with internal polypropylene bladder. Tank is also contained within an earthen bund.	Water level	Continuous using sensors and remote monitoring. Tank is equipped with level instrumentation, alarms and trips, to ensure the tank does not over fill.	Network (currently 24) of monitoring bores installed at the facility at varying depths located up-gradient, down-gradient and cross hydraulic gradient of the water infrastructure. The bores are designed to both monitor groundwater (chemical, physical and hydraulic) (see table 4 parameters) and intercept groundwater where this is found to be present. Additional perched water layers are monitored at a number of locations to assess any vertical migration of groundwater.
					Inflow and outflow	Continuous using flow meters and remote monitoring.	
	Biblewindi Pond 2	22.9	12	HDPE membrane thickness of 2 mm.	Water level	Daily monitoring and recording.	
					Inflow and outflow	Continuous using flow data from wellhead pumps, outflow pumps and remote monitoring.	
					Embankment seepage	Monthly	
					Embankment erosion	Quarterly	
					Pond crest integrity and capping	Quarterly	
					Hydraulic structures	Quarterly	
					Pipework and valves including	Weekly	
					Pond water quality	Monthly for pH, temperature and TDS Six monthly for other quality parameters	
Rainfall and evaporation	Weekly						
Pond liner condition	Monthly						

Santos Energy NSW – Produced Water Management Plan: PEL238, PAL2 and PPL3

Facility name	Storage name	Full Supply Level Volume (ML)	Maximum Operating Level Volume (ML)	Controls to prevent and minimise pollution			
				Lining system	Facility monitoring (when storage contains produced water)		Shallow groundwater monitoring around storage
					Monitoring aspect	Frequency	
					Embankment deformation	Monthly	
					Vegetation growth	Quarterly	
					Wildlife management systems (fences etc.)	Quarterly	
	Biblewindi Pond 3	182.5	165.4	HDPE membrane thickness of 2 mm.	Water level	Continuous using sensors and remote monitoring.	
Inflow and outflow					Continuous using flow data from wellhead pumps, outflow pumps and remote monitoring.		
Embankment seepage					Monthly		
Embankment erosion					Quarterly		
Pond crest integrity and capping					Quarterly		
Hydraulic structures					Quarterly		
Pipework and valves including					Weekly		
Pond water quality					Monthly for pH, temperature and TDS Six monthly for other quality parameters.		
Rainfall and evaporation					Weekly		
Pond liner condition					Monthly		
Embankment deformation					Monthly		
Vegetation growth					Quarterly		
Wildlife management systems (fences etc.)	Quarterly						

Facility name	Storage name	Full Supply Level Volume (ML)	Maximum Operating Level Volume (ML)	Controls to prevent and minimise pollution			
				Lining system	Facility monitoring (when storage contains produced water)		Shallow groundwater monitoring around storage
					Monitoring aspect	Frequency	
Leewood Produced Water and Brine Management Facility	Produced water Pond	389 (design)	300 (design)	Primary polyethylene geomembrane liner underlain by leak detection system underlain by a secondary liner. The secondary liner will be underlain by 300 mm of smooth clayey sub grade. The leak collection system transfers any produced water collected below the liner directly back into the pond. The system includes an alarm to notify of any sudden changes in pump operational trends.	Water level	Continuous using sensors and remote monitoring.	Network (currently 7) of monitoring bores installed at the facility at varying depths located up-gradient, down-gradient and cross hydraulic gradient of the water infrastructure. The monitoring bores are screened at a number of shallow perched water layers below the surface. Sampling of standard groundwater parameters (see table 4 parameters) is undertaken quarterly and results reviewed for any unexpected changes to physical and chemical water quality parameters and water levels.
					Inflow and outflow	Continuous using flow meters and remote monitoring.	
	Embankment seepage	Monthly					
	Embankment erosion	Quarterly					
	Pond crest integrity and capping	Quarterly					
	Hydraulic structures	Quarterly					
	Pipework and valves including	Weekly					
	Pond water quality	Weekly for pH, temperature and TDS Monthly for other quality parameters					
	Rainfall and evaporation	Weekly					
	Pond liner condition	Monthly					
	Embankment deformation	Monthly					
	Vegetation growth	Quarterly					
Wildlife management systems (fences etc.)	Quarterly						
Tintfield Produced Water Facility	Tintfield Pond 1	22.9	15.3	HDPE membrane thickness of 2 mm.	Water level	Continuous using sensors and remote monitoring.	Network (currently 23) of monitoring bores installed at the facility at varying depths located up-gradient, down-gradient and cross hydraulic gradient of the water infrastructure. The monitoring
	Tintfield Pond 2	92.0	72.6		Inflow and outflow	Continuous using flow data from wellhead pumps, outflow pumps and remote monitoring.	

Facility name	Storage name	Full Supply Level Volume (ML)	Maximum Operating Level Volume (ML)	Controls to prevent and minimise pollution			
				Lining system	Facility monitoring (when storage contains produced water)		Shallow groundwater monitoring around storage
					Monitoring aspect	Frequency	
				Embankment seepage	Monthly	bores are screened at a number of shallow perched water layers below the surface. Sampling of standard groundwater parameters (see table 4 parameters) is undertaken quarterly and results reviewed for any unexpected changes to physical and chemical water quality parameters and water levels.	
				Embankment erosion	Quarterly		
				Pond crest integrity and capping	Quarterly		
				Hydraulic structures	Quarterly		
				Pipework and valves including	Weekly		
				Pond water quality	Monthly for pH, temperature and TDS Six monthly for other quality parameters		
				Rainfall and evaporation	Weekly		
				Pond liner condition	Monthly		
				Embankment deformation	Monthly		
				Vegetation growth	Quarterly		
				Wildlife management systems (fences etc.)	Quarterly		

4. Options for produced water treatment and reuse

Produced water has the potential to be used beneficially in a number of applications. In order to increase the options for beneficial use, produced water may be treated in order to improve its quality. The potential treatment options and beneficial uses of this water are described in further detail below.

The implementation of treatment and/or reuse of produced water from exploration and appraisal activities will be subject to regulatory requirements, including the conditions of the Environment Protection Licence for CSG activities. Where treatment and reuse requires further legislative impact assessment processes, this PWMP will be updated in accordance with the outcomes of the process.

4.1. Desalination

Desalination is often used to treat produced water to reduce the concentration of Total Dissolved Solids (salts) and other constituents so that it may be beneficially used.

Reverse Osmosis (RO) desalination typically involves several steps (as shown in Figure 5) that include:

- Pre-treatment by filtration, clarification, ion exchange and bio-fouling control;
- Desalination; and
- Post treatment as required by final water use (potentially including ammonia removal, dechlorination, calcium and magnesium addition to achieve required (sodium adsorption ratio (SAR) and pH adjustment).

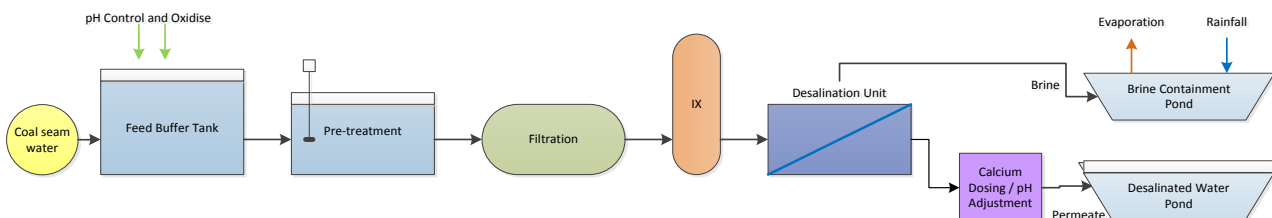


Figure 5 Summary of desalination process

RO is the leading technology for the removal of dissolved solids in produced water from CSG activities. The principal reasons for this are:

- The technology is well proven and readily available in Australia from several reputable vendors with a proven track record;
- The method is readily scalable and will achieve a final water quality that is suitable for a range of proposed uses; and
- The technology can be readily leased or purchased.

In addition to generating a high-quality desalinated water stream, RO also produces a comparatively small volume of concentrate (brine). Concentrate management is discussed further in section 4.5.

4.2. Chemical amendment

Chemical amendment is sometimes undertaken to lower the sodium adsorption ratio (SAR) of the produced water to acceptable levels for the desired beneficial uses. Amendment of permeate from RO treatment is likely to involve SAR adjustment using Gypsum and/or Magnesium Sulfate.

4.3. Amendment using other water sources

Amendment of produced water by mixing with other water sources to lower the SAR of the produced water to acceptable levels for certain beneficial uses may be undertaken. Amendment of produced water using bore water, RO permeate or other sources is able to produce a water of appropriate quality for certain beneficial uses such as dust suppression, construction and drilling, firefighting and irrigation.

4.4. Beneficial uses of produced water

Following treatment, produced water may be directed to beneficial uses that could include:

- Dust suppression, use in construction and drilling and firefighting;
- Irrigation; and/or
- Discharge to surface water as environmental flows.

The use of produced water from exploration and appraisal activities for dust suppression, construction and drilling activities and for firefighting will be in accordance with regulatory requirements, including the conditions of the Environment Protection Licence for CSG activities.

Where treatment and reuse requires further legislative impact assessment processes, this PWMP will be updated in accordance with the outcomes of the process.

4.5. Concentrate management

Where RO or other desalination methods are used for treatment of produced water prior to beneficial use, a brine concentrate will be generated that requires management. The volume of concentrate generated is dependent on the volumes and chemical properties of the produced water and the efficiency of the treatment process. Methods of reducing the volumes of concentrate generated will be investigated. These include:

- Enhancing treatment processes to increase recovery rate;
- Investigating options for secondary treatment of concentrate (brine concentration); and
- Identifying further beneficial uses of untreated produced water.

The Leewood Produced Water Facility will have a storage pond designed and constructed to enable the storage of the brine concentrate. Options for concentrate management being investigated include:

- Treatment to recover salt as a commercial product;
- Disposal of solid salt (not including brine) at an appropriately licensed landfill and/or recycling facility.

As outlined above, where treatment and reuse requires further legislative impact assessment processes, this PWMP will be updated in accordance with the outcomes of the process, including in respect to concentrate management.

5. Record keeping of produced water management

Santos has a comprehensive data management plan for the Narrabri Gas Fields that outlines the policies and procedures that will be implemented to ensure that data is managed in a consistent, efficient and effective manner in order to provide accurate records of activity operations and enhance the value of the data collected.

All data collected as part of produced water management activities will be stored and managed within Santos' environmental database, EQUIS, with web based access to data entry and reporting and a full suite of technical procedures for data collection, work flow, reporting and other functions.

Key records associated with this PWMP that will be stored and managed will include:

1. Inspection and monitoring records for facilities and dams;
2. Operational monitoring and performance data for treatment systems;
3. Water sampling and laboratory analytical reports;
4. Calibration records for field instruments and continuous water quality monitoring systems;
5. Waste Transportation and Disposal Certificates;
6. Annual Inspection reports and/or certifications of storages.

Monitoring data is subject to quality assurance (QA) and quality control (QC) protocols and procedures that ensure that data is accurate and usable. Data is subjected to consistent validation and verification procedures. Any data that fails QA and QC procedures is rejected for future use. QA and QC procedures include:

- For each batch of water quality samples sent to the laboratory, results are validated against the analysis requested on the chain of custody (COC) to ensure all results have been received;
- All results, including quality control samples (QCS) including method blanks, laboratory control samples, matrix spikes samples and surrogate samples must fall within the specific quality control limits. Appropriate field quality control samples (i.e. duplicates, field blanks, trip blanks and triplicate samples, etc.) will also be used to assist in the quality control of the data obtained from the monitoring programs;
- Program monitoring guidelines (minimum and maximum values) will likely be configured in the environmental database for each monitoring compliance requirement or to detect anomalous results. The guidelines act as quality control measures to verify that data falls within an acceptable range.

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26 February 2014

Mr Chris Rudens
Principal Operations Officer
Office of Coal Seam Gas
NSW Trade and Investment
516 High Street
Maitland NSW 2320


Dear Mr Rudens

Further information for Produced Water Management Plan

This letter is in response to the Office of Coal Seam Gas's (OCSG) request on 21 February 2014 for further information in its assessment of the Produced Water Management Plan for PEL238, PAL2 and PPL3 (PWMP).

1. As you are aware, Santos is currently well advanced in the construction of Stage 1 of the Leewood Produced Water Management Facility. This is a purpose built water storage facility located on Santos owned land outside of the Pilliga forest. As set out in the PWMP, upon its completion and certification there will be a staged transfer of the current contents of Bibblewindi Pond 3 to Leewood. The produced water from the current exploration and appraisal program will also ultimately go to Leewood for storage and possible future treatment and reuse, subject to further approvals. The use of the Bibblewindi Ponds 2 and 3 and Tintfield ponds 1 and 2 will be for the interim storage of produced water prior to its transfer to Leewood.

The timeframe for use of Bibblewindi Pond 3 in its current form is still to be determined and will depend on approvals and timing for completion and certification of the Leewood facility. At this stage however it is envisaged that produced water will be removed from Bibblewindi Pond 3 by the end of Q1, 2015. After this time and the pond will be assessed to determine its future use. Options to be considered include removal, repair and replacement, with the final decision depending on the outcome of the assessment.

2. The Environment Protection Authority is currently assessing Santos' application for an Environment Protection Licence (EPL) under the *Protection of the Environment Operations Act 1997*. Santos understands that the EPA is considering the inclusion of a requirement for a Pollution Reduction Program (PRP) on the EPL. The OCSG may wish to contact the EPA in relation to its proposed EPL conditions. Santos' use of Bibblewindi Pond 3 will be in accordance with any EPL conditions, including any requirement for the preparation and implementation of a PRP in relation to Bibblewindi Pond 3.
3. The PWMP provides maximum operating levels (MOL) for each of the produced water storages in Table 5. The MOL is the maximum water level of the storage under normal operating conditions and is set at a level that provides an allowance for incident rainfall. Attached is further information on pond management strategies including a TARP for elevated pond management levels.

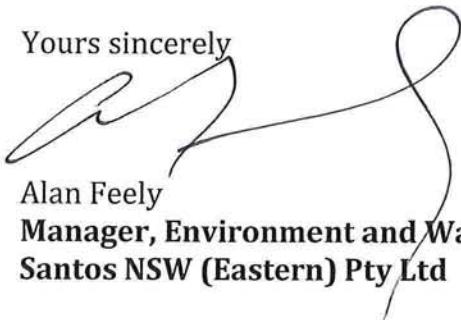
In relation to the Bibblewindi transfer tank, the tank system will incorporate sensors and automatic shut down systems that will be monitored through the SCADA system. If the tank approaches its high level set point an alarm will be triggered in the control centre. If this alarm is not acknowledged, an automatic signal is sent to the wells to shut down the field in and therefore cease water production. Field staff will also conduct monitoring at the site daily. The tank will be operated in accordance with Santos' engineering standards and standard operating procedures.

4. It is worth noting that the disposal of produced water to a waste facility would be a last resort as produced water treatment technologies are both well known and readily available. Santos is confident that there is sufficient capacity within NSW to accept the volume of produced water. A number of trade waste disposal facilities have been considered for disposal of produced water including the Homebush Bay Waste Treatment Facility. Produced water transported to the site may be blended with stormwater or other water to meet the relevant acceptance criteria at the facility.

Santos appreciates the OCSG's timely assessment of the PWMP. Delays to the finalisation of the PWMP will impact on Santos' ability to recommence pilot resting operations and therefore delay receipt of the necessary pilot data to inform our commercial gas project decisions.

Should you require any further information, please do not hesitate to contact Ms Sofia Oliver, Regulatory Approvals Coordinator, on telephone (07) 3838 5823 or email Sofia.Oliver@santos.com.

Yours sincerely



Alan Feely
Manager, Environment and Water
Santos NSW (Eastern) Pty Ltd

Further information on management of water levels in produced water storage facilities

1.0 SCOPE

The intent of this further information is to provide details of the management of water levels to support Santos' Produced Water Management Plan for PEL238, PAL2 and PPL3. Santos proposes to operate produced water and brine storage ponds to support its Coal Seam Gas Exploration and Appraisal Program in the Narrabri area. The produced water storage facilities are Bibblewindi Ponds 2 & 3, Tintsfield Ponds 1 & 2 and the Leewood Produced Water Pond and the Leewood Brine Ponds. Further information on the trigger action response plan (TARP) in the event of exceedances of standard operating levels is also included.

2.0 DEFINITION OF PRODUCED WATER STORAGE MANAGEMENT LEVELS

For the purpose of monitoring and managing pond levels the pond levels are defined below. These definitions are based on the Queensland guidelines '*Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*' (Department of Environment and Resource Management, 2011).

- Wet Season Containment (**Maximum Operating Level (MOL)**) – Includes a minimum spare storage capacity (Design Storage Allowance) required at the nominal start of the wet season (1 November each year) to give the regulatory agency confidence that wet season inputs can be managed without loss of containment (i.e. spillway discharge).
- Storm Event Containment (**Emergency Reporting Level (ERL)**) – The dam level at which loss of containment could potentially occur within a single storm event (72 hour duration event) triggering notifications and further action.
- Spillway Capacity (**Full Supply Level (FSL)**) – Sufficient spillway capacity is required to ensure that the design flood event can be conveyed by the spillway without causing overtopping of the dam embankment which could lead to catastrophic failure of the dam structure.

3.0 PRODUCED WATER STORAGE LEVELS DETAIL

The defined management levels are set out for each produced water storage facility in Table 1.

Table 1: Defined Pond Operating Levels

Produced Water storage facility	Full Supply Level (FSL) (m AHD)	Emergency Response Level (ERL) (m AHD)	Maximum Operating Level (MOL) (m AHD)
Bibblewindi Pond 2	280.9	280.58	279.90
Bibblewindi Pond 3	282.6	282.29	281.65
Tintsfield Pond 1	225.84	225.46	224.57
Tintsfield Pond 2	225.84	225.53	224.85
Leewood Produced Water Pond	249.85	249.41	249.03
Leewood Brine Pond	250.4	249.92	249.59

4.0 PRODUCED WATER STORAGE LEVEL MEASUREMENT & REPORTING

Monitoring of storage levels is undertaken with the use of pressure sensors that continuously measure and record storage depth, volume and surface area based on hydrostatic pressure. These automated meters are submersed in the pond to a depth as close to the base of the pond as reasonably practicable, and are used in conjunction with surveyed data to determine the water level of the pond. Telemetry is used to allow for remote real-time monitoring of the pond levels and this is used to monitor storage capacity in conjunction with other parameters such as upstream pilot or wellhead water production data.

Field operators are required to record the pond level and volume on a daily basis. Other operating markers/indicators may also be used in conjunction with the pressure sensor monitoring, such as volume and MOL indicator markers on storage facility walls. The level sensors system used in the existing ponds undergoes regular assessment and, when necessary, recalibration occurs six monthly in order to ensure the accuracy of readings.

In addition to monitoring, regular forecasting of predicted water production will be undertaken to identify the potential for elevated levels as early as possible to allow strategies to be implemented to minimise the potential for pond levels to exceed the MOL.

5.0 TRIGGER ACTION RESPONSE PLAN

Trigger Action Response Plans (TARPs) are developed to identify, assess and respond to abnormal conditions and are implemented to manage risk to operations, personnel and the environment. The TARP provides the actions to be taken if defined pond management levels are reached. The TARP for pond level management is provided in Table 2.

Produced Water Storage Pond Level: Trigger Action Response Plan

Trigger Level	Characteristics of Level	Possible Reasons	Actions	Action By	Notification
NORMAL	≤ 95% of MOL water level	Normal operations	<ul style="list-style-type: none"> No remedial action necessary Quarterly water quality sampling Monthly review meeting 	No special action required	None necessary
	95% of MOL	Normal operations approaching MOL	<ul style="list-style-type: none"> Review field production strategy Develop water reduction strategies. Quarterly water quality sampling Weekly review meeting 	Field Supervisor	<ul style="list-style-type: none"> Manager, Environment and Water, Santos NSW Water Management Review Team Site Operators Field Production Team
LEVEL 1	> MOL to ≤ ERL water level	<ul style="list-style-type: none"> Heavy rainfall Increased produced water production 	<ul style="list-style-type: none"> Implement actions to reduce pond level to below MOL. Actions may include: <ul style="list-style-type: none"> ➢ Reduce or cease produced water production ➢ Transfer of water to other produced water storage facilities ➢ Removal of water for disposal at appropriately licensed facilities Weekly water quality sampling Weekly review meeting 	Field Supervisor	<ul style="list-style-type: none"> Manager, Environment and Water, Santos NSW Water Management Review Team Site Operators Field Production Team
LEVEL 2	> ERL to ≤ FSL water level	<ul style="list-style-type: none"> Heavy rainfall Increased produced water production 	<ul style="list-style-type: none"> Cease produced water production Implement actions to reduce pond level as per Level 1 Daily water quality sampling Daily review meeting 	Operations Manager	<ul style="list-style-type: none"> Incident Management Team Office of Coal Seam Gas Environmental Protection Authority Any relevant land holders Manager, Environment and Water, Santos NSW

Produced Water Storage Pond Level: Trigger Action Response Plan

Trigger Level	Characteristics of Level	Possible Reasons	Actions	Action By	Notification
					<ul style="list-style-type: none"> Water Management Review Team Site Operators Field Production Team
UNACCEPTABLE	> FSL water level Water is being released to the environment.	<ul style="list-style-type: none"> Heavy rainfall Increased produced water production 	<ul style="list-style-type: none"> Activate Incident Management Team, in accordance with Santos procedure Implement Emergency Response Plan* Execute mitigation and spill containment strategies as appropriate Implement actions to reduce pond level as per Level 1 Daily water quality sampling Daily review meeting 	Operations Manager	<ul style="list-style-type: none"> Incident Management Team Office of Coal Seam Gas Environmental Protection Authority Any relevant land holders Manager, Environment and Water, Santos NSW Water Management Review Team Site Operators Field Production Team

*Santos has an Emergency Response Plan (ERP) for the operation of all facilities in the Narrabri area. The ERP contains details about:

1. Means by which an emergency response is initiated
2. Defined key roles and responsibilities required to respond to an emergency
3. Facilities required to co-ordinate the emergency response (e.g. Emergency Operations Centre)
4. Key contact list
5. Criteria for escalating an emergency and the means by which the Santos Incident Management Plan is initiated
6. Likely emergency scenarios and guidelines for responding to such scenarios
7. Communication and documentation requirements
8. Evacuation protocols and muster points.