GasFields Commission Queensland

CSG Water Treatment and Beneficial Use

in Queensland, Australia

Technical Communication 2

November 2014

About GasFields Commission Queensland

The GasFields Commission is the independent statutory body formed to manage and improve sustainable coexistence between rural landholders, regional communities and the onshore gas industry in Queensland, Australia.

The Commission's formal powers and functions are enshrined in the *Gasfields Commission Act 2013* which took effect from 1 July 2013. These include: review and provide advice on the effectiveness of legislative frameworks for the onshore gas industry; encourage factual information and scientific research to help address concerns about the potential impacts of the onshore gas industry on water and other resources; and level the playing field in land access and compensation negotiations between landholders and gas companies through more and better information.

For more information visit the GasFields Commission website at www.gasfieldscommissionqld.org.au

About this Technical Communication

One of the Commission's key functions is to obtain and publish information that can assist in improving knowledge and understanding about the onshore gas industry including its interactions with and impacts on rural landholders and regional communities.

The Commission's technical communications aim to fill a gap in information between the simple fact sheet and the full technical reports or scientific papers. They provide an easy to read collation of the science and draw on technical material from a range of sources including CSIRO, universities, Australian and Queensland Government departments, independent technical specialists and scientific experts, and Queensland's onshore gas industry.

Disclaimer

This technical communication is distributed by the GasFields Commission Queensland as an information source only. It provides general information which, to the best of our knowledge, is correct as at the time of publishing. Any references to legislation are not an interpretation of the law. They are to be used as a guide only. The information contained in this technical communication does not constitute advice and should not be relied on as such. While every care has been taken in preparing this technical communication, the GasFields Commission Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained within. Where appropriate, independent legal advice should be sought.

Contents

Tables

Figures

Introduction

Effectively managing the water made available as a by-product of coal seam gas (CSG) production is important for improving sustainable coexistence between rural landholders, regional communities and the onshore gas industry.

It is currently estimated that 1,700 gigalitres (GL) of water will be produced over the life of the major CSG projects in Queensland to 2040. Almost all of the CSG water will be treated and beneficially used, and the community expects that treated CSG water is safe for use.

This paper outlines the methods used to treat CSG water and the standards that CSG companies are required to meet to ensure that this water is safe and fit for purpose. The paper also explores how treated CSG water is beneficially used in the agricultural industry and regional communities.

Why is there water in coal seams?

Coals in Australia were formed up to 350 million years ago. Vegetation such as grasses, trees, leaves and other organic material fell to the earth in swamps or in areas that later became inland seas. Where the vegetation collected in sufficient quantities, and under the right conditions, the process of coal formation, or "coalification", occurred (Bailey, 2013).

It is not unusual for the coal seams to contain water, collected either as the coal was forming "in situ" or by water entering recharge points in the coal seam in a similar manner to recharge processes for other groundwater aquifers (CSIRO, 2014).

Water trapped in situ contains salts and minerals that were a part of the inland seas in which they were formed. Water that has entered the coal seam via aquifer recharge will collect salts and minerals as it travels through the surrounding geological formations. These salts and minerals are then captured in the water within coal seams in the same way that they are found in surrounding aquifers (CSIRO, 2014).

CSG water contains various dissolved salts, and is best described as "brackish" water. For comparative purposes, seawater contains on average 35,000mg/l ppm (milligrams per litre) of salt and CSG water usually contains less than 6,000mg/l of salt (Independent Expert Scientific Committee, 2014).

Why is water extracted from the coal seam?

The breakdown of the vegetation during coalification also resulted in the formation of methane gas.

CSG is a mixture of gases, but is mostly made up of methane (generally 95-97 per cent pure methane), nitrogen, carbon monoxide, carbon dioxide and inert gasses (Cook, 2013; CSIRO, 2013).

Methane gas is compressed within the coal inside a complex arrangement of cracks and fractures – called "cleats". Within the cleats, the gas is bound to the surface of the coal and held in place by the water pressure in the coal seam (CSIRO, 2013). The gas is only released from the coal when the water pressure in the coal seam is reduced to less than 35 metres of Head.

To reduce the water pressure and extract the gas, a gas well is drilled through the overlying geological formations to the target coal seam (Figure 1).

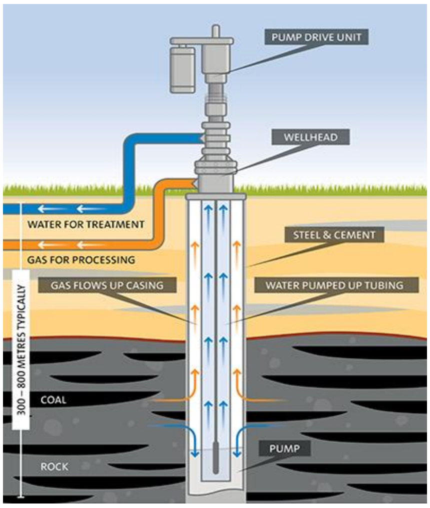

Figure 1: Schematic of a CSG well. Source: *QGC, 2014*

To prevent gas leaking from the gas well into other geological formations and aquifers above the coal, the driller inserts a steel pipe (known as casing) from the surface, down to the coal seam. This casing is then fully cemented into place. To ensure a complete and secure bond between the casing and the side of the well, pressure testing is always conducted, and if necessary, the well is logged. This involves a process of testing the thickness and competency of the cement before it is completed for production (DNRM, 2013).

Water is pumped from the target coal seam to the surface in order to release the pressure within the coal seam, and in turn, release gas from the cleats in the coal (CSIRO, 2014a).

A well produces the most water at the start of the pumping phase. As water is removed, pressure is released from the coal seam and gas begins to flow to the surface via the gas well (National Water Commission, 2011).

As water production from the coal seam declines, gas production increases (Figure 2).

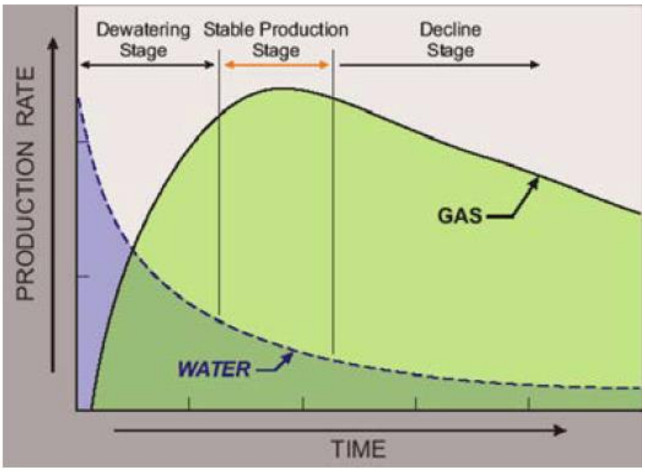

Figure 2: CSG production curve, gas production vs water decline for a well. *Source: National Water Commission, 2011*

The gas and any water mixed with the gas are passed through surface equipment called a "separator". A separator is typically a tank about the size of a small car through which the gas and water pass and are allowed to separate. The water and the gas are sent to processing facilities in separate pipes, one for water and the other for gas. Gas processing facilities for coal seam gas are technically simple. The gas is dried, by removing any remaining water vapour that has travelled with the gas, and then compressed ready for input into the high pressure steel gas pipelines that take the gas to the customer.

CSG Water Management

Where properly managed and treated, CSG water can be reused in a range of different ways including irrigation. The Coal Seam Gas (CSG) Water Management Policy 2012 sets out the Queensland Government's framework for the management of CSG water. The objective of the policy is:

"To encourage the beneficial use of CSG water in a way that protects the environment and maximises its productive use as a valuable resource".

The General Beneficial Use Approval – Associated Water (including coal seam gas water), issued by the Queensland Department of Environment and Heritage Protection (DEHP) supports the objective of the CSG Water Management Policy 2012, by stating the standards that need to be met where CSG water is used for beneficial purposes. Where these standards and conditions are complied with, no specific approval is required from the Department.

The general beneficial use approval (BUA) states the conditions for the following uses of associated water:

1. aquaculture
2. coal washing
3. dust suppression
4. construction
5. landscaping and revegetation
6. industrial and manufacturing operations
7. research and development
8. domestic, stock, stock intensive and incidental land management

The conditions of this general BUA apply to both the producer and user of the resource. The approval has three parts:

1. General conditions;
2. Requirements for use; and
3. General monitoring and operation conditions.

Where these conditions cannot be complied with, for example due to an inability to match the quality of untreated CSG water with suitable beneficial uses, an application for a specific BUA must be made which requires an individual assessment.

The majority of treated CSG water in Queensland is managed under the general beneficial use approval and is therefore treated in order to meet these conditions and enable its use as a valuable resource.

Water Treatment and Management Systems

In order to fulfil the requirements of the CSG Water Management Policy, companies are required to investigate options for beneficial reuse of the CSG water and to treat the water so that it is fit for purpose.

While the level of salt in CSG water varies depending on the source location, CSG water treatment processes typically involve desalination, and the most commonly used desalination technique is reverse osmosis (RO).

The Reverse Osmosis Process

Reverse Osmosis involves forcing the saline water under pressure against a semi-permeable membrane. The semi-permeable membrane allows water molecules to pass though, leaving larger molecules such as salt, behind in a higher concentration. The concentrated brine (called “reject”) is then collected for further processing (Figure 3).

Another way of conceptually thinking about a semi-permeable membrane is that it is like a flyscreen door. The screen will allow air to freely pass through the screen in both directions, but will reject larger objects, such as leaves and insects. RO is similar, in that the water passes through the very small holes of the membrane leaving behind the salt and other compounds.

There are about 240 RO desalination plants in Australia, most of which are small scale plants used to desalinate seawater or brackish water. RO technology is used for a range of purposes including supplying drinking water for towns and tourist facilities (e.g. Kangaroo and Rottnest Islands) or water for industrial processes, irrigation of sporting grounds and agriculture (Victorian Department of Environment and Primary Industries, 2014).

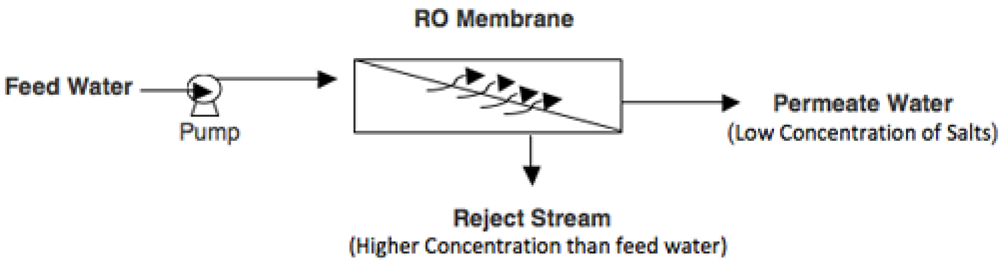

Figure 3: Reverse Osmosis Process. Source: Pure Water Tech (2014)

What are the Water Treatment Steps?

There are a range of steps involved in the treatment of CSG water (Figure 4). Key steps involve the collection and storage of the raw CSG water, filtration to remove solids, removal of beneficial ions for later re-use, removal of the main salts through desalination and then water amendment and/or blending to ensure an appropriate final water quality for the intended use:

- **Raw Water Holding Ponds** – primarily used for water storage prior to the processing of the water in the RO treatment plant. The ponds create a buffer for storing raw CSG water in the event that the water treatment plant is required to recirculate water for quality improvement, or if there is an issue with the beneficial use outlets (e.g. flood events). The ponds are also a starting point to monitor water quality parameters before water is sent to the RO plant.

- **Solids Removal** – Prior to entering the RO plant, the raw water is first filtered to remove large particles and foreign material. This includes any soil and sediment that may be in the water as well as algae and other foreign material.

- **Ultra Filtration (UF)** – The water is forced under pressure through fine filters. The water must be clean and free from all foreign material that would clog the RO membranes. At this stage the water is clean and free from all solids, but still is saline.

- **Ion Exchange (IX)** – a process used to soften the water and remove calcium (Ca++) and magnesium (Mg++) before the water passes through the RO membranes. Calcium and magnesium extracted at this stage are often added back into the water after desalination to adjust the Sodium Adsorption Ratio (SAR) for compatibility with certain soil types, making the water more suitable for irrigation.

- **Reverse Osmosis (RO)** – the main desalination process, responsible for the removal of the salts from the water. A reverse osmosis filter has a pore size of approximately 0.0001 micron and removes 90-99% of salt from the water.

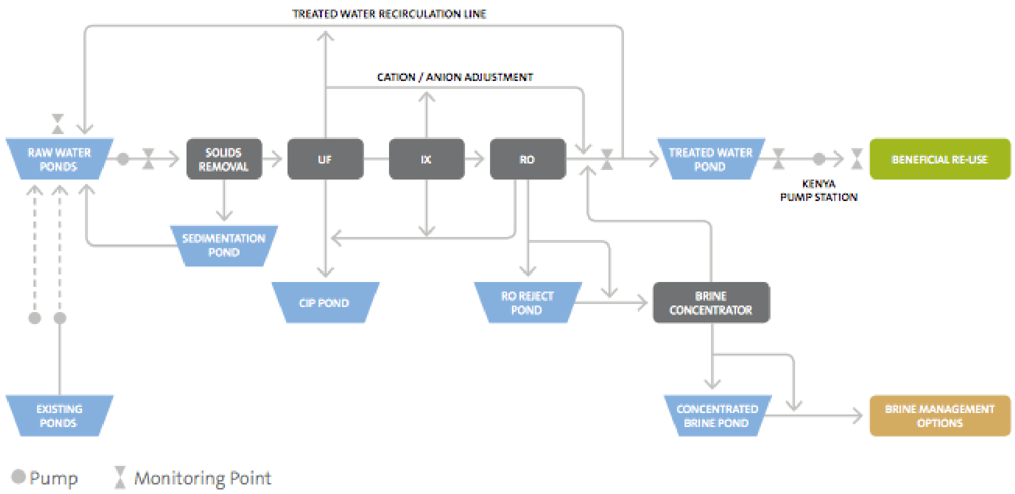

Figure 4: Schematic of a CSG Water Treatment Plant. Source: Queensland Gas Company (2013)

While small amounts of some chemical compounds may pass through the RO membranes, the DEHP has assessed the environmental and human health impacts and has placed limits on their release to the environment. The CSG companies have strict environmental reporting requirements and must report any non-compliance with the licensed release limits.

The following sections provide examples of the management processes involved in the use of treated CSG water for irrigation and aquifer reinjection in Queensland.

Water Treatment for Irrigation and River Discharge

The QGC Kenya Water Treatment Plant and the SunWater Pipeline to the Chinchilla weir provide an example of the treatment and beneficial use of CSG water for irrigation and river discharge.

SunWater is a Government Owned Corporation, responsible for the supply of bulk water to customers. It is responsible for the management of the water supply scheme from the Chinchilla Weir and the supply of water to landholders 35km upstream and 53km downstream of the weir.

Water from QGC's gas production fields is treated at the company's Kenya Water Treatment Plant. This plant recovers approximately 90% of the raw CSG water for beneficial use.

QGC transfers custody of the treated water to SunWater at the outlet of the water treatment plant's treated water pond. The water is then supplied via a 20km pipeline, constructed by SunWater from the Kenya Water Treatment Plant to the Chinchilla Weir, on the Condamine River.

Once in the pipeline, the water can be supplied to agricultural producers. SunWater has contracted water supply to 20 landholders along the pipeline route, who use the water for irrigation.

Any excess water supply passes through to the Chinchilla Weir and supplements the water available to other regional users. These include the Western Downs Regional Council, which uses water from the weir for urban and industrial customers.

Monitoring and Controls

The decision notice approving Sunwater's use of the treated CSG water includes conditions relating to the quality of the water and the way in which the water may be used (DERM, 2011).

The resource approval sets out conditions that place a limit on the chemical and physical characteristics (Table 1), the management of the water, and the monitoring and reporting required. Compliance with the conditions is mandatory, and regular audits are conducted by suitably qualified, independent third party auditors.

Table 1: Water Quality requirements under SunWater BUA - ENBU02701811. Source: DERM 2011

Characteristics of resource	Quality Limit	Limit type	Monitoring frequency
Electrical Conductivity (µS/cm)	500	Maximum	Continuous
pH (pH unit)	6.5-8.5	Range	Continuous
Total suspended solids (mg/L)	175	Maximum	Monthly
Calcium (mg/L)	6	Minimum	Weekly
Chloride (mg/L)	135	Maximum	Weekly
Fluoride (mg/L)	0.5	Maximum	Weekly
Magnesium (mg/L)	4.5	Minimum	Weekly
Sodium (mg/L)	95	Maximum	Weekly
Sulphate (mg/L)	8.8	Maximum	Weekly
Total Dissolved Solids (mg/L)	320	Maximum	Weekly
Alkalinity (mg/L)	20	Maximum	Weekly
SAR	6	Maximum	Weekly
Boron (mg/L)	1	Maximum	Weekly

Beneficial Use Agreements

Key agreements govern the operation of the QGC/SunWater Chinchilla Weir project. The principal agreement between QGC and SunWater for the supply of the water from the Kenya Water Treatment Plant requires SunWater to take all the water produced from the Water Treatment Plant.

SunWater has secondary agreements with each of the water customers along the pipeline. These agreements cover 100% allocation of the water from the pipeline (QGC, 2013).

Monitoring and Reporting

Under its BUA, SunWater is required to undertake monitoring of the water available for use by third parties.

In accordance with regulatory requirements, SunWater undertakes a comprehensive monitoring program designed to detect any potentially negative impacts from the use of the water. All tests must be conducted by NATA (National Association of Testing Authorities) certified laboratories.

SunWater publishes the results of the testing from its beneficial reuse scheme on a quarterly basis. The most recent report, *"Chinchilla Beneficial Use Scheme, Annual Report"*, was released in August 2014 and summarises the results of water quality analyses against the thresholds noted in Table 1.

Table 2 provides a summary of the non-compliances and corrective actions that were recorded during the reporting period.

In this example of reporting corrective actions taken to remedy perceived non-compliances, two of the four notifications were laboratory errors, and one was a sampling procedural error (SunWater, 2014).

Table 2: Chinchilla Weir Pipeline Water Quality Non-Compliances. *Source: SunWater, 2014*

Date	Incident	Root Cause	Corrective Action
09/09/2013	Total Petroleum Hydrocarbons limit of 200mg/L exceeded by 40mg/L.	Minor oil spill during routine maintenance contaminated the treated water pump station with less than 1L of mineral pump oil.	Oil removed from pump station. Maintenance procedures altered to remove the risk of oil leaking into pump station.
20/01/2014	A false exceedance of the limit for Iron of 300µg/L – the limit was reported as being exceeded by 30µg/L.	Incorrect transposing of the result by the laboratory.	Amended with the correct laboratory analysis result of 130µg/L.
20/01/2014	A false exceedance of the limit for N-Nitrosodimethylamine (NDMA) 0.1µg/L.	Incorrect reporting of the result as <0.5µg/L.	Amended with the correct laboratory analysis limit for reporting of <0.1µg/L
26/05/2014	An exceedance of the limit for lead 10µg/L was recorded from sampling at offtake 17.	Sample contamination due to incorrect flushing of the sampling point before sampling.	Site re-sampled using correct flushing procedure. All results returned were within the final water quality criteria.

Water Treatment for Aquifer Recharge

Recharge of aquifers using treated CSG water has a range of benefits including increasing the water pressure in the aquifer, assisting the flow of groundwater bores in the region, counteracting the effects of CSG water extraction and providing water storage for future uses.

APLNG has commenced reinjecting up to 30ML/day of treated CSG water within the Surat Basin. Santos has also proposed a Managed Aquifer Recharge (MAR) project near Roma to inject up to 24ML/day of treated CSG water into groundwater aquifers which have been partially depleted from town and agricultural use.

One of the key requirements is to ensure that the quality of the treated CSG water is compatible with the groundwater aquifers targeted for injection.

When CSG water is treated using RO, the oxygen and other gasses are removed and where appropriate some salts are added back into the treated water to ensure that the water for injection matches the quality of the groundwater. Finally, non-chemical disinfection is undertaken to prevent coliform bacteria, sulphate reducing bacteria and iron reducing bacteria from being injected into the aquifers.

Both APLNG and Santos have completed comprehensive testing to demonstrate that reinjection is technically and physically possible. Both companies have worked with CSIRO to establish a baseline of groundwater qualities in the receiving aquifer and to predict any changes that may occur to the physical nature of the aquifer (rock) over time due to any incompatibility of the existing aquifer water and the injected water.

An example (Table 3) of the treated CSG water quality parameters required for reinjection is provided by the Environmental Authority for the APLNG activities (DEHP, 2014).

To demonstrate that the injection of the water is not causing adverse effects to aquifers, the companies are required to install groundwater monitoring bores to measure the interaction of the existing and new water in the injection zone and detect any adverse changes in the water quality in the injection zone (DEHP, 2014).

Companies with reinjection activities are also required to provide DEHP with an annual report prepared by a suitably qualified person on the results of the monitoring program including any adverse effects of the injection program.

Table 3: Example water quality limits for reinjection of treated CSG water. Source: DEHP 2014

Water Quality Parameter	Limits for reinjection
Dissolved Oxygen	500 µg/L
Electrical Conductivity	460 µS/cm
Total Dissolved Solids	300 mg/L
pH	6.5 (min) 8.5 (max)

Summary

1. Water is extracted from coal seams as a by-product of the coal seam gas process.
2. In Queensland, CSG companies are required to treat produced water and ensure it is used in a beneficial way, including irrigation for agriculture and groundwater aquifer recharge, for future use.
3. There are strict controls and ongoing monitoring of treated CSG water that is supplied for beneficial use in Queensland.

Conclusion

The extraction of water from coal seams is integral to the production of coal seam gas. This water is brackish, has limited beneficial use in its raw form and is normally desalinated using reverse osmosis processes.

The community expects that treated CSG water is safe, fit for purpose and is used for beneficial purposes. Under Queensland environmental protection legislation, conditions are imposed on the beneficial use of produced water to protect the environment and community health and safety.

The majority of treated CSG water in Queensland is used for irrigation or reinjected into aquifers for future use. Ongoing monitoring and reporting of the results are increasing the transparency and accountability of the Queensland onshore gas industry to the community.

Glossary

Term	Definition
APLNG	Australia Pacific LNG (APLNG) is a joint venture with Origin Energy, ConocoPhillips and Sinopec
Aquifer	Aquifers are underground layers of very porous waterbearing soil or sand typically surrounded by "aquitards" or "aquicludes" which provide a water rich reservoir, (National Water Commission 2014).
Aquitard	Aquitards are compacted layers of clay, silt or rock that retard water flow underground; that is, they act as a barrier for groundwater, (National Water Commission 2014).
Coal Seam Gas	Coal seam gas (CSG), also known as coal bed methane, is a form of natural gas typically extracted from coal seams at depths of 300-1000 metres. CSG is a mixture of a number of gases, but is mostly made up of methane (generally 95-97 per cent pure methane). It is typically attached by adsorption to the coal matrix, and is held in the coal by the pressure of formation water in the coal cleats and fractures, (CSIRO 2013).
GLNG	Gladstone LNG (GLNG) is a joint venture between Santos GLNG, PETRONAS, Total and KOGAS
Managed Aquifer Recharge	Managed aquifer recharge is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit; the managed process assures adequate protection of human health and the environment. Aquifers may be recharged by diversion of water into wells or infiltration of water through the floor of basins, galleries or rivers (Natural Resource Management Ministerial Council, 2009).
Produced water	Water that is extracted from the target formation or from formations (aquifers) that the well bore passes through while drilling ahead to the target formation. This water is typically pumped back to holding ponds via High Density Poly Ethylene (HDPE) Pipe for treatment prior to disposal. (also commonly referred to as CSG Water)
QCLNG	Queensland Curtis LNG (QCLNG) is being developed by QGC (Australian subsidiary of BG Group)
Salinity	The relative concentration of dissolved salts, usually sodium chloride, in a given water. (Ahmadi, 2014)
Total Dissolved Solids (TDS)	A measure of the amount of material dissolved in water (mostly inorganic salts). Typically aggregates of carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, etc. of calcium, magnesium, manganese, sodium, potassium, and other cations which form salts. (Ahmadi, 2014).

References

Ahmadi, M. (2014) Environmental Engineering Dictionary. Retrieved from http://www.ecologydictionary.org/Environmental-Engineering-Dictionary Date accessed 14 September 2014

Bailey, J. (2013) Is Coal Still being Formed Today? Retrieved from http://www.abc.net.au/science/articles/2013/02/18/3691317.htm Date accessed 23 July 2014 CSIRO (2013) What is Coal Seam Gas? Retrieved from: http://www.csiro.au/Outcomes/Energy/Energy-from-oil-and-gas/What-is-coal-seam-gas.aspx Date accessed 14 September 2014

CSIRO (2014) Great Artesian Basin and Coal Seam Gas. Factsheet 14-00589. Canberra. Retrieved from: http://www.csiro.net.au Date accessed 23 July 2014

CSIRO (2014a) Coal Seam Gas – Produced Water and Site Management Retrieved from: http://www.csiro.au/Outcomes/Energy/Energy-from-oil-and-gas/UnconventionalGas/Learn-more/Coal-seam-gas-produced-water.aspx Date accessed 14 September 2014

Cook, P (2013) Lifecycle of Coal Seam Gas Projects: Technologies and Potential Impacts, CSRIO. Report prepared for the New South Wales Office of Chief Scientist and Engineer. New South Wales Government, Sydney

Department of Environment and Heritage Protection (2012) Coal Seam Gas Water Management Policy, Queensland Government, Brisbane.

Department of Environment and Heritage Protection (2014) APLNG Spring Gully Environmental Authority, EPPG00885313, Effective 02 October 2014

Department of Environment and Primary Industries (2014) Desalination History. Retrieved from http://www.depi.vic.gov.au/water/urban-water/desalination-project/desalination-background/desalination-historyDepartment of Environment and Resource Management (2011) Decision Notice, Permit Number ENBU02701811, Approval of a Resource for Beneficial Reuse. Queensland Government, Brisbane.

Department of Natural Resources and Mines (2013) Code of Practice, for Constructing and Abandoning Coal Seam Gas Wells and Associated Bores in Queensland, Ed. 2. Queensland Government, Brisbane.

Independent Expert Scientific Committee (2014) Fact sheet: Coal Seam Gas Extraction and Co-Produced Water. Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Australian Government, Department of Environment, Canberra.

National Water Commission (2011) Onshore Co-produced Water: Extent and Management. Waterline Report Series No. 54, September 2011

Natural Resource Management Ministerial Council (2009), Australian Guidelines for Water Recycling Australian Guidelines for Water Recycling. National Water Quality Management Strategy, Document No 24

Pure Water Tech (2014), *What is Reverse Osmosis.* Retrieved from http://puretecwater.com/what-is-reverse-osmosis.html, date accessed 24 September 2014

Queensland Gas Company Limited, (2013) Stage 3 Water Monitoring and Management Plan Ensuring Responsible CSG Water Management.

SunWater (2014) Chinchilla Beneficial Use Scheme, Annual Report, 18 July 2013 – 30 June 2014. Sunwater, Brisbane.