REUSE AND DISPOSAL OPTIONS FOR CSG PRODUCED WATER: THE GLOUCESTER GAS PROJECT, NSW

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ABSTRACT

The paper summarises the investigation of the potential beneficial uses of the Coal Seam Gas (CSG) produced water in Australia. This paper is based entirely on a case study from the Gloucester Basin. Produced water is traditionally seen as a by-product of the oil and gas industries, and is typically evaporated and disposed (in Australia) or reinjected (in USA). New environmental and legislation challenges faced by the industry drives the search for alternative beneficial uses, in some cases requiring some water treatment. While no single stand-alone option was identified as feasible for the 2 ML/d produced water stream at Gloucester, combining options is feasible and preferred, including irrigation of crops and/or public parks; intensive farming (for livestock, aquaculture or silviculture); industrial uses and aquifer storage and recovery to shallow high permeability aquifers.

INTRODUCTION

Australian experience is relatively limited in terms of CSG produced water management practices, but other countries provide a wealth of practical experience, notably the USA. The beneficial use of produced water represents an opportunity for petroleum and gas producers to maximise the resource value by providing water (including trading) to other parties for use. In a dry continent such as Australia, water resources are frequently constrained due to drought, climate variability and sustainable diversion limits. It may be possible to use fit-for-purpose CSG water to manage short-term transitions in water management and the acute effects of drought. It is important to understand that CSG and produced water flows are neither permanent nor constant, and have variable quality. The gas reserves from any given area are predicted to have a 5–20 year life per well, and a typical gas project with multiple supply areas may have a 25–35 year production window. CSG water production is variable and depends largely on hydrogeology which may render it incompatible with the reliability of supply required for domestic, industrial and environmental users. The variable quality of produced water may require treatment for specific beneficial uses.

In the USA, the majority of poorer quality produced water has been disposed of in the past through evaporation and infiltration impoundments (Ruckelshaus Institute of Environment and Natural Resources, 2005). More recently, poorer quality produced water is largely reinjected. The onshore petroleum industry in Australia typically uses evaporation ponds due to the generally poor quality of produced water but ponds are being phased out. NSW and Queensland legislation does not allow the storage of untreated CSG water in non-lined storages, making the installation and maintenance of evaporation ponds an expensive and practically non viable option for the future.

CSG FLOW BACK AND PRODUCED WATER

Flowback water is associated with the establishment phase of the well, which includes the depressurization of the coal seam aquifers after hydraulic fracture stimulation and prior to CSG production. Flowback water is a mixture of hydraulic fracturing fluid and formation water, making it physically and chemically different to produced water. Produced water is defined as water that is brought to the land surface during the production process of recovering methane gas. Produced water is chemically different to freshwater and other groundwater sources. It is generally high in dissolved salts, metals, dissolved or dispersed hydrocarbons, dissolved gases and naturally occurring radioactive materials (Gore and Davies, 2013). Minor traces of hydraulic fracturing fluid and other chemicals associated with well development may sometimes be found in produced water, depending on the local hydrogeology, degree of aquifer connectivity and the effectiveness of the injection - depressurization cycles.

The amount of produced water from a CSG well depends on the geology (rock permeability and faulting) of the coal seam and surrounding formations and proximity and connection to aquifiers. The water yield in the Gloucester and Hunter CSG coalfields is 1.2 to 1.5 times the volumes from Sydney Basin CSG coalfields, while Queensland’s Surat Basin wells yield about 25 times as much produced water as the NSW fields (Gore and Davies, 2013). Water yield is not constant during the production period, and is typically greatest in the first month to one year of
operation, with a subsequent decline to a steady-state extraction rate (Figure 1).

![Typical CSG water and gas production curves for individual wells. Source: Centre for Water in the Minerals Industry, Sustainable Minerals Institute, University of Queensland, 2008](image)

**Figure 1: Typical CSG water and gas production curves for individual wells. Source: Centre for Water in the Minerals Industry, Sustainable Minerals Institute, University of Queensland, 2008**

**GLOUCESTER GAS PROJECT STAGE 1 (GGP1)**

AGL has plans to progress CSG extractions within the Gloucester Basin in NSW. The GGP1 establishment phase of 2-5 years will be followed by a 15 year production phase, for a total duration of about 20 years.

The estimated water production rates for individual GGP1 bores range from 0.3 L/s during the first 6 months, to long term rates of less than 0.06 L/s after 18 months. This means that, depending on the operating schedule, the total production rate during the establishment phase could reach 3 ML/d, declining to 1 ML/d over the following 5-10 years, and to around 0.5 ML/d thereafter. For the purpose of the options evaluation, a nominal rate of 2 ML/d during the life of the project was considered, acknowledging that extraction volumes will be variable and generally declining with time.

The produced water quality profile from field surveys (PB, 2013, 2014) may be summarised as:

- Water is brackish (3,500 to 8,000 μS/cm) and slightly alkaline (pH 7.5 to 9.5).
- Major ion chemistry is sodium and chloride dominant, with some traces of bicarbonate (i.e. brackish and high sodicity water).
- Groundwater in the coal seams has generally low concentrations of dissolved metals except for Aluminium, Zinc, Barium and Strontium, although these are considered natural and not unusual for Permian coal seams.
- Ammonia, total Phosphorus and reactive Phosphorus concentrations are elevated at some monitoring locations.
- BTEX was detected at some monitoring locations, in particular Toluene and Benzene were identified, but Benzene levels did not exceed ANZECC (2000) 95% trigger values for the protection of fresh water ecosystems (there is no trigger value for Toluene).

- Total Petroleum Hydrocarbons (TPH) were generally low (below 1,000 μg/L): Methane concentrations in the coal seams and interburden rocks were detected at an average of 10,000 μg/L, reaching 30,000 μg/L in some instances, which are higher concentrations than the overlying alluvial or shallow rock groundwater (average of 100 μg/L and 5,000 μg/L respectively).

It should be noted that methane, as well as other recoverable hydrocarbons (including TPH), are expected to be extracted and separated from the produced water at the central processing facility, and the final concentration of methane and hydrocarbons in the produced water depends of the effectiveness of this separation process.

**WATER OPTION STUDY STRUCTURE**

Figure 2 (presented below) depicts the work-flow structure of the Gloucester water options evaluation study. The Gloucester study is shown as a meso-scale investigation, positioned below the high level strategic context, allowing for review input from the community, and providing some independent guidance to the more in-depth studies that will be undertaken in future by AGL for the GGP1.

**DATA COLLECTION**

A review of the regulatory framework, the regional and socio-economical context of the Gloucester Local Government Area (LGA), and the biophysical characteristics of the Gloucester geological basin was carried out as part of the evaluation. The main findings were:

- The regulatory framework is complex, with state and commonwealth legislation applying to CSG exploration, production and associated activities. Specific legislation and guidelines related to water use, water discharge, environmental protection and human health can apply depending on the water use option chosen. Legislation regulating CSG in NSW has recently been amended, creating significant changes to the CSG regulatory framework.
- The region is predominantly rural, with the agricultural industry accounting for around 15% of total jobs. There were about 700 agricultural holdings in the Gloucester LGA in 2009, estimated to contribute $35 million to the local economy each year.
- Surface water is the main source of water in the region. Annual water consumption for agricultural uses is estimated at over 1,000 ML pa, while 375 ML pa is used for industrial and domestic uses. Mining extracts about 500 ML pa of groundwater, which is fully reused in mining related operations.
- The fertility of the soils in the region is considered moderately low, and only small portions of land along the Avon and Gloucester Rivers have moderately high or high fertility.
- The climate is sub-tropical, with an average annual rainfall of 1,000 mm, distributed across wet summers (average 130 mm per month) and dry winters (average 40 mm per month). Approximately 50% of the rainfall becomes overland runoff contributing to rivers and surface water bodies (PB, 2013b).

- The rivers in the region are mainly perennial (continuously flowing), with short periods of no flow in the Mammy Johnsons and Avon Rivers. Rivers do not show evidence of flow stress and show a general good health, with only the Avon River downstream of Stratford showing symptoms of poor water quality and erosion.

- The geology of the Gloucester Basin is characterised by Permian sedimentary rocks from terrestrial and marine deposition, overlain by Quaternary alluvium and colluvium deposits. The coal seams targeted by the GGP1 are contained within the Permian coal measures at 150 m to 1500 m depth, embedded within the low permeability interburden rock. The geological basin forms a synclinal structure, partially fractured and with extensive faulting, which may provide limited vertical connection between hydrogeological units.

- The permeability indicates low water extraction and reinjection yields for the shallow aquifers and the deeper coal seam gas aquifers.

- The general geology and the observed groundwater levels suggest that the deeper aquifers within the target coal seams and the less permeable interburden rocks are not highly interconnected to the more shallow alluvium and shallow rock aquifers.

- The water in the Gloucester basin aquifers varies from fresh in the alluvium to brackish in the shallow rock aquifer and slightly saline in the deeper interburden and coal seam aquifers. The water in the shallow aquifer (<150 m) is more saline than the deeper aquifers (150-1500 m).

About 75% of the Gloucester sub-region native vegetation has been cleared. However, the region retains many environmental values, including numerous national parks and state conservation areas, and 68 threatened species and 6 endangered ecological communities are believed to occur in the region.

PRODUCED WATER MANAGEMENT OPTIONS

Water Reuse Options:
Reusing CSG produced water is a complex issue and requires matching the characteristics of the produced water with the requirements of the end user and/or the adoption of specifically designed treatment processes.
The study evaluated the following water reuse options for GGP1 produced water:
- Irrigation of industrial crops (hemp), pasture and feed crops (Lucerne).
- Intensive and non-intensive livestock farming, which includes cattle (beef and dairy), sheep and pig farming.
- Poultry farming.
- Intensive (recirculated) aquaculture, which includes inland fresh to saline aquaculture; particular species assessed include Barramundi, Trout, Silver Perch and Murray Cod.
- Silviculture for timber production.
- Energy and Mining Sector; for example, reusing water for drilling and hydraulic fracture stimulation as part of the gas extraction process and the possibility of coal washing at the nearby coal processing facilities.
- Industrial and commercial sector, and non-potable applications, which included water for concrete production and irrigation of urban parks and green areas.
- Drinking water supply, direct (into the supply network) or indirect (surface water discharge upstream of drinking water off-takes).
- Aquifer Storage and Recovery (ASR) in shallow aquifers (nominally less than 150 m depth) for later irrigation use.

**Water Disposal Options**

The study evaluated the following GGP1 produced water disposal options:
- Direct surface water discharge to the Avon River, Mammy Johnsons River and Gloucester River.
- Direct sea discharge.
- Injection to deep aquifers, including re-injecting to coal seam aquifers after gas extraction has been completed.
- Surface water storage and/or evaporation.

**OPTION EVALUATION**

Each of the identified options was evaluated using a multi-criteria matrix developed for this study. The evaluation is based on the objective information available, and takes into account potential limitations (risks) and benefits of each option. The potential limitations evaluated include:

- Regulatory risk: evaluates the degree and complexity of regulatory compliance and application processes (i.e. Environmental Impact Statements, Development Consents, etc.) that an option should undertake and the risk of the option not being approved. Options such as implementing surface storages for water evaporation and drinking water applications may encounter difficult and tedious application processes with significant risk of licensing not being granted, indicating very high regulatory risk. This is due mainly to the current prohibition of implementing CSG water evaporation ponds in one case, and the strict compliance requirements for drinking water in another. Irrigation of urban parks and green areas and ASR options have been assessed as high regulatory risk, due to the residential exclusion zones for mining activities, and the exclusion of reinjection licensing from Part 3A of the 2011 development consent.
- Commercial risk: evaluates the risks of the option being commercially viable, which is a combination of the initial and ongoing investment compared to the value of the product and marketplace risk. It is a measure of the commercial potential for success of the option, which could determine largely its viability and implementation. The evaluation does not intend to cost each option but simply to outline the comparative degree of investment. Of the reuse options, drinking water has been assessed as the highest commercial risk, due to its high costs of implementation, which is probably not justified by the low return value of the water in the market, followed by poultry water supply for similar reasons. Of the disposal options, direct sea discharge and reinjection to deep aquifers have high commercial risk due to their estimated high costs of implementation and operation respectively.
- Treatment needed: treatment varies from no treatment or blending/minimum settlement to the maximum treatment to comply with drinking water standards. Treatment adds costs and complexity to the option and it is seen as a potential limitation. While some treatments, like settlement or alkalinity correction, were considered and add little cost to the final investment, Reverse Osmosis (RO) treatment increases the costs substantially. RO treatment has been sub-classified into simple (only RO with perhaps upstream filtration) and complex (requiring also filtration and/or adsorption for hydrocarbon removal and metal precipitation). Again, the evaluation does not intend to define the treatment needed for each option, simply to outline the degree of treatment related to its complexity and implied costs.
- Risks to human health: contact (via physical contact or consumption) with CSG produced water may be detrimental to human health, depending on the degree of treatment, the nature of contact and potential direct or indirect exposure pathways for contaminants to affect the human consumption chain. None of the options were assessed as having a very high risk to human health, although drinking
water and irrigation of urban parks were assessed as having high risk to human health due to the potential exposure pathways.

- Risks to the environment: focuses on the potential for untreated produced water to contaminate surface water and/or groundwater. None of the options was identified as high or very high risk to the environment, indicating that no options have a high possibility of untreated CSG produced water reaching groundwater or surface water. Surface storage for water evaporation and intensive livestock farming have a medium to high possibility of untreated water reaching groundwater only, and were assessed as medium to high environmental risk.

The potential benefits evaluated include:

- Economic benefit: estimated as the amount of economic support to existing industries or revenue for new investments, accounted as the estimated number of new jobs created. Obviously, disposal options have very little or no economic benefit. Irrigation, intensive livestock farming and aquaculture have been assessed to create 20 to 50 new jobs in the region. None of the options is considered to have a high or very high economic benefit (no more than 50 jobs are projected).

- Social benefit: The estimated benefit to the community, not including economic benefit. This focuses on the potential for CSG produced water to support communal assets (public parks and recreational areas), as well as the sustainability of the regional water resources for future generations. Most of the options have low to very low social benefits. Irrigation of urban parks and green areas, drinking water and ASR have medium social benefits.

- Environmental benefit: Focusses on the potential of produced water to support and increase habitat. Most of the options have been assessed as having low to very low environmental benefits. Only silviculture and irrigation of urban parks and green areas have been assessed as having medium environmental benefit as they may support to expand existing habitats.

Table 1 details the evaluation criteria developed for the Gloucester water options study.

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<tbody>
<tr>
<td>Very Low</td>
<td>Consent required only</td>
<td>Low set upgoing costs, good market and high value product</td>
<td>No treatment or blending / minimum sediment settling</td>
<td>No contact or minimal possibility direct or indirect contact of humans with treated or untreated CSG produced water</td>
<td>No possibility of treated or untreated CSG water reaching surface water or groundwater</td>
<td>No or un-measurable economic benefits</td>
<td>No social benefits</td>
<td>No environmental benefits</td>
</tr>
<tr>
<td>Low</td>
<td>Licences required</td>
<td>Low set upgoing costs, unknown market/medium value of product</td>
<td>Treatment without RO</td>
<td>Some possibility of direct or indirect human contact with treated CSG produced water</td>
<td>Low possibility of untreated CSG water reaching surface water or groundwater</td>
<td>Support existing industry and/or create new industry, &lt;20 jobs created</td>
<td>CSG produced water used as backup to maintain community assets/venues</td>
<td>Support existing habitat</td>
</tr>
<tr>
<td>Medium</td>
<td>Approvals required (simple)</td>
<td>Medium set upgoing costs, known market value of product</td>
<td>Simple RO</td>
<td>Direct or indirect human contact with treated CSG produced water</td>
<td>Medium possibility of untreated CSG water reaching surface water or groundwater</td>
<td>Support existing industry and/or create new industry, &gt;20 jobs created</td>
<td>CSG produced water used to maintain community assets/venues</td>
<td>Support and expand existing habitat</td>
</tr>
<tr>
<td>High</td>
<td>Approvals required (complex)</td>
<td>Medium set upgoing costs, unknown market/medium value of product</td>
<td>Complex RO</td>
<td>Indirect human contact with untreated CSG produced water</td>
<td>High possibility of untreated CSG produced water reaching groundwater only</td>
<td>Support existing industry and/or create new industry, &gt;60 jobs created</td>
<td>CSG produced water used to maintain and upgrade community assets/venues</td>
<td>Improve environmental diversity, support and expand the existing habitat</td>
</tr>
<tr>
<td>Very High</td>
<td>Legislation prohibits option</td>
<td>High set upgoing costs, unknown market/low value of product</td>
<td>Maximum treatment (comply with drinking water standards)</td>
<td>Direct human contact with untreated CSG produced water</td>
<td>High possibility of untreated CSG produced water reaching surface water</td>
<td>Create new to area industry, and/or &gt;100 jobs created</td>
<td>CSG produced water used to maintain, upgrade and build new community assets/venues</td>
<td>Improve environmental diversity, support the habitat of rare or endangered species</td>
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Table 1: Evaluation Criteria Definitions
The options, evaluated qualitatively according to the criteria, were scored quantitatively using a scoring system developed for the study (Table 1), where benefits are better valued than limitations, weighting the preference for options with significant benefits rather than with few limitations. Once all the options were evaluated and scored, an overall score was calculated as a percentage of the accumulated score over the maximum achievable score (88 points). Using this scoring system, the lower the score, the more feasible is the option (less limitations and more benefits).

The overall score was then translated into the final evaluation output according to the criteria summarised in Table 2.

Table 3 summarises the overall score and evaluation output for each water management option based on the evaluation process outlined.

**OPTION EVALUATION OUTPUTS**

The following points summarise the outputs of the evaluation:

- None of the options has been identified as a feasible and preferred stand-alone option. A combination of complementary options has been assessed to be potentially viable. Factors that lead to this conclusion include:
  
  o The CSG produced water is extracted continuously without seasonal variation, with production declining from the nominal 2 ML/day after the first years of production; this is difficult to match with the demands for beneficial uses of water.
  
  o The produced water quality renders some of the options unviable or requiring a degree of treatment that is not economical.

- Disposal options add very little value (economic, social or environmental) to the region and have been assessed as:
  
  o Direct discharge to surface water is considered feasible but not a preferred option. Benefits of environmental flows and water quality of degraded streams are limited and require RO treatment. Some potential impacts on receiving water courses could also arise, however limited, including increasing fluvial erosion and changes to natural flow patterns. Direct discharge is better assessed as complementing beneficial uses like irrigation, livestock or industrial and commercial non potable applications.
  
  o Direct sea discharge is likely to be too costly to be viable.

<table>
<thead>
<tr>
<th>Overall Score</th>
<th>Evaluation Output</th>
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<tbody>
<tr>
<td>0-50%</td>
<td>Feasible / Preferred stand-alone option</td>
</tr>
<tr>
<td>50 - 60%</td>
<td>Feasible / Preferred option in combination with other options</td>
</tr>
<tr>
<td>60 - 70%</td>
<td>Feasible but Not Preferred</td>
</tr>
<tr>
<td>70 - 100%</td>
<td>Not Feasible / Not Preferred</td>
</tr>
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**Table 3: GGP1 Overall Score and Evaluation Output**

<table>
<thead>
<tr>
<th>REUSE OPTIONS</th>
<th>OVERALL SCORE</th>
<th>EVALUATION OUTPUT</th>
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<tbody>
<tr>
<td>Irrigation</td>
<td>56.8%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
<tr>
<td>Livestock farming</td>
<td>64.8%</td>
<td>Feasible Not Preferred</td>
</tr>
<tr>
<td>Livestock farming (intensive)</td>
<td>58.0%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
<tr>
<td>Poultry farming</td>
<td>75.0%</td>
<td>Not Feasible / Not Preferred</td>
</tr>
<tr>
<td>Aquaculture (intensive)*</td>
<td>58.0%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
<tr>
<td>Silviculture</td>
<td>50.0%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
<tr>
<td>Energy and Mining Sector</td>
<td>53.4%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
<tr>
<td>Concrete Production</td>
<td>63.6%</td>
<td>Feasible / Not Preferred</td>
</tr>
<tr>
<td>Urban parks and green areas</td>
<td>53.4%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
<tr>
<td>Drinking Water Supply</td>
<td>70.5%</td>
<td>Not Feasible / Not Preferred</td>
</tr>
<tr>
<td>Aquifer Storage and Recovery (ASR)</td>
<td>60.2%</td>
<td>Feasible / Preferred in combination with other solution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DISPOSAL OPTIONS</th>
<th>OVERALL SCORE</th>
<th>EVALUATION OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Surface Water Discharge</td>
<td>67.0%</td>
<td>Feasible / Not Preferred</td>
</tr>
<tr>
<td>Direct Sea Discharge</td>
<td>70.5%</td>
<td>Not Feasible / Not Preferred</td>
</tr>
<tr>
<td>Reinjection to Deep Aquifers</td>
<td>73.9%</td>
<td>Not Feasible / Not Preferred</td>
</tr>
<tr>
<td>Surface Storage and Evaporation</td>
<td>78.4%</td>
<td>Not Feasible / Not Preferred</td>
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</table>
- Reinjection to deep aquifers requires additional approvals and may be not feasible during Stage 1 due to the risk of re-pressurising the coal seam aquifers, diminishing the gas production.
- Surface storage and evaporation have regulatory constraints that may make it not viable. Evaporation ponds have been recently banned in NSW and surface storage is costly, usually requiring the construction of double lined impermeable storages. However, some storage will be needed to complement beneficial use options.
- Irrigation of industrial crops (hemp), pastures or feed crops (Lucerne) is a feasible and preferred option in combination with other options. Produced water will need to be blended with fresh water to dilute dissolved solids and reduce its salinity. Minimum treatment, such as alkalinity correction and metal precipitation (the latter for pasture and feed crops only) will also be needed. Irrigation combined with intensive livestock farming is a preferred option, possibly with a degree of storage and/or disposal to match the steady water production to the unbalanced demand schedule. Further analysis is required to confirm the suitability of soils, long term impacts of irrigation on soil and rehabilitation measurements.
- Intensive livestock farming is potentially a feasible and preferred option, in combination with irrigation of pasture and feed crops and a degree of storage and/or disposal. Due to the produced water salinity, suitable livestock includes beef cattle, sheep and pigs. CSG produced water will not need to be blended but minimal treatment may be required, such as filtration or absorption to eliminate hydrocarbons, metal precipitation and disinfection. There is an extensive beef farming tradition and an existing cattle market in the region, which provides additional benefits in this case: however, sheep are generally not considered physiologically suitable for the Gloucester climate.
- Intensive (recirculated) aquaculture has also been identified as a feasible and preferred option in combination with other options, mainly because it requires a constant water supply that can be tailored to match the non-seasonal production rates. Produced water may require desalination treatment depending on the species selected. Species that do not require desalination treatment include Barramundi and Silver Perch, with Barramundi being the more commercially viable of the two species. Other treatment may be needed, including oxygenation, filtration, metal precipitation and disinfection.
- Silviculture (forestry) is a feasible and preferred option in combination with other options, mainly because of its low initial and ongoing costs and the related environmental benefits. Produced water may need to be blended with fresh water, but further treatment may not be required. Silviculture is a long term investment, which may suit implementation in combination with other options that have shorter term revenue.
- The Energy and Mining application sector has been identified as a feasible and preferred option in combination with other options, primarily due to the existing coal mining industry in the region. The existing Stratford Coal Handling and Preparation Plant (CHPP) has, according to the available information, a nominal water usage of 2,800 ML pa. While surface and groundwater intercepted from mining operations currently meets the water demand for the CHPP, CSG produced water could be used to supply a base percentage of the plant demand if required. CSG water will not require treatment for this purpose.
- Irrigation of urban parks and green areas is also a feasible and preferred option in combination with other options. Around 100 hectares of green areas have been identified within the Gloucester urban area than may benefit from produced water irrigation, including one golf course and a holiday park. Irrigation for grass species in the Gloucester region is expected to require irrigation all year round with variable demand, as demonstrated when comparing nominal grass water demand with local rainfall on a monthly basis. Water storage may be needed to balance the water demand. Produced water may not need desalination (depending on the grass species), although other treatment may be required (e.g. filtration for hydrocarbons removal and disinfection). The use of CSG produced water in urban areas may find regulatory and social impediments and would require specific approval.
- Aquifer Storage and Recovery (ASR) may be potentially feasible when complementing irrigation. Produced water could be re-injected in the shallow rock aquifers (50 to 100 m depth) in the winter months and extraction could then occur in the summer months, to meet peak irrigation demand. Shallow rock aquifers are slightly more saline than the produced water, so no desalination treatment will be needed. Some minor treatment may be required, including disinfection prior to re-injection. The permeability of the shallow rock is highly variable and research (including injection trials) will be needed to identify the areas with high permeability for injection.
- Non intensive livestock farming is feasible but not recommended, as water needs for this
option are usually met by rainfall and additional water supplies do not have a significant impact on productivity, hence added value is low.

- The use of CSG produced water for concrete production was identified as a feasible but not preferred option, due to the degree of treatment required and the low water demand for this application in the region.
- Poultry farming is not a feasible option, due to the degree of treatment needed (including desalination) and the low specific water usage.
- Using CSG produced water for drinking water supply is not a feasible option, due to the expected extensive regulatory controls that would be required, the degree of treatment needed, the existence of a secure water supply in the region and the general community opposition expected to be found.

CONCLUSIONS

The management of co-produced water is important for successful unconventional gas projects. There is an increasing interest and social pressure to find beneficial uses for the little valued by-product to contribute to enhance environmental, social and economic assets. Gas companies could also benefit from trading produced water if there is sufficient market and community support.

The methodology developed in this study for the GGP1 could be applied to other cases for the evaluation of water management options within the unconventional gas industry.

In this case, while none of the singular options was preferred, some option combinations were:
- Irrigation of industrial, pasture and feed crops
- Intensive livestock farming
- Aquaculture of Barramundi and Silver Perch
- Silviculture
- AGL operations and the Stratford Coal Handling and Preparation Plant
- Irrigation of Urban Parks and green areas
- Aquifer Storage and Recovery (ASR) of shallow aquifers (provided targets can be found nearby the project site).

These will require further detailed investigation in future studies to confirm specific parameters, allowing the development of a more tangible water management strategy.

ACKNOWLEDGEMENTS

This paper summarises the water options evaluation study carried out by RPS for the Gloucester Shire Council and available for download at the site:


Special contributors to that report include David Freebairn and Rob Salisbury.

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