Gloucester Gas Project – Extracted Water Management Strategy

Consultation Draft

Date: 21 August 2014

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Document Revision History

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Glossary and Abbreviations

GLOSSARY

Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Aquitard	A low-permeability unit that can store groundwater and also transmit it slowly from one aquifer to another. Aquitards retard but do not prevent the movement of water to or from an adjacent aquifer.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Coal	A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock.
Coal seam	A layer of coal within a sedimentary rock sequence.
Coal seam gas (CSG)	Coal seam gas is a form of natural gas (predominantly methane) that is extracted from coal seams.
Contamination	Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Desalinated Water	Desalinated water is essentially the same as treated water. It is extracted water that has been through all the processes at the water treatment plant and is suitable for a large range of beneficial uses.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Electrical Conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.
Extracted Water	For the purpose of this EWMS, extracted water is the collective term for both flowback water and produced water.
Fracture stimulation	A stimulation technique that increases a gas well's productivity by creating a pathway into the targeted coal seam by injecting sand and fluids through the perforated interval directly into the coal seam under high pressure.
Flowback	The process of allowing fluids to flow from a gas well following a treatment, either in preparation for exploration testing, a subsequent phase of treatment / workover, or in preparation for returning the well to production.
Flowback water	Flowback water is fracture stimulation fluids and deep groundwater pumped to the surface after a fracture stimulation program before water transitions to natural formation water (groundwater), after which fluid flowing from the well is termed produced water.
Fractured rock aquifer	Aquifers that occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary aquifers.
General Solid Waste (GSA)	General solid waste as defined in the NSW DECC Waste Classification Guidelines - July 2009
Groundwater	The water contained in interconnected pores or fractures located below the water table in an unconfined aquifer or located at depth in a confined aquifer or water bearing zone.
Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.

Hydraulic fracturing	A technique that increases the productivity of a gas well by creating a pathway into the targeted coal seam by injecting sand and fluids through the perforated interval directly into the coal seam under high pressure.
MicroSiemens per centimetre (µS/cm)	A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters.
Monitoring bore	A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter.
pH	The potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
Piezometric surface	The potential level to which water will rise above the water level in an aquifer in a bore that penetrates a confined aquifer; if the potential level is higher than the land surface, the bore will overflow and is referred to as artesian.
Produced water	Natural groundwater generated from coal seams during flow testing and production dewatering.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).
Salinity classification	***Fresh water quality –*** water with a salinity <800 µS/cm. ***Marginal water quality –*** water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. ***Brackish quality –*** water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. ***Slightly saline quality –*** water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. ***Moderately saline quality*** – water that is more saline than

brackish water and generally waters between 10,000 and 20,000 µS/cm.

Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm.

Seawater quality – water that is generally around 55,000 µS/cm.

Sandstone — Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).

Sedimentary rock aquifer — These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest volumes of groundwater.

SAR — Sodium Adsorption Ratio is a measure of the suitability of water for use in agricultural irrigation, as determined by the concentrations of certain metals dissolved in the water. It is a ratio of sodium to calcium and magnesium ions, and if the ratio is elevated, water can affect the structure of some soil types.

Source Water — In this report, this term is used to define raw water that is used for fracture stimulation programs. The raw water can be either fresh water or brackish produced water.

Standing water level (SWL) — The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.

Stratigraphy — The depositional order of sedimentary rocks in layers.

Target criteria — The water quality criteria that is being targeted for treated water for a particular reuse or disposal purpose.

Threshold criteria — The water quality criteria (based on established guidelines or site specific data) that is acceptable for different uses or different receptors.

Treated water — Treated water is essentially the same as desalinated water. It is extracted water that has been through all the processes at the water treatment plant and is suitable for a large range of beneficial uses.

Water bearing zone	Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.
Well	Pertaining to a gas exploration well or gas production well.
Working water	Water that has been treated at the WTP and is suitable for return to the field for drilling, fracture stimulation and well workover purposes.

ABBREVIATIONS

AGL	AGL Upstream Infrastructure Investments Pty Ltd
ANZECC	Australian and New Zealand Environmental Conservation Council
ASR	Aquifer Storage and Recovery
AWG	(Gloucester Councils) Agricultural Working Group
BST	Brine storage tank
bbl/d	Barrels per day
CSE	Chief Scientist and Engineer
CSG	Coal seam gas
CPF	Central processing facility
DECCW	Department of Environment Conservation, Climate Change and Water (now EPA) (NSW)
DEHP	Department of Environment and Protection (DEHP) (Qld)
DII	Department of Industry and Investments (now, DPI) (NSW)
DoE	Department of Environment (Cth)
DoPE	Department of Planning and Environment (NSW)
DoPI	Department of Primary Industries (NSW)
DoTI	Department of Trade and Investment (NSW)
DRE	Division of Resources and Energy (NSW)
DWP	Discharge water pond
EA	Environmental Assessment
EPA	Environment Protection Authority
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW)

EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Cth)
EPL	Environment Protection Licence
EWMS	Extracted Water Management Strategy
FSMP	Fracture stimulation management plan
GRL	Gloucester Resources Ltd
GFDA	Gas field development area
GGP	Gloucester Gas Project
GSC	Gloucester Shire Council
GSW	General Solid Waste
ha	Hectares
HCRCMA	Hunter Central Rivers Catchment Management Authority (now HLLS)
HLLS	Hunter Local Land Services
IX	Ion exchange
km	Kilometre
km^2	Square kilometres
m	Metre
mm	Millimetres
MCW	MidCoast Water
mg/L	Milligrams per litre
ML	Megalitre
ML/d	Megalitres per day
ML/yr	Megalitres per year
MMscf	Millions of standard cubic feet

Mscfd	Thousands of standard cubic feet
Mt	Megatonnes
NGSF	Newcastle Gas Storage Facility
NOW	NSW Office of Water
OCSG	Office of Coal Seam Gas (NSW)
OWS	Oily water separator
PAC	Planning Assessment Commission
PEL	Petroleum Exploration Licence
POEO Act	Protection of the Environment Operations Act 1997 (NSW)
PPL	Petroleum Production Lease
PWMP	Produced Water Management Plan
RO	Reverse Osmosis
RWP	Receiving water pond
SAR	Sodium Adsorption Ratio
STP	Stratford to Tomago pipeline
STV	Short term trigger values
t	Tonne
t/d	Tonnes per day
TDS	Total Dissolved Solids
TED	Tiedman East Dam
TND	Tiedman North Dam
TSD	Tiedman South Dam
TSS	Total Suspended Solids
TWP	Treated water pond

UF	Ultra filtration
µS/cm	MicroSiemens per centimetre
WAL	Water Access Licence
WM Act	Water Management Act 2000 (NSW)
WTP	Water treatment plant

Executive Summary

AGL's Extracted Water Management Strategy (EWMS) for the Gloucester Gas Project (GGP) seeks to maximise the reuse of high quality treated water for local beneficial purposes.

The preferred extracted water management strategy provides a flexible and sustainable water management approach that will incorporate available and proven water treatment technologies and appropriate water management practices. If new technologies emerge for the slightly salty extracted water or brine then these can easily be adapted.

AGL received Project Approval 08_0154 for Stage 1 of the Gloucester Gas Project (GGP) from the New South Wales (NSW) Planning Assessment Commission (PAC) under (the now repealed) Part 3A of the *Environmental Planning and Assessment Act 1979* (*EP&A Act*) in February 2011.

The project also received approval (EPBC 2008/4432) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) in February 2013.

Condition 3.12 of the Project Approval requires AGL to develop an EWMS to the satisfaction of the Director-General of the Department of Planning and Environment (DoPE) in consultation with relevant government agencies prior to commencement of the construction of the project.

This document is the EWMS for the Stage 1 Gas Field Development Area (GFDA).

Extracted water is the collective term for both flowback water and produced water. Control, management, monitoring, reuse and/or discharge of these waters and disposal of any associated waste streams are key considerations for Stage 1 of the GGP and important issues for the local community.

The Stage 1 project approval allows for a maximum of 2 megalitres per day (ML/d) of produced water (on average over any 12 month period) to be dewatered, treated and then either irrigated or disposed. The current water balance modelling suggests that the maximum water production rates will be around 1.1 ML/d within the first 30 months and flows will then diminish over the next 30 months to less than 0.2 ML/d.

Infrastructure

The project comprises the following water management infrastructure:

- Stage 1 GFDA, including:
  - 110 coal seam gas wells and associated wellhead infrastructure
  - Existing holding ponds at the Tiedman property
  - Water gathering lines
  - Water distribution lines
- Central Processing Facility (CPF) with associated infrastructure, including:
  - Receiving water pond
  - Pre-treatment system
  - Water treatment plant
  - Water treatment pond
  - Discharge water pond
  - Brine management system
  - Water reuse infrastructure within the CPF

› Associated ancillary infrastructure and works such as:
  » Existing and new irrigation infrastructure
  » River discharge infrastructure
  » Stock watering works

Preferred Strategy

AGL is committed to maximising the reuse of extracted water for local beneficial purposes. Upon careful consideration of all the options, AGL's preferred strategy for extracted water and associated salt is:

› Treatment and desalination of extracted water to produce treated water and brine;
› Reuse of treated water for CPF, drilling, fracture stimulation and workovers (i.e. working water);
› Beneficial reuse of high quality treated water for local irrigation, farming and stock purposes;
› Discharge of treated water (to a fresh/drinking water standard) to streams (when irrigation or stock watering is not possible); and
› Landfilling of the mixed salt from the brine stream.

The engineering components of the preferred strategy at the CPF are:

› Centralised water treatment facility with a variety of treatment plants and process water storages;
› Pre-treatment to condition extracted water for desalination;
› Desalination of extracted water using various technologies but primarily reverse osmosis for working water, beneficial reuse and surface water discharge;
› Brine concentration; and
› Crystallisation of salt.

Infrastructure will be sized and operated to meet the expected water production profile. While the capacity of the WTP will initially be around 2 ML/d there will be excess capacity in place to cater for variable flows. As flowback water volumes diminish and produced water volumes decline, the desalination capacity of WTP will be scaled back to reflect the production profile. This will also mean decreasing irrigation areas, fewer releases to the Avon River, and less crystallised salt waste. Water for general consumption at the CPF and stock usage is expected to be maintained.

Irrigation areas of around 60 ha are planned on local properties. More area may be developed initially to cater for production peaks and for crop rotational purposes, however water volumes and irrigation areas will decline after the first few years. In dry to average seasons most water will be irrigated with minimal discharges to the Avon River.

The desalinated water quality from the final discharge water pond will be low salinity and suitable for a variety of uses. Desalinated waters are expected to be between 100 and 200 mg/L total dissolved solids (TDS). The target water quality for different reuses and stream discharge is expected to be between 150 and 500 mg/L TDS.

The natural salt to be landfilled is expected to peak at 7 t/d at the same time that water production peaks. Over time the salt production will reduce to less than 0.3 t/d with the average for the whole field development being around 1.1 t/d.

New market opportunities for water and mixed salt will be further investigated, depending on 'Expressions of Interest' received for the available water and salt over the next 12-18 months. Potential users should be aware of the highly variable water production profile and the fact that water availability is not guaranteed.

Consultation Strategy

The proposed consultation strategy involves:

- Publishing and exhibiting the Consultation Draft of the EWMS on AGL's website.
- Holding workshops with Council, regulators and other government agencies.
- Organising community information sessions for the general public.
- Being available (via mail, phone or drop in to the local office) to answer any queries during the development of the EWMS.
- Finalising the EWMS and submitting it to the NSW and Commonwealth Government for their assessment/approval.
- Publishing the draft and final EWMS at various milestones.

AGL is seeking comment on the EWMS from regulators and the broader community throughout August and September 2014. Written submissions must be received by AGL by the 19 September.

Submissions on this Consultation Draft of the EWMS can be sent to either of the following addresses:

Postal address:

AGL Upstream Investments Pty Ltd
Submission – Gloucester Gas Project EWMS
Locked Bag 1837
St Leonards NSW 2065

OR

Email address:

gloucester@agl.com.au

1. Introduction

1.1. Background

AGL Upstream Infrastructure Investments Pty Ltd (AGL) received Project Approval 08_0154 for Stage 1 of the Gloucester Gas Project (GGP) from the New South Wales (NSW) Planning Assessment Commission (PAC) under (the now repealed) Part 3A of the *Environmental Planning and Assessment Act 1979* (*EP&A Act*) in February 2011. The approval was upheld after a challenge in the Land and Environment Court.

The project also received approval (EPBC 2008/4432) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) in February 2013.

The GGP includes the Stage 1 gas field development area (GFDA) comprising 110 gas wells. To allow gas to flow from these wells, deep groundwater will be extracted with the gas (referred to as produced water). To extract gas safely and efficiently, wells may be fracture stimulated and depressurised. Water produced from fracture stimulation is called flowback water. The term 'extracted water' refers predominantly to produced water but also includes flowback water when wells are first fracture stimulated.

Condition 3.12 of the Project Approval requires AGL to develop an Extracted Water Management Strategy (EWMS) to the satisfaction of the Director-General (now secretary) of the Department of Planning and Environment (DoPE) in consultation with relevant government agencies prior to commencement of the construction of the project. This document complies with condition 3.12. It also summarises the background studies and regulatory framework that apply to extracted water management for the GGP, and describes the preferred process for extracted water management for the Stage 1 GFDA.

1.2. Overview of the GGP

The GGP will provide AGL with an additional supply of gas for distribution to commercial, industrial and residential customers within NSW, thereby reducing the requirement for gas to be imported from other states.

For Stage 1 of the GGP, activities will be undertaken and infrastructure will be constructed to produce up to 80 TJ/day of gas into the NSW gas supply network via AGL's Newcastle Gas Storage Facility (NGSF). These activities and infrastructure are:

- Stage 1 GFDA:
    - Upgrade of existing roads and tracks and construction of new internal access roads. AGL will consult with land owners in relation to access to properties required for the upgrade of existing road and formation of new roads.
    - Preparation and construction of well site locations, including establishment of a construction hardstand working area.
    - Drilling of wells, geophysical logging, cementing and casing.
    - Well completion, including but not limited to perforating of the well casing at the production zone and fracture stimulation as required.
    - Production, including the installation of surface infrastructure at the wellhead.
    - Installation of buried gas and water gathering systems.

- » Pumping and treatment of produced water.
- » Rehabilitation of each gas well site to a minimised surface area for gas production and ongoing operations.

› Central Processing Facility (CPF): The CPF will include construction and subsequent operation of gas compression, water treatment facilities and water storage. The CPF will be located at the southern end of the Stage 1 GFDA south of Stratford near the junction of Bucketts Way and Parkers Road.

› Stratford to Tomago Pipeline (STP): A 100 km high pressure gas pipeline will be constructed and operated to transfer gas south from the CPF near Stratford to Tomago (10 km NW of Newcastle). The pipeline will connect to a transfer point at the NGSF and then to the existing NSW gas distribution network at Hexham via an existing 5.5 km pipeline.

In relation to the water infrastructure and management, the approval includes the construction and operation of:

› a water gathering system and associated infrastructure within the Stage 1 GFDA;

› a water treatment plant within the CPF for desalination of extracted water;

› an oily water separator within the CPF for removal of oil-in-water emulsions from the process water generated by the compression process;

› three new storage ponds, each of up to 25 ML capacity located within the CPF to store extracted water, treated water, and final discharge water; and

› associated infrastructure.

The approvals under the EP&A Act comprise the Concept Plan Approval (PAC, 2011a) and the Project Approval (PAC, 2011b) for Stage 1 of the GFDA. The Concept Plan Approval allows for the extraction of coal seam gas (CSG) as a staged development within the approved concept area in the Gloucester Basin. The Project Approval allows for gas to be extracted from 110 wells and associated infrastructure in the Stage 1 GFDA which is located to the north-east and south-east of Stratford.

The Concept Plan Approval and Project Approval were modified in [*month*] 2014 to allow minor realignments to STP corridor and to allow the connection of the pipeline to the NGSF at Tomago rather than the Hexham gas delivery station.

The Concept Plan Area, including associated GGP infrastructure covers approximately 210 km^2. The Project Approval area for the Stage 1 GFDA is approximately 50 km^2. The extent of the GGP is defined by the boundary identified as PEL 285 shown in **Figure 1.1**.

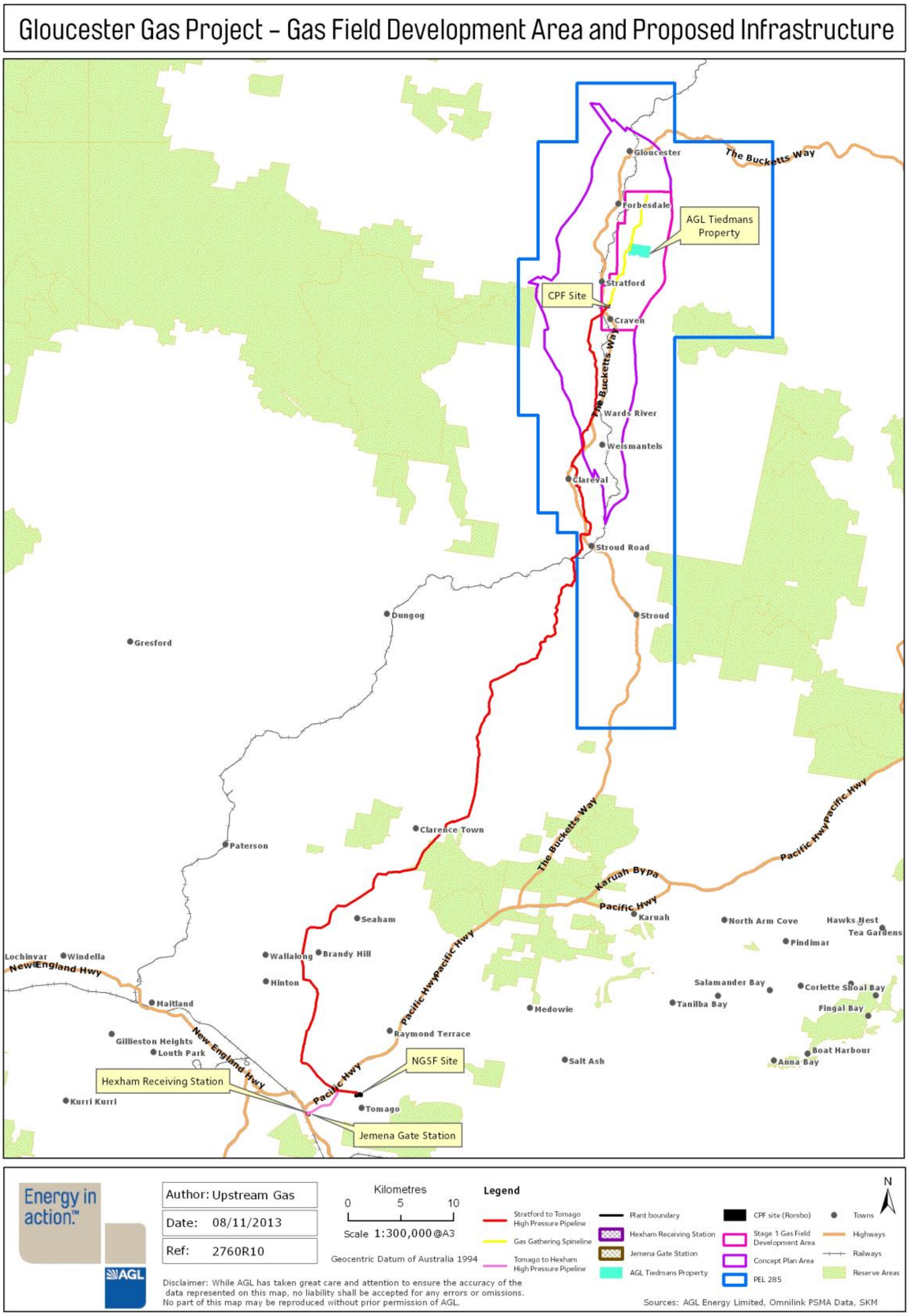


Figure 1.1: Gas Field Development Area and Proposed Infrastructure

1.3. Purpose

The objectives of this EWMS are to:

- provide a framework for the reuse of extracted water for the GGP;
- summarise background studies and the regulatory framework that are applicable to GGP extracted water management;
- document the stakeholder consultation undertaken for the development of the EWMS;
- describe and evaluate options that are available for GGP extracted water treatment (reuse and disposal);
- provide information on the estimated quality and quantity of GGP extracted water;
- describe AGL's preferred option for extracted water treatment including:
  - existing and proposed water management infrastructure;
  - treated water quality targets;
  - the irrigation of treated water;
  - the discharge of treated water by stream discharge (if required); and
  - waste, brine and salt management;
- describe the proposed monitoring program that is required to support the EWMS to protect the environment;
- outline contingency management practices including as analysis of potential impacts to groundwater, surface waters, and associated groundwater dependent ecosystems;
- inform the requirements of any PWMP; and
- meet the requirements of the Part 3A Condition 3.12: Extracted Water Management.

1.4. Consultation

The management of extracted water is critical to the gas development program, and it presents opportunities and challenges for long term social outcomes and protection of water and the environment. Consequently, the interests of a wide range of stakeholders have been recognised in the development of the EWMS.

The EWMS provides a clear description for the community, regulators and other stakeholders of how AGL proposes to manage extracted water for Stage 1 of the GGP. The EWMS has been developed in consultation with DoPE, OCSG, NOW, EPA, Hunter Local Land Services, MidCoast Water, Gloucester Council, and the community. Stakeholder and community feedback will be taken into account as part of the EWMS consultation process.

The EWMS is based on a sustainable approach to development and has been guided by the following principles:

- minimising adverse environmental impacts and enhancing environmental benefits associated with the activities, products or services;
- conserving, protecting, and enhancing, where the opportunity exists, the availability of water resources in the operational areas;
- engaging regularly, openly and transparently with people and communities affected by the activities, considering their views in the decision-making process;

- working cooperatively with communities, governments and other stakeholders to achieve positive economic, social and environmental outcomes, and seeking partnership approaches where appropriate;
- protecting public and animal health, identifying and managing aspects of public concern, and being cognisant of community issues in relation to outputs to the environment; and
- identifying, assessing, managing, monitoring and reviewing risks to the property, the environment and the communities within the project area.

The EWMS may evolve over the life of the Stage 1 GFDA of the GGP as:

- modifications to planning approvals are sought;
- technological advances are developed in water treatment and brine management;
- new reuse opportunities are identified; and
- regulations and industry standards change.

2. Regulatory Framework

2.1. Background

AGL received Concept Plan approval for the GGP from the PAC under the former Part 3A of the EP&A Act in February 2011. The Project Approval for Stage 1 of the GGP was issued at the same time (Application 08_154). The project also received approval under the Commonwealth EPBC Act in February 2013 (EPBC 2008/4432).

The Project Approval and EPBC Approval apply to the following water management infrastructure:

- Stage 1 GFDA, including:
  - 110 coal seam gas wells and associated wellhead infrastructure;
  - existing holding ponds at the Tiedman property; and
  - water gathering lines;
  - water distribution lines;
- CPF with associated infrastructure, including:
  - receiving water pond;
  - pre-treatment system;
  - water treatment plant;
  - water treatment pond;
  - discharge water pond;
  - brine management system; and
  - water reuse infrastructure within the CPF;
- Associated ancillary infrastructure and works such as:
  - existing and new irrigation infrastructure;
  - river discharge infrastructure
  - stock watering works.

2.2. Legislative Requirements

The EWMS has taken into consideration the requirements of existing project approvals and legislation, and the potential for additional approvals. A summary of the NSW and Commonwealth legislation relevant to extracted water management at the GGP is provided in **Table 2.1.**

Table 2.1 Regulatory Framework for Management of Extracted Water

ACTIVITY	APPROVAL AND LEGISLATION	RESPONSIBLE AUTHORITY
Design, construction, operation and monitoring of storage ponds for flowback water, produced water, treated water and the brine water (concentrated brine stream)	Project Approval EPBC Approval	DoPE DoE
Petroleum licence to produce CSG and therefore generate extracted water as a by-products	Exploration - PEL 285 issued under the *Petroleum Onshore Act 1991* Operation - PPLs issued under the *Petroleum Onshore Act 1991* Given approval has been granted under Part 3A of the EP&A Act, a PPL cannot be refused and must be generally consistent with the Part 3A approval	OCSG within DoTI
Dewatering and the pumping of groundwater to surface (where it becomes produced water) and reuse for beneficial uses (such as industrial and irrigation)	Operation – Part V bore licences issued under the *Water Act 1912* Given approval has been granted under Part 3A of the *EP&A Act*, a bore licence cannot be refused and must be generally consistent with the Part 3A approval	NOW
Reuse or discharge of extracted water (for reuse or disposal)	Non-scheduled activity requiring an EPL issued under the *POEO Act*. Given approval has been granted under Part 3A of the *EP&A Act*, an EPL cannot be refused and must be generally consistent with the Part 3A approval	EPA
Transport of salt products (for reuse or disposal)	Tracked in accordance with the *Protection of the Environment Operations (Waste) Regulation 2005*	EPA
Supply of untreated or treated water to a third party	*Water Management Act 2000 (WM Act)*	NOW

Environment Protection Licence

Under the provisions of the POEO Act, EPA issued Environment Protection Licence (EPL) 20358 for certain scheduled activities within the Petroleum Exploration Licence (PEL) 285. AGL must not allow (through act or omission) the pollution of land, water or air in managing the extracted water for the project. In accordance with Clause 9A of Schedule 1 of the POEO Act, the relevant scheduled activity is "*Coal seam gas exploration, assessment and production*".

As the project has been approved under Part 3A of the EP&A Act, an EPL cannot be refused as it is necessary for carrying out the Stage 1 GGP and must be substantially consistent with the Project Approval.

Water Management Act 2000

Under the provisions of the *Water Management Act 2000*, approvals are required to carry out certain activities within and near waterways and for the use of water. However, given the project has been approved under Part 3A of the EP&A Act, a water use approval under Section 89, a water management work approval under Section 90, or an activity approval under Section 91 of the

Water Management Act 2000 are not required for the project, including for extracted water management. However, Water Access Licences (WALs) are required where the water take from water sources under the respective Water Sharing Plans (WSPs) exceeds 3 megalitres (ML) per year. At the present time only surface water sources are covered by WSPs. AGL currently has valid water licences under the WSP which would be used as the basis for extracting water for construction activities.

AGL currently holds 11 bore licences under the *Water Act 1912* for the extraction of deep groundwater from the sedimentary rocks. These existing licences will be replaced by new licences for the gas wells proposed for the Stage 1 GFDA. These applications are in the process of being lodged and will allow up to 730 ML per year to be extracted for the GGP. As the licences allow for the construction of the gas wells and the take of water for industrial, stock and irrigation purposes, these licences will be sufficient to authorise the take and reuse/discharge of produced water. It is expected that conditions reflecting the requirements of the Aquifer Interference Policy will be applied to each of these licences.

Protection of the Environment Operations (Waste) Regulation 2005

Brine, crystallised salt, or solids resulting from the treatment of flowback water or produced water would be required to be classified in accordance with the NSW Waste Classification Guidelines (DECCW 2008) and disposed of at an appropriately licensed facility. Salt is generally considered to be a General Solid Waste (Commercial and Industrial) and is accepted at licensed solid waste landfills in NSW.

Under the provisions of the Protection of the Environment Operations (Waste) Regulation 2005, the transport (for reuse or disposal) of "*non toxic salts*", such as the salt products resulting from the treatment of produced water, is required to be tracked.

Policies, Guidelines and Codes of Practice

The NSW Government has published a number of CSG policies and Codes of Practice. These documents require consideration in identifying management options for CSG by-products, including extracted water and treated water. Consideration of the objectives and strategies set out in the Queensland Government Coal Seam Gas Water Management Policy have also provided a framework for the development of water management initiatives for this project.

Water quality guidelines will also be taken into consideration to identify the appropriate level of treatment for the intended end use. Relevant policies, codes and guidelines are listed in **Table 2.2.**

Table 2.2 Policies, procedures and guidelines for management of Extracted Water

PLANS POLICIES AND CODES OF PRACTICE	YEAR	AUTHOR	RELEVANCE
NSW State Groundwater Policy and its various component policies	August 1997	DLWC now NOW	Protection of water resources (groundwater quantity and water quality) and groundwater dependent ecosystems
ANZECC Guidelines for Fresh and Marine Water Quality	October 2000	ANZECC	Water quality criteria for different beneficial uses and for the protection of aquatic ecosystems
Waste Classification Guidelines	December 2009	DECCW now EPA	Disposal and transport of liquid and solid wastes
Code of Practice for Coal Seam Gas - Fracture Stimulation	September 2012	DoTI	Fracture stimulation activities
Code of Practice for Coal Seam Gas - Well Integrity	September 2012	DoTI	Well design, drilling, completion, workover and abandonment activities
NSW Aquifer Interference Policy	September 2012	NOW	Management and protection of groundwater systems where that activity is an interference activity rather than a consumptive use activity
Coal Seam Gas Water Management Policy	December 2012	DEHP	CSG water management framework in QLD

2.3. Environmental Approvals

An Environmental Assessment (EA) (*AECOM, 2009*) was submitted to the then NSW Department of Planning and Infrastructure in November 2009 to seek approval for the GGP and Stage 1 GGP under Part 3A of the EP&A Act. In May 2010, following public exhibition of the EA, a Submissions Report was prepared for the project (*AECOM, 2010*).

Concept plan and project approvals were granted in February 2011 (Application 08_154).

2.3.1. Part 3A Project Approval Conditions

Condition 3.12 of the Part 3A Project Approval requires that, prior to commencement of construction of the project, AGL must develop an EWMS to the satisfaction of the Director-General. The EWMS is required to be developed in consultation with the OCSG within DoTI (formerly DII), NOW, HLLS (formerly HCRCMA), EPA, (formerly part of DECCW) and relevant Councils.

Condition 3.13 provides that AGL must ensure that any water storage ponds development at the CPF or the Tiedman site are appropriately lined.

This EWMS has been prepared to satisfy the requirements of Conditions 3.12 and 3.13. **Table 2.3** lists the components of Conditions 3.12 and 3.13 and where these components are addressed in the EWMS.

Table 2.3 Condition 3.12 and 3.13 Requirements and the EWMS

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
Condition 3.12 Introductory Paragraph Unless otherwise agreed to by the Director-General, prior to the commencement of construction of the project, the Proponent shall develop an Extracted Water Management Strategy in consultation with DII, NOW, HCRCMA, DECCW and relevant Councils and to the satisfaction of the Director-General.	The process and outcomes of consultation with the relevant agencies and Councils are provided in Section 7, and throughout the EWMS.
Condition 3.12 a) Identifies the final suite of water disposal and re-use option(s) that would be implemented to manage groundwater extracted from the gas production wells.	The key components of the water discharge and reuse options that would be implemented for extracted water management are: • treatment of extracted water at the WTP which includes reverse osmosis for desalination of produced water; • water reuse for hydraulic fracture operations; • water reuse for non-potable uses at the CPF; • water reuse for stock purposes; • treated water irrigation at properties in the local area (including AGL properties); • discharge of treated water to the Avon River via Dog Trap Creek, a tributary of the Avon River; and • salt products disposed to licensed landfill as a general solid waste. Details of these components are provided in Sections 5, 8, 9, 11, 12 and 13.
Condition 3.12 b) Identifies the water quality required to achieve the disposal / re-use option(s) identified in a) above, including the procedure for monitoring of treated water to ensure that required water quality criteria are achieved.	Water quality thresholds are provided in Section 2.4. Treated water quality targets are provided in Section 10. Treated water monitoring requirements are provided in Section 14.

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
Condition 3.12 c) If discharge to surface waters is proposed identifies details of all practical measures investigated to prevent, control, abate or mitigate that discharge; details of the receiving environment including water quality and flow conditions; proposed discharge rate and frequency; and details of all practical measures investigated to protect the environment from harm as a result of that discharge including demonstration that any discharge would satisfy the requirements of condition 3.1.	The EWMS identifies reuse as the preferred option for treated water; however if required, treated water will be discharged to surface water (i.e. the Avon River via Dog Trap Creek, a tributary of the Avon River). The following information regarding the discharge of treated water to surface water is provided: • prevention, control, abatement and/or mitigation measures for treated water discharged to surface water (Section 12); • details of the receiving environment including water quality and flow conditions (Section 12.2); • proposed discharge rate and frequency (Section 12.3 and 12.4); and • practical measures to protect the environment from harm as a result of discharge to surface water (Sections 10.4 and 14.4).
Condition 3.12 d) If re-use for irrigation is proposed -- demonstrates that there is demand for the volumes of water to be generated, details of all practical measures investigated to protect the environment from harm including details of optimal application rates to prevent over irrigation and associated salinity issues or groundwater contamination, and demonstration that any discharge would satisfy the requirements of condition 3.1.	The EWMS identifies reuse as the preferred option for treated water. The reuse of treated water for stock and irrigation is proposed. The following information regarding the reuse of treated water for irrigation is provided: • demand for the volumes of water to be generated (Section 11.1, 11.4, 11.5); • practical measures to protect the environment from harm (including details of optimal application rates to prevent over irrigation and associated salinity issues or groundwater contamination) (Section 11.3, 11.4, 11.5); and • practical measures to protect the environment from harm as a result of irrigation of treated water (Sections 10.3, 11.5, 14.3 and 14.4).

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
Condition 3.12 e) If extracted water is proposed to be made available to the market demonstrates that suitable buyers of the water have been secured and where the water is proposed to supplement drinking water supplies, demonstration that the water quality is suitable for drinking water supplies;	There are no contracts in place to supply water to third parties at this time, although a Memorandum of Understanding (MoU) has been signed with Dairy Connect to explore opportunities in the future. It is expected that treated water will be available for community use. Prior to further consideration of the supply of treated water to the market, AGL will undertake a thorough investigation (which will include development of an Expression of Interest with interested parties, identification of regulatory requirements, assessment of proposed water use quality and quantity criteria and management and monitoring controls). This investigation is expected to have a long lead time (over 12 months) to enable consultation and information gathering and sharing.
Condition 3.12 f) Identifies the final option for the management of the salt volumes produced from the extracted water treatment process.	The EWMS proposes that salt (brine) produced following the treatment of produced water will be further concentrated to create a mixed salt suitable for disposal offsite by road transport to a licensed landfill. The description of brine treatment and salt volumes is provided in Section 13.
Condition 3.12 g) Includes a contingency strategy for the management of extracted water should the volumetric rate of groundwater extraction be greater than two mega litres per day (consistent with the requirements of condition 3.11), including analysis of associated risks to groundwater users and/ or surface waters and groundwater dependent ecosystems.	A description of the contingency plan for the management of greater than 2 ML/d extracted water is provided in Section 9.8.
Condition 3.12 h) Provides an assessment of the need for control measures to be implemented at the extracted water and brine evaporation ponds to minimise wildlife (including bird) access to these ponds, with consideration to the water quality and associated risks to wildlife likely to be posed by these storage ponds.	The EWMS proposes that ponds will be fenced with a 2 m high chain linked fence with 250 mm of the bottom fence buried to prevent animals digging below the fence for access. Control measures for wildlife are provided in Section 9.9. No brine evaporation ponds are proposed. Brine will be contained in a dual-lined storage tank with a nominal capacity of 2 ML.

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
Condition 3.12 i) Provide for the development of site specific water quality criteria in accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC Guidelines, 2000), as necessary, in consultation with DECCW, for the purposes of conditions b), c), d) and e) above.	Water quality targets for each proposed end use of treated water are provided in Section 10.
Condition 3.13 The Proponent shall ensure that any water storage ponds developed at the CPF or on the Tiedman property as part of the project (including extracted water, treated water and brine evaporation ponds) are appropriately lined to ensure no leaching of stored waters and designed consistent with a 1 in 100 year flood design standard.	No brine evaporation ponds are proposed. New ponds for the GGP containing water will be double lined (i.e. dual layers) using high density polyethylene (HDPE) for leak detection and capture purposes. The ponds will be designed consistent with a 1 in 100 year flood design standard. There is also an existing double lined pond for storing extracted water at Tiedmans. The existing single lined ponds at the Tiedman property will only be used to store treated water prior to irrigation. Details of existing and proposed water storage ponds are provided in Sections 8.1 and 9.2.

2.3.2. EPBC Approval Conditions

This EWMS has been prepared to satisfy the requirements of Conditions 21, 22 and 23 of the EPBC approval (EPBC 2008/4432) for Stage 1 GGP. **Table 2.4** lists the wording of Conditions 21, 22, and 23 and where these components are addressed in the EWMS.

Table 2.4 Condition 21, 22 and 23 Requirements and the EWMS

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
Condition 21 The person taking the action must provide the department with a copy of the extracted water management strategy (also known as produced water management strategy) required under state approval conditions. If the strategy is not to the satisfaction of the Minister (and in particular if it does not consider the feasibility and likely effectiveness of reinjection of extracted water), he may require a supplement to be developed, which must be approved by the Minister prior to commencement of the action, and must be implemented	In accordance with the requirement of Condition 21 the EWMS has included a review of the feasibility and likely effectiveness of reinjection of extracted water (refer to Section 9.7 of this report entitled *Aquifer Storage and Recovery*) which concluded that reinjection of produced water is not considered to be appropriate for the Gloucester Basin and the GGP. Details are provided in Section 9.7.
Condition 22 The person taking the action must ensure that no more than 2 megalitres per day (averaged over a twelve month period) of groundwater is extracted. In addition, the person taking the action may only extract sufficient groundwater as is required to undertake the action in accordance with these conditions.	Various sections with additional details provided in Section 9.8.
Condition 23 The person taking the action must ensure that any water storage ponds associated with the action are appropriately lined to ensure no leaching of stored waters and designed consistent with a 1 in 100 year flood design standard.	Section 9.2 confirms this requirement.

2.4. Other Environmental Considerations

2.4.1. Water Quality Thresholds for Irrigation

Irrigation of extracted water has the potential to impact soils and adjacent (and underlying) water resources if not appropriately managed. Extracted water has a higher salt content than fresh water, which may not be able to be accommodated by the plants, the soils or the water resources.

AGL is mid-way through a two-year irrigation program on its Tiedmans property using stored produced water from its exploration activities blended with freshwater sources accessible under AGL's water access licences. The blended water is compliant with ANZECC irrigation guidelines (except for minor pH, iron and phosphorus exceedance).

Monitoring of the irrigation program for the produced water from historical exploration programs has indicated that marginal to brackish irrigation water can be irrigated reasonably successfully in this high rainfall landscape. In the relatively short irrigation program period from April 2013 to June 2014, approximately 85 ML of blended water (with a salinity of around 1,500 µS/cm) was irrigated across 16 ha with the following results:

- there were no salinity impacts to the Avon River and the underlying groundwater system;
- treated soils were effective in minimising the SAR hazard;
- salt tolerant crops grew effectively;
- there was some salt exported in crops; and
- there was some slight build-up of salt in the soil profile, but the loading was small.

The ANZECC guidelines (2000) for irrigation use have been adopted for the GGP as the threshold values for treated water that is to be irrigated (i.e. the adopted water quality criteria that should not be exceeded). The target values that AGL plans to adopt for irrigation water will be much less than these threshold values (these are discussed further in Section 10.3). The key parameters summarised in **Table 2.5** show the threshold values for irrigation. The adopted values for metals are the short term trigger values (STV) which are defined as the maximum concentration in the irrigation water which can be tolerated for relatively short periods of time (20 years) assuming the same maximum annual irrigation loading to soil as assumed for long term trigger values.

Table 2.5 Threshold values for irrigation water

Parameter	Unit	Irrigation Guideline Value[(1)]
pH (range)	pH units	6.0 – 9.0
EC (salinity)	µS/cm	1,000-3,000[(2)]
Sodium	mg/L	230-460[(3)]
Chloride	mg/L	350-700[(4)]
Boron	mg/L	2.0-6.0[(5)]
Iron	mg/L	10.0
Manganese	mg/L	10.0
Total Phosphorus	mg/L	0.8-12[(6)]
Fluoride	mg/L	2.0
Aluminium	mg/L	20
Arsenic	mg/L	2
Beryllium	mg/L	0.5
Cadmium	mg/L	0.05
Chromium (VI)	mg/L	1.0
Cobalt	mg/L	0.1

Parameter	Unit	Irrigation Guideline Value[(1)]
Copper	mg/L	5.0
Lead	mg/L	5.0
Mercury	mg/L	0.002
Molybdenum	mg/L	0.05
Nickel	mg/L	2.0
Selenium	mg/L	0.05
Uranium	mg/L	0.1
Vanadium	mg/L	0.5
Zinc	mg/L	5.0

(1) ANZECC 2000 Water Quality Guidelines: Water quality for irrigation waters and general use, short-term threshold values.
(2) Plant specific but this is the general range for improved pastures and likely crop types.
(3) For moderately tolerant crops – sodium range
(4) For moderately tolerant crops – chloride range
(5) For moderately tolerant to tolerant crops – boron range
(6) Requires site specific assessment

2.4.2. Water Quality Thresholds for Surface Water Discharge

The water quality of surface waters in the Avon River catchment is highly variable and is reflective of the soils and underlying geology. It is a disturbed catchment and is generally referred to as a saline catchment because of sodic and saline soils that are derived from the underling rocks that were deposited in estuarine and shallow marine environments (DIPNR, 2004).

It is known that the catchment flows become more saline as stream flows diminish and groundwater base-flow becomes a more dominant part of the surface water regime. High salinity outflows are also evident in stream water quality immediately after high rainfall events.

AGL proposes to develop site specific guideline values based on actual water quality data collected, as these are considered to more appropriately reflect local conditions than the ANZECC freshwater ecosystem criteria. However there is insufficient available data to develop these site specific values at this time.

The ANZECC (2000) guidelines for the protection of freshwater ecosystems have been adopted as the thresholds for the EWMS at this time. The 95% trigger values for the protection of ecosystems are considered the most appropriate for the Avon River catchment, although there are some degraded tributaries where the 80% trigger values may be more appropriate. The ANZECC (2000) criteria are provided in **Table 2.6**.

Table 2.6 ANZECC (2000) Criteria for Discharge to Surface Waters

Analyte	Units	ANZECC 2000 guidelines 95% protection (1)	ANZECC 2000 guidelines 80% protection (3)
pH	pH units	6.5 - 8.0(2)	
EC	µS/cm	125 - 2200(2)	
Dissolved Oxygen	%	85 - 110(2)	
Turbidity	NTU	6 - 50(2)	
Major ions			
Suspended Solids	mg/L	-	-
Total Hardness as $CaCO_3$	mg/L	-	-
Silica	mg/L	-	-
Fluoride	mg/L	-	-
Sulphur	mg/L	-	-
Sulphate as SO_4^-	mg/L	-	-
Chloride	mg/L	-	-
Hydroxide Alkalinity as $CaCO_3$	mg/L	-	-
Carbonate Alkalinity as $CaCO_3$	mg/L	-	-
Bicarbonate Alkalinity as $CaCO_3$	mg/L	-	-
Total Alkalinity as $CaCO_3$	mg/L	-	-
Calcium	mg/L	-	-
Magnesium	mg/L	-	-
Sodium	mg/L	-	-
Potassium	mg/L	-	-
Dissolved metals			
Aluminium	mg/L	0.055	0.150
Arsenic (As V)	mg/L	0.013	0.140
Barium	mg/L	-	-
Beryllium	mg/L	ID	ID
Boron	mg/L	0.37	1.30
Bromine	mg/L	-	-
Cadmium	mg/L	**0.0005**	**0.0022**

Analyte	Units	ANZECC 2000 guidelines 95% protection (1)	ANZECC 2000 guidelines 80% protection (3)
Cobalt	mg/L	ID	ID
Chromium (Cr VI)	mg/L	**0.0025**	**0.1**
Copper	mg/L	**0.0035**	**0.0063**
Iron	mg/L	ID	ID
Manganese	mg/L	1.9	3.6
Molybdenum	mg/L	ID	ID
Nickel	mg/L	**0.0275**	**0.0425**
Lead	mg/L	**0.0136**	**0.0376**
Selenium	mg/L	0.011 (total)	0.034 (total)
Strontium	mg/L	-	-
Vanadium	mg/L	ID	ID
Zinc	mg/L	**0.02**	**0.0775**
Mercury	mg/L	0.0006	0.0054
Uranium	mg/L	ID	ID

(1) ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystem.

(2) ANZECC 2000 - Water Quality Guidelines: default trigger values for the protection of freshwater aquatic ecosystems, South-East Australia, low lying river ecosystems.

(3) ANZECC 2000 - Water Quality Guidelines: 80% protection levels (trigger values) for the protection of freshwater aquatic ecosystem.

(4 ID – insufficient data to determine guideline.

(5) **Bold** values have been corrected for moderate water hardness (based on ANZECC 2000 Table 3.4.4).

3. Background Studies

3.1. AGL Irrigation Program Studies

As part of its current exploration program, AGL has been irrigating produced water from pilot testing programs ahead of the commencement of the GGP. The approved program is to irrigate a maximum of 70 ML of produced water over a maximum area of 40 ha. The water from exploration programs, which was stored in the Tiedman and Stratford dams, was blended with water from freshwater sources to ensure the water quality for irrigation use was suitable.

A surface water and groundwater monitoring program commenced in October 2011 and was established in accordance with the approved Tiedman Water Management Plan (AGL 2012). The monitoring aims to ensure that the quality of the water used for irrigation meets the ANZECC irrigation criteria and that the application of irrigated water does not result in impacts on the local surface water or groundwater resources. Water level and water quality data are evaluated for each monitoring period. There are also soil baseline and periodic sampling reports for the irrigation area.

Irrigation has been occurring across two areas on the Tiedman property; the Stage 1A area – 12 ha and the Stage 1B area – 4 ha. The irrigation areas are shown on **Figure 3.1**.

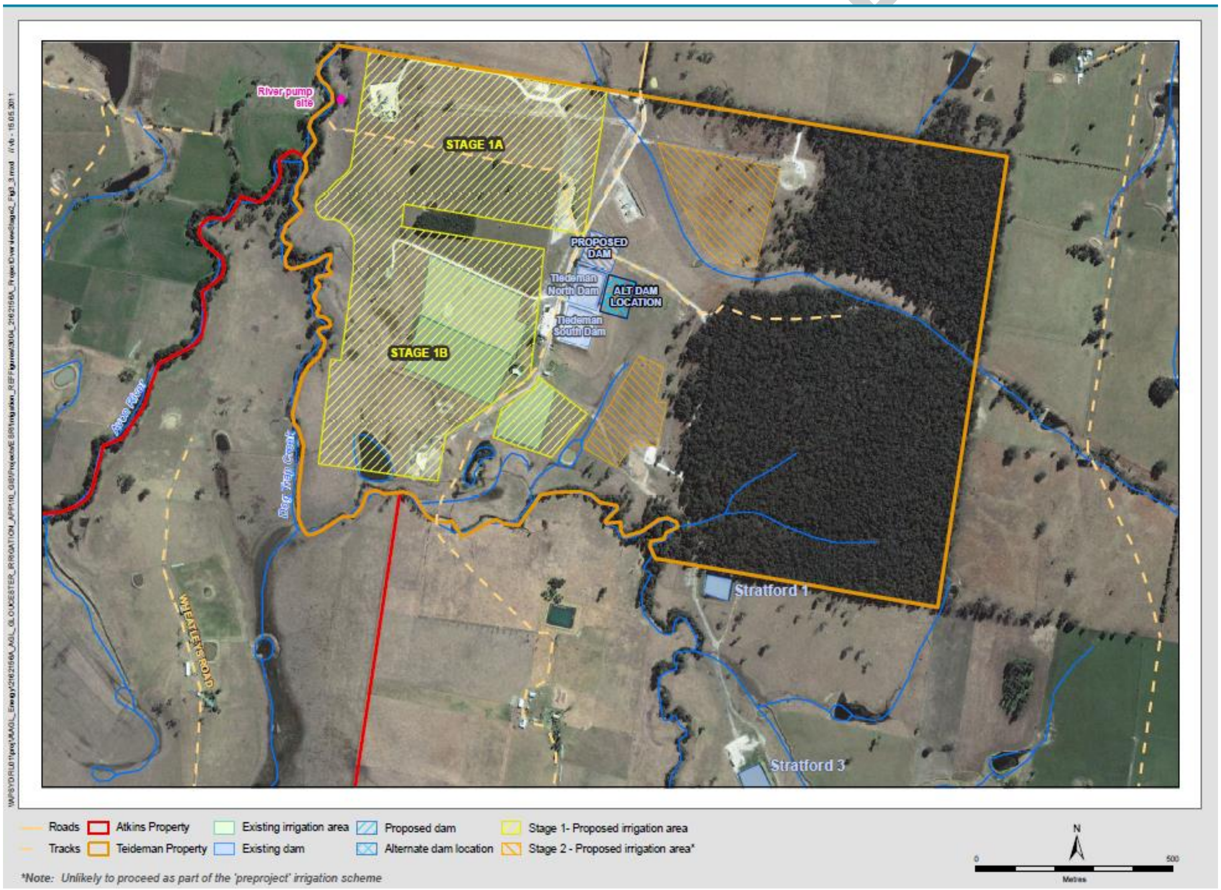


Figure 3.1: Current Tiedman Irrigation Areas

A series of three six-monthly reports have been prepared as part of an approval requirement of the DoTI. The first compliance report (PB 2013c) covered the baseline and the initial irrigation period to 30 June 2013. The second compliance report covered the period 1 July 2013 to 31 December 2013 (PB, 2014a). The third baseline report covered the period 1 January 2014 to 4 July 2014 (PB, 2014d).

The findings of the recent water compliance reports was that monitoring during the 12 month period to 4 July 2014 showed that there was no change in stream levels, alluvial or shallow fractured rock groundwater levels attributable to the irrigation program activities. Similarly there was no change in the water quality characteristics of the adjacent Avon River and underlying groundwater systems. Salt tolerant crops have been successfully grown with no impacts to surface water or groundwater, and only a minimal increase in salt levels to soils.

These studies have confirmed that deficient irrigation with appropriate monitoring is a suitable reuse approach for produced water.

3.2. AGL Water Monitoring Network and Program

AGL implemented an extensive surface water and groundwater monitoring program in 2011. For this program, a comprehensive groundwater network comprising nested monitoring bores was established. Subsequent and ongoing site investigations have continued to expand this network. The current water monitoring network is 45 groundwater and nine surface water monitoring sites. Two annual monitoring reports (for years 2012 and 2013) have been prepared which provide a review of the groundwater monitoring data for the period January 2011 to June 2013, representing 30 months of baseline data, but focusing on the last monitoring period (July 2012 to June 2013). The next annual status report for 2013/14 is due out in September 2014. These reports are available on AGL's project website.

The 2013 Annual Status report highlighted that groundwater level trends in the monitoring bores vary depending on the lithology and depth of the screened interval. This report provided the following observations:

› Alluvial aquifer water quality is fresh to slightly saline, has slightly acidic to neutral pH and reducing conditions exist. The major ion chemistry is sodium-chloride dominant.

› Groundwater in the shallow rock unit is marginal to slightly saline, has neutral to alkaline pH conditions. The major ion chemistry is sodium-chloride-bicarbonate dominant.

› Groundwater quality of the interburden is brackish. The major ion chemistry is sodium-chloride dominant.

› Groundwater salinity in the coal seams is typically brackish to slightly saline, with neutral to alkaline pH. The major ion chemistry is generally sodium-chloride-bicarbonate dominant.

This comprehensive monitoring program is continuing at the dedicated groundwater sites in accordance with the existing program. Results are published periodically on AGL's website.

Some of these monitoring locations will be key site locations for where AGL is undertaking irrigation reuse or controlled stream discharge.

3.3. AGL Flow Testing Programs

There have been few flow testing programs in recent years to fully characterise the deep groundwater (produced) water quality across the Gloucester Basin. The best available water quality information is from recently completed testing programs on Waukivory 03 and Craven 06 (PB, 2014c). The water quality from Craven 06 is slightly saline, is sodium-chloride-bicarbonate dominant, is low in trace metals and has few other analytes. This water quality has been used extensively in this EWMS as being typical of expected water qualities throughout the Stage 1 GFDA. However a more conservative water quality range will be used for the purpose of desalination plant design.

The proposed Waukivory fracture stimulation and flow testing will also provide additional information on water production profiles and water quality.

3.4. AGL Hydrology Study

A hydrology study of the Avon River catchment (and downstream areas) was completed in 2014 (PB, 2014b). The purpose of this study was to characterise surface water features across the Gloucester Basin, particularly in the vicinity of the GFDA by reviewing surface hydrology and water quality information previously collated and collecting additional data following a gap analysis.

This information was useful in determining appropriate river discharge locations for excess treated water during high rainfall periods.

Although high salinity values have been recorded in the Avon River catchment, the higher flow volumes from the Gloucester River and Barrington River, have the ability to dilute natural salt loads from the Avon River (DIPNR 2004).

3.5. Gloucester Shire Council Property Surveys

Gloucester Council (using consultants SMEC), under the Water Study Project initiative (see Section 7.9), completed water surveys of farming properties in private ownership within the Stage 1 GFDA in March 2013. Properties owned by GRL, Yancoal and AGL were not included in the water surveys. GRL has confirmed that there are no existing groundwater supply works on their properties. There are no existing groundwater supply works at AGL's properties.

The surveys involved sighting all private water supply sites and infrastructure and taking water samples from:

- all groundwater assets (if present);
- from at least one surface water site; and
- one rainwater tank water site.

Property survey reports have been sent to all 19 landowners and summary information is available from http://www.gloucesterwaterstudyproject.com.au/.

The surveys did not locate any groundwater bores or shallow wells/excavations within the Stage 1 area. Summary details of the property surveys are provided in **Table 3.1**.

Table 3.1 Summary statistics from the property surveys – Stage 1 area

Attributes	Number / Description
Number of properties surveyed	19
Number of bores and wells	Zero
Number of springs	2
Number of dams #	14
Number of surface water sites #	10
Number of rainwater tanks #	14

Typical usage	Springs – Stock Dams – Stock and irrigation Creeks and rivers – Stock and irrigation Rainwater tanks – Domestic

Note # - these are the sampled sites only and not necessarily the total number of sites

There is negligible groundwater used for water supply in the Stage 1 GFDA. The two identified spring locations intercept either perched groundwater or shallow groundwater (from fractured rock) in the landscape. Water from rivers and creeks or water captured and stored in farm dams is the primary source of supply for agriculture and grazing. Tank water is used for potable and non-potable domestic purposes.

In relation to the EWMS, these surveys have emphasised the importance of surface water sources over groundwater sources.

3.6. Bioregional Assessment Study

The Gloucester Sub region Bioregional Assessment (GSBA), is funded by the Commonwealth Department of the Environment, and is part of the Bioregional Assessment Program being delivered by the Office of Water Science. The context statement for the Gloucester Sub Region was released in May 2014 (DoE, 2014).

The GSBA is an independent scientific analysis of the current extent of knowledge on the ecology, hydrology, geology and hydrogeology of the Gloucester sub region with an explicit assessment of the potential direct, indirect and cumulative impacts of CSG and large coal mining developments on water resources.

It provides information that is relevant to understanding the regional context of water resources within which CSG and coal mining development is occurring. The GSBA will address many of the water assets and attributes of the catchment.

4. Evaluation of Extracted Water Options

4.1. Gloucester Shire Council Produced Water Evaluation Study

A water evaluation study was prepared for Gloucester Shire Council by consultant RPS Group, as part of an independent assessment of produced water disposal and reuse options for Stage 1 of the GGP (RPS, 2014).

The water evaluation study identified a number produced water reuse and disposal options covering a wide spectrum of possibilities.

Produced water reuse options considered were:

› 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.

› Silviculture for timber production.

› Energy and Mining Sector, which includes, among others, reusing water for drilling and hydraulic fracture stimulation as part of the gas extraction process and 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.

Produced water disposal options considered were:

› Direct surface water discharge to regional water bodies, including the Avon River, Mammy Johnsons River and Gloucester River.

› Direct sea discharge.

› Reinjection to deep aquifers, including re-injecting the coal seam aquifers after gas extraction has been completed.

› Surface water storage and/or evaporation.

The evaluation concluded that none of the produced water reuse and disposal options are feasible as stand-alone options. However, a combination of complementary options were assessed and found to be potentially viable. These included:

› Irrigation of industrial crops (like hemp), pastures or feed crops (like lucerne) is a feasible and preferred option in combination with other options.

› Irrigation in combination with livestock intensive farming is a preferred option, possibly with a degree of storage and/or disposal to meet the water production to demand unbalanced schedule.

› Intensive (recirculated) aquaculture was considered 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 production rates.

- Silviculture (forestry) was considered a feasible and preferred option in combination with other options, mainly because of its low initial and ongoing costs and the environmental benefits associated.
- The Energy and Mining application sector was identified as a feasible and preferred option in combination with other options, primarily due to the existing coal mining industry in the region.
- Irrigation of urban parks and green areas is also a feasible and a preferred option in combination with other options. Around 100 ha 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.
- Artificial Storage and Recovery (ASR) of shallow aquifers was evaluated as a means of storing water for irrigation uses, which may or may not be feasible subject to finding a suitable location and depending on particular conditions of the shallow aquifers in the region, especially permeability and achievable injection rates.

Direct surface water discharge to surface water such as the Avon River was feasible but not preferred unless it was a lesser option associated with a feasible and preferred reuse option. Combined options are more likely to be successfully implemented, especially if the options chosen are complementary and make the most of the productivity of the land and water used.

In summary, the preferred reuse groupings from this independent assessment were:

- Irrigation;
- livestock;
- aquaculture; and
- industrial.

The water evaluation study conclusions are consistent with AGL's preferred water management strategy outlined in AGL's Environmental Assessment (AECOM, 2009).

4.2. AGL's EA Produced Water Options

Numerous options were identified for the beneficial use or disposal of the produced water and treated water in the EA for Stage 1 of the GGP (AECOM, 2009). The suitability of each option was qualitatively evaluated based on the following criteria:

- Technical
- Environmental
- Social
- Economic
- Regulatory.

Each option was given a score out of 25 (higher score represents a better outcome) based on the criteria. The results for different reuse and disposal opportunities for produced water and brine are summarised in **Table 4.1.**

Table 4.1 Options Considered for Produced Water and Brine Disposal and/or Reuse (*AECOM, 2010*)

Disposal/ Use	Description	Treatment	Result	Comment
Water Disposal / Reuse Options				
Produced Water				
Surface Discharge	Discharge of all produced waters to a receiving surface waterway	Salt removal to meet approval requirements	15	Treatment necessary for discharge approval. High cost for no beneficial use
Underground Re-injection	Re-injection of produced water into coal seam or other aquifer	Likely to be required	7	Significant investigation and field studies would be required to prove feasibility
Evaporation	Evaporation of all produced water	Mechanically assisted process required as climate is not conducive to solar evaporation	10	Capital and energy intensive
Removal	Transport all water in trucks to licensed disposal facility	Not required	14	Costly solution that has positive and negative impacts
Recharge Ponds	Store produced water in shallow ponds to allow recharge to shallow aquifers	Salt removal to meet requirements	7	Significant investigation and field studies would be required to prove feasibility
Artificial Wetlands	Use a constructed wetland to treat water and provide wildlife habitat	Salt removal likely to eliminate issues with long-term loading	12	Long-term loading and water quality maintenance issue.
Recreation	Constructed storage to create facility for local recreation (water sports, wildlife habitat)	Treatment required to improve quality	12	May not be suitable in local landscape. Long-term water supply issue.
Stock watering	Supply of produced water to local farms for stock watering	Some salt removal or dilution required, though less than other options	17	Impractical disposal option for all flows though viable in combination with other agricultural uses.

Disposal/ Use	Description	Treatment	Result	Comment
Water Disposal / Reuse Options				
Irrigation (agriculture)	Supply of produced water to local farms for irrigation	Salt removal required	20	Practical beneficial use for water appropriate for local land use
Irrigation (horticulture)	Supply of produced water to local horticultural or agribusiness operations	Salt removal required	20	New business opportunities. Appropriate beneficial use.
Aquaculture	Supply of produced water to an aquaculture enterprise	May not be required	15	Challenging management of flows. Local operator would be required.
Industrial	Supply of produced water to local industry most likely coal processing	Would be determined by end user	14	No identified demand; sharing disposal with mine influenced by expected mine life
Municipal	Supply of water to supplement local town potable supplies or for irrigation of municipal reserves and properties	High level of treatment required for potable supply	14	Not an economic alternative to existing (adequate) supplies
Brine				
Evaporation	Evaporation of concentrated waste stream in purpose built evaporators	Not applicable	14	Standard approach to waste disposal in inland areas; probably not viable in high rainfall/coastal areas
Aquifer Re-injection	Injection of concentrated waste stream into coal seam or other aquifers	Not applicable	7	Costly investigation, infrastructure and approval process
Transport	Haulage of all concentrated waste to licensed disposal facility	Not applicable	14	May be suitable for low volumes
Salt Production by transporting salt to a salt producer	Use of advanced yet proven technology to create a saleable salt product and zero liquid emissions	Not applicable	17	Ideal solution if feasible. Requires investigation and interest from third party.

The assessment in the EA indicated that the reuse of produced water for irrigation (agriculture and horticulture) and stock watering would be the most beneficial to the community and also result in the least potential environmental issues once the produced water is treated to meet acceptable standards. The assessment also highlighted that stream discharge was favoured as the preferred disposal strategy if reuse opportunities were limited.

For the final solid salt product, the assessment indicated that the transport of the product to a salt producer for reuse would be the most suitable method of disposal.

Based upon the quality of produced water from the early pilot wells, the EA considered that treatment of the produced water would be required prior to beneficial reuse or disposal.

A number of produced water treatment options were discussed in the EA, comprising:

- sterilisation;
- evaporation;
- filtration;
- desalination;
  - Reverse Osmosis (RO);
  - Capacitive Desalination (CDI);
  - Electrodialysis Reversal (EDR);
  - distillation; and
  - SAR reduction.

The EA considered that the RO desalination process is the most suitable produced water treatment option. The RO desalination process results in two streams: a low salinity water stream (treated water); and a concentrated brine stream.

The EA proposed that the treated water would be stored in holding ponds located at the CPF and at the Tiedman property prior to reuse or disposal. A storage capacity of 25 ML for treated water was proposed at the CPF site with additional balance storage at the Tiedman property. Management of the treated water was proposed to be through reuse (e.g. such as irrigation) or, if reuse is not possible, discharge to surface water.

The EA identified that concentrated brine was to be stored separately to the treated water in a brine tank at the CPF.

Based on the options analysis in the EA (AECOM, 2009), the top six water reuse/disposal options were:

- Treated water for irrigation
- Treated water for local horticultural or agribusiness
- Supply of produced water to local farms for stock use
- Discharge of treated water to a receiving surface waterway
- Aquaculture
- Salt production by exporting the salt to a salt producer or landfill

These options align with those options in the recent GSC study (RPS, 2014) described in Section 4.1.

5. AGL's Preferred Water Reuse and Discharge Strategy

AGL has reviewed the results of the current Tiedman irrigation program to blend and irrigate produced water from historical exploration activities, re-visited and had regard to the broad opportunities that were described in the Gloucester Shire Council report (RPS, 2014), and re-evaluated the original beneficial reuse proposals presented in the EA in 2009 (AECOM, 2009 and 2010).

Upon careful consideration of all the options and following community feedback, AGL's preferred strategy for extracted water is:

- Treatment and desalination of extracted water to produce treated water and brine;
- Reuse of treated water for CPF, drilling, fracture stimulation and workovers (i.e. working water);
- Beneficial reuse of treated water for stock and irrigation purposes;
- Discharge of treated water to streams (when irrigation is not possible); and
- Landfilling salt from the brine stream.

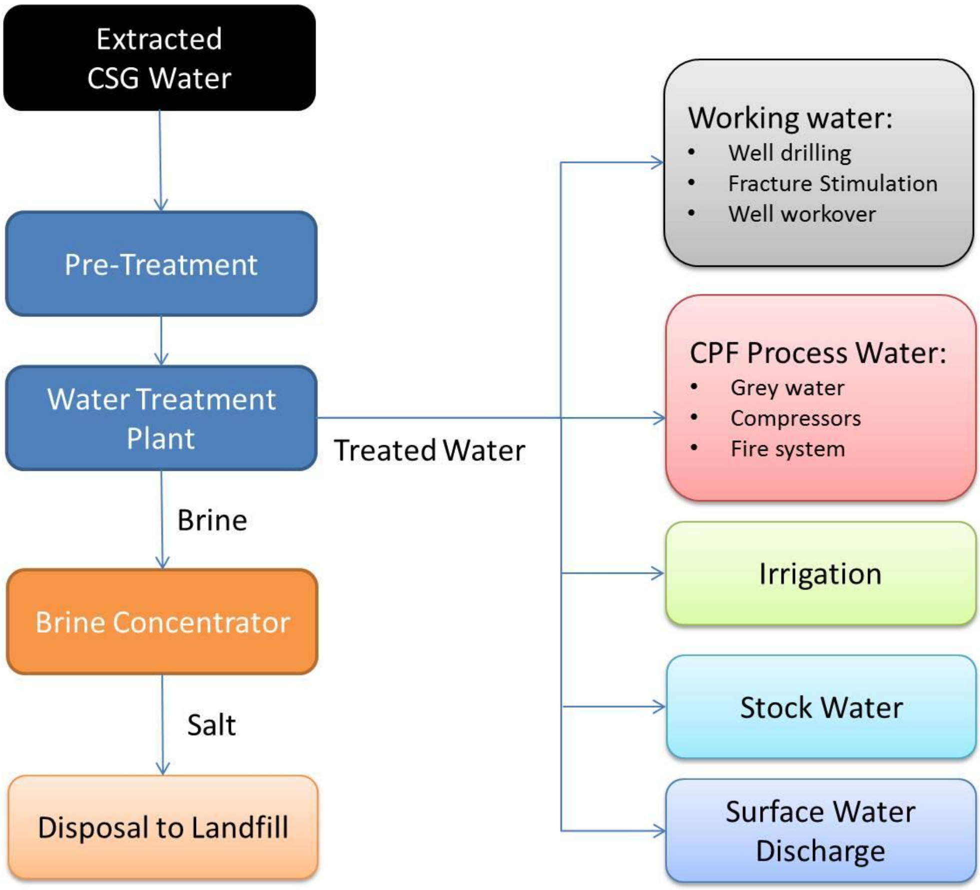
The concentration and crystallisation of the brine stream will produce a mixed dry salt. This will be trucked off-site and disposed to licensed landfills as general solid waste.

Water balance modelling together with the current water production profile for 110 wells developed over a 24 month period has been used to generate the volumetric estimates for treated water for reuse and brine water for disposal. The irrigation requirements in this strategy are based on:

- 60 ha of available irrigation area; and
- Application rates of 4 ML/ha/yr.

5.1. Extracted Water Management Components

The proposed extracted water management system is shown in **Figure 5.1**. This flowchart represents the proposed flow path for extracted water for Stage 1 of the GGP.



(Note – the treated water is the final desalinated water)

Figure 5.1: Extracted Water Management Flowchart

AGL has undertaken a comprehensive assessment of the options for water reuse and discharge and has identified the following engineering components for the preferred strategy:

- Centralised water treatment plant to be located at the CPF;
- Pre-treatment of extracted water prior to desalination;
- Desalination of extracted water for:
  - working water (drilling, fracture stimulation, and well workover),
  - CPF process water,
  - beneficial reuse and
  - surface water discharge;
- Brine concentration; and
- Crystallisation of brine water.

The engineering components of the strategy are described in detail in the following sections.

5.1.1. Extracted Water Gathering System

The main components of the extracted water gathering system consist of a central spine line with a network of smaller pipes from each of the wells. The flowback and produced water will be gathered and transferred to the receiving water pond located at the CPF. It is proposed that an additional (return) line will be installed adjacent to the extracted water gathering line to provide working water to each well for drilling, fracture stimulation and work-over requirements (and potentially stock purposes). Another pipeline will be installed between the Tiedman dams and the CPF to allow water (mainly treated water) to be transferred between these two storage facilities. Installation of produced water and working water lines will reduce the number of vehicle and truck movements over the life of the project.

5.1.2. Pre-treatment System

The extracted water will be treated by the pre-treatment system to remove any particulate matter and residual fracture stimulation additives to render this water acceptable as feed water to the water treatment plant (WTP).

Note that at this time it is not planned to reuse this water for drilling, fracture stimulation and well workover purposes although water after pre-treatment is suitable for recycling and reuse for these purposes. Desalinated water will be preferentially used instead, however if not available, pre-treated water would be suitable. For the GGP start-up, it is expected that water from fresh water sources or residual produced water located in the Tiedman dams from exploration programs will be used instead. This is likely to be at the very start of the GGP prior to wells being dewatered.

5.1.3. Water Treatment Plant

Water from the pre-treatment system will be desalinated by the WTP. A suite of alternative desalination technology options has been evaluated for the treatment of produced water. Reverse osmosis (RO) membrane separation technology has been adopted as the preferred desalination option. RO technology is well proven, robust and is widely applied within the Australian CSG industry as the preferred produced water desalination technology.

RO desalination potentially offers the lowest life cycle cost and the highest water recovery (i.e. potentially treated water recovery greater than 90%) to minimise the size, capital cost, and energy consumption. High water recovery will also reduce the operating cost associated with the further treatment of the RO brine concentrate using thermal brine concentration and crystallisation technology to produce salt.

5.1.4. Brine Management

Based on the composition of produced water and the design of the WTP, it is estimated that several hundred megalitres (ML) of brine will be produced over the life of the project. A preliminary review of a wide range of brine management options was undertaken with the preferred option involving a brine concentration and crystallisation process which would produce a dry mixed salt.

AGL's preferred approach is the production of a mixed salt suitable for transport from site to a licensed landfill as a GSW. This approach will remove all the salt from site for disposal at an appropriately licensed facility.

The mixed nature of the salt and the low volumes produced means that it is unlikely to be commercially viable to reuse this product. However, the design of the WTP and brine management system will be such that new treatment technologies can be 'bolted on' in the future if appropriate.

5.1.5. Water Reuse and Discharge

To maximise beneficial reuse of the treated water, AGL prefers irrigation as the prime beneficial reuse option with discharge to the Avon River at times when irrigation is not possible. The treated water quality will be managed to ensure that:

- The water quality for irrigation will meet the proposed ANZECC irrigation thresholds; and
- The discharge to the Avon River will meet the ANZECC environmental thresholds and flow conditions.

In practice it is expected that the target water quality (see Sections 10.1, 10.2, 10.3 and 10.4) will be significantly less that the proposed irrigation and river discharge thresholds.

5.1.6. Water Distribution

The balance between the various extracted water reuse and discharge options will vary for the Stage 1 GFDA of the project. An indicative distribution of extracted water supply and demands for the Stage 1 project is presented in **Figure 5.2**.

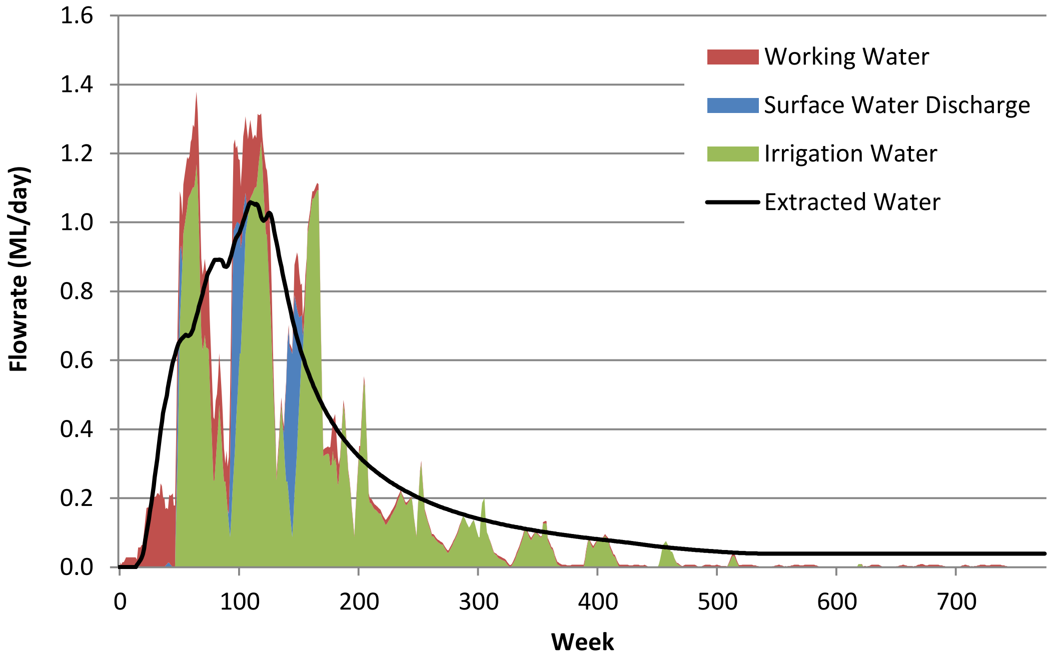


Figure 5.2: Overview of Indicative Extracted Water Reuse and Discharge Rates

5.2. Reuse for Working Water

5.2.1. Reuse for Drilling and Workovers

It is estimated that approximately 0.2 ML of water will be required during drilling of each well. Drilling water will be sourced from existing freshwater storages or the WTP treated water (same as for fracture stimulation programs). When available treated water will be used in preference to fresh water sources.

Well workover operations will be conducted over the life of the project. Working water will be sourced from freshwater sources or the WTP. It is expected that workover frequency and associated working water demands for each well will decrease over the life of the well. Estimated daily working water requirements are shown in **Figure 5.3**.

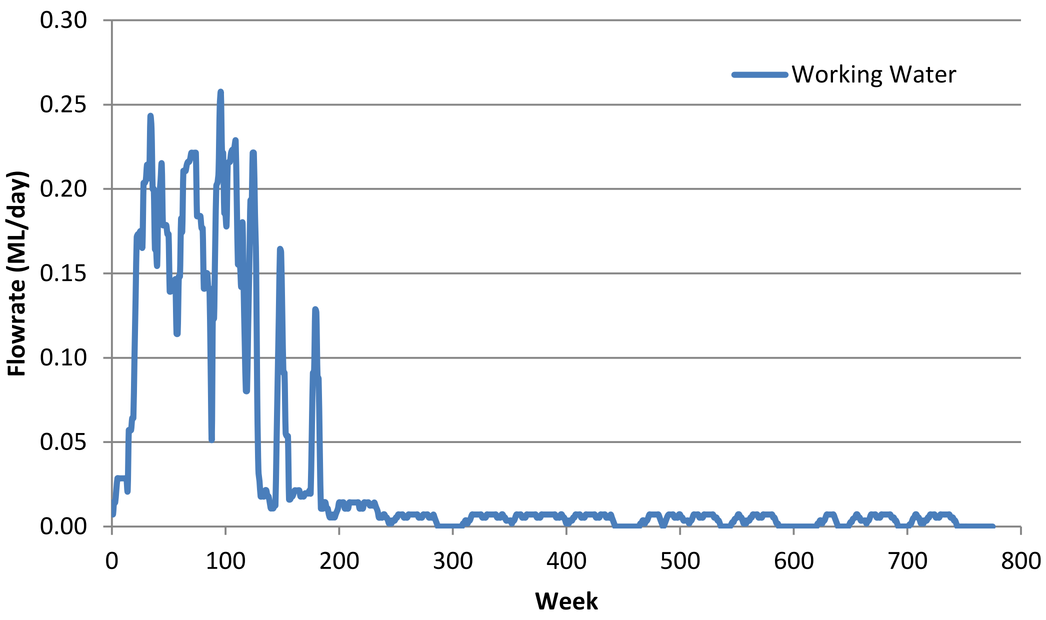


Figure 5.3: Estimated Daily Drilling, Fracture Stimulation and Workover Water Demand

5.2.2. Reuse for Fracture Stimulation

The initial fracture stimulation water will be sourced from AGL's existing freshwater or stored produced water storages at the start of the drilling and fracture stimulation campaign. Once treated water from the WTP is available, this recycled water will be used for fracture stimulation instead of using freshwater. AGL estimates between 0.5 and 1.5 ML of water will be required to fracture stimulate each well. Volumes will be dependent on the final well designs. It is estimated that the total demand for fracture stimulation water will be approximately 100 ML over the well development phase. Fracture stimulation and working water quality requirements and targets are discussed in Section 10.1.

5.3. Reuse for CPF Operations

There will be a small demand for water at the CPF to supply the following:

› General use (e.g. for domestic needs);

› Process water for compressors and cooling systems;

› Service water for wash down, maintenance, landscaping and dust suppression; and

› Fire water systems.

These demands for water at the CPF will be sourced from the treated water pond. The quantity of water required to supply CPF operations is very small and is estimated to be approximately 2 ML per annum.

Drinking water at the CPF will be trucked to the site.

5.4. Reuse for Stock

There is expected to be a small demand for stock water supplies on AGL owned properties and neighbouring properties within and adjacent to the Stage 1 development. Quantities and qualities have not been determined at this time. Water is expected to be delivered via the working water delivery lines and potentially the low level river discharge location on the Avon River. Delivery via the extensive working water pipelines is preferred to minimise losses.

5.5. Reuse for Irrigation

The preferred extracted water management option is irrigation to support agriculture. Under this option, treated water from the WTP would be transferred to storage ponds at the Tiedman property (and possibly to the Pontilands Dam) and applied to local crops and pasture.

Crops potentially available for cultivation would include lucerne, hemp, forage sorghum, triticale and oats. The improved pasture is likely to be a mixture of kikuyu, ryegrass, clover and chickory. The rate of water uptake by these crops/pasture is estimated to be approximately 4 ML/ha/year on average. This estimate is based on the irrigation program that has been successfully conducted at the Tiedmans property since April 2013. Irrigation rates are expected to be seasonal and vary according to soil moisture and weather conditions. Demand for irrigation water will be higher during dry periods when evapotranspiration exceeds rainfall (mostly spring and summer). Seasonally the irrigation application rates could vary between 2 ML/ha/year and 6 ML/ha/year.

Irrigation water quality requirements are discussed in Section 10. The estimated daily rate of irrigation using treated water for the Stage 1 GFDA is presented in **Figure 5.4**. The estimated annual rate of irrigation using treated water is presented in **Figure 5.5**.

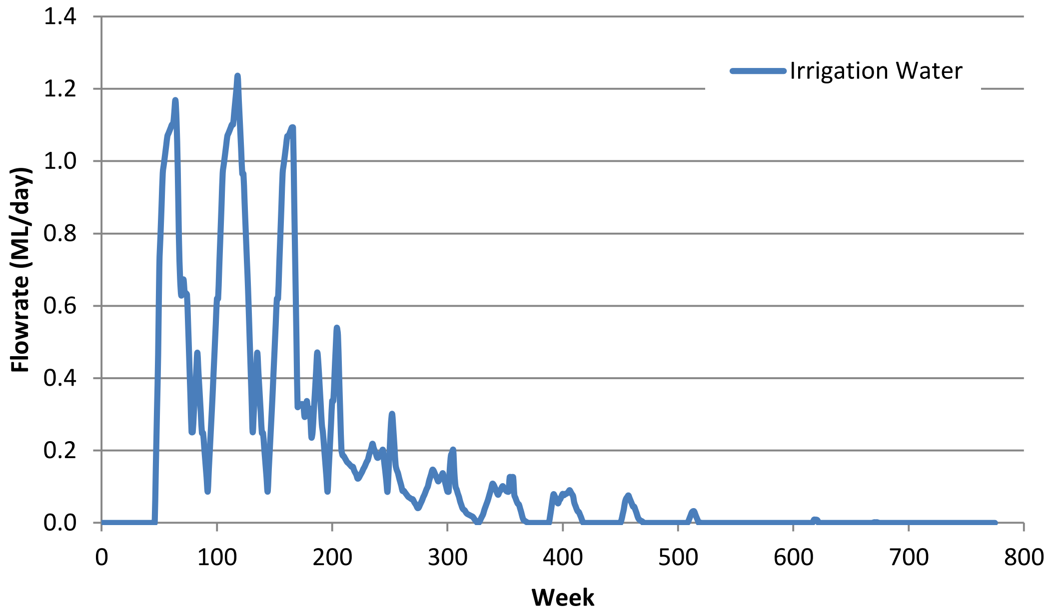


Figure 5.4: Estimated Daily Irrigation Rate using Treated Water

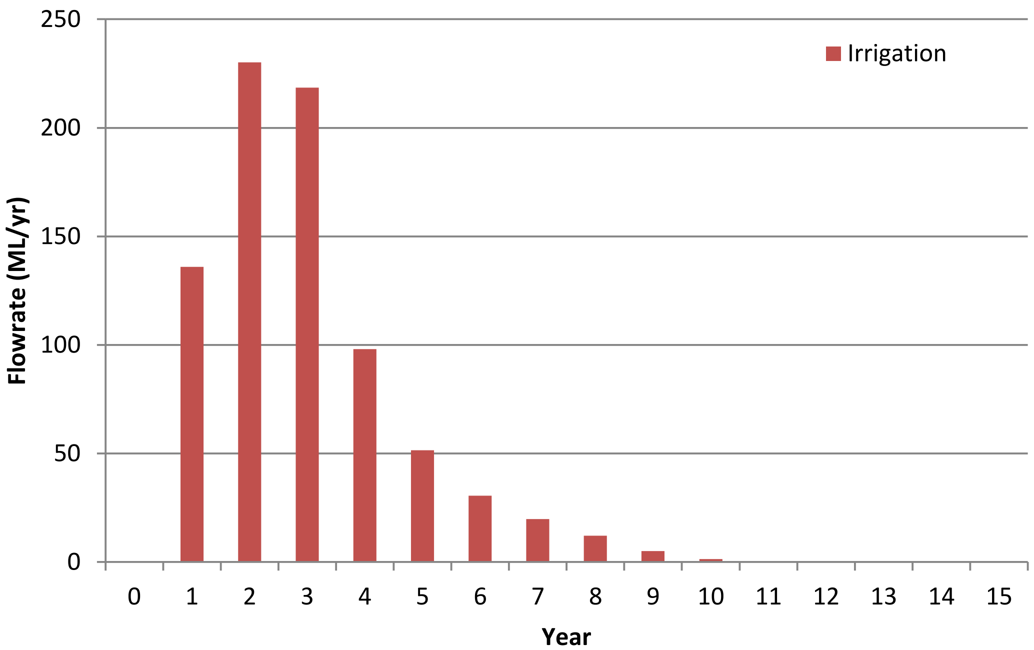


Figure 5.5: Estimated Annual Irrigation Rate Using Treated Water

5.6. Surplus Water Discharge to Surface Water

The secondary extracted water management option is to discharge treated water to surface waters. Discharge to the Avon River via Dog Trap Creek would occur when the preferred irrigation option is not available due to climatic conditions, namely extensive wet weather periods. Dog Trap Creek (immediately upstream of the confluence of the Avon River) has been chosen as the preferred location for stream discharge because:

› it is not as incised as the Avon River;

› it has stable banks;

› scouring can be avoided;

› the proposed high level discharge location is towards the edge of the floodplain; and

› the water return lines are likely to be located near the proposed discharge locations.

Very few discharges of treated water are expected if average to dry seasons prevail as most water can be beneficially reused though stock and irrigation use.

This option is only expected to be required during the initial Stage 1 GFDA development period, when the wells are being dewatered. After the first three years, AGL does not expect to use this option as there will be sufficient storage for produced water and treated water in all but the wettest years.

Discharge to the Avon River would be managed in accordance with the necessary EPA and NOW approvals. It is expected that most water would be discharged during periods of higher flow when irrigation is not possible because of antecedent wet conditions. However AGL is not discounting the opportunity to discharge water during lower flow periods to provide stock water supplies to downstream users, to maintain small environmental flows and to improve the health of the river.

AGL is seeking feedback from stakeholders and the community on whether discharges during drought periods would be useful for:

› the riverine environment; and/or

› downstream stock and irrigation users who are beyond the limit of the working water lines and distribution pipeline from the CPF to the Tiedman storage ponds.

It is expected that periods of moderate to high flow conditions would represent the most favourable conditions for discharge of treated water. These periods would represent those times when most mixing would occur. These conditions are likely to occur during or following periods of sustained rainfall when irrigation water demands are low. Therefore, surface water discharge represents a complementary option to the preferred reuse for irrigation. Water quality of the treated water can be controlled to closely mimic the water quality of the receiving environment at any time.

Surface water discharge quality targets are presented in Section 10.4 and discussed further in Section 12. The estimated daily rate of discharge to surface waters for the Stage 1 GFDA and high and low rainfall events is low (generally less than 1 ML/d) and is presented in **Figure 5.6**. If there was an extreme wet weather event slightly larger river discharges are likely however rates greater than 1.5 ML/d are not anticipated. Discharge rates between 0.5 and 1.5 ML/d will not increase the flood risk. The extra flows (when the Avon River system is in flood) would be less than 1% of the flood flows. The estimated annual discharge to surface waters for wet (P90), average (P50) and dry (P10) years is presented in **Figure 5.7**.

The figures show that during particularly wet years (as represented by the P90 rainfall), there is an increase in the volume of surplus water for discharge. This is due to the decreased demand for irrigation using treated water. It should be noted that during periods of high rainfall, environmental flows in local streams would generally be higher. Therefore, even though the discharge volumes would be higher, they would be a relatively lower proportion of flow to the total Avon River flow.

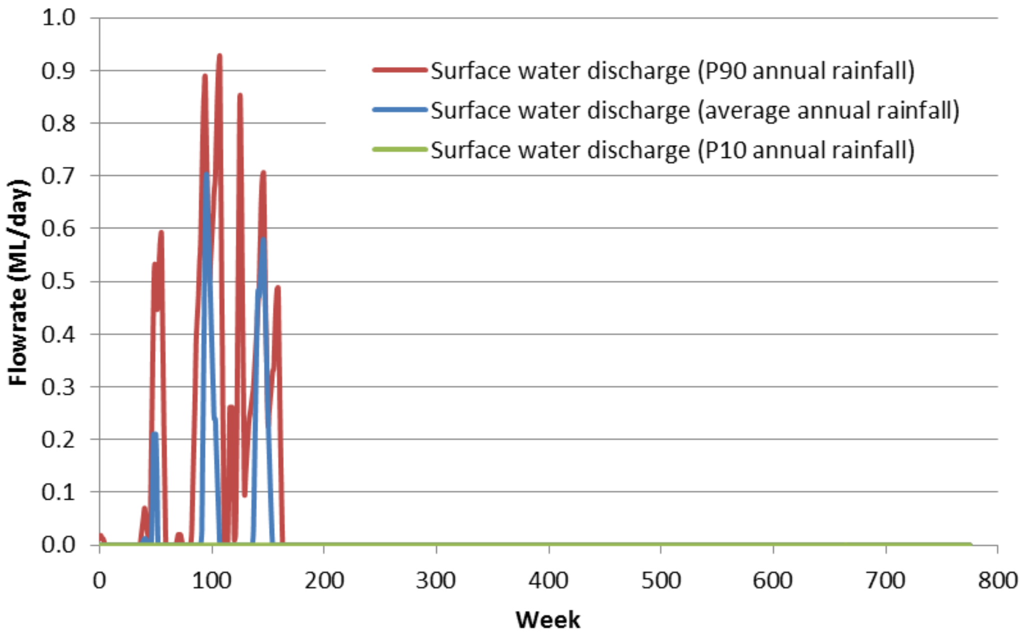


Figure 5.6: Variations in Estimated Daily Rate of Discharge to Dog Trap Creek

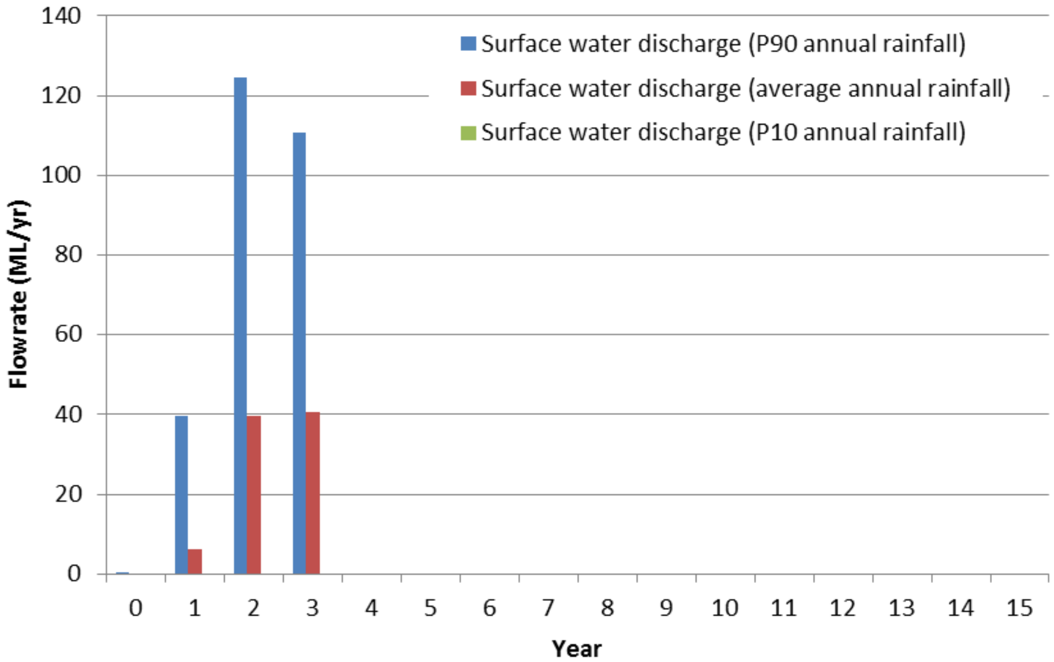


Figure 5.7: Variations in Estimated Annual Discharge to Dog Trap Creek

These graphs are based on 60 ha of irrigation area and irrigation application rates of 4 ML/ha/year. If lesser irrigation applications occurred (e.g. in wet seasons) then increased stream discharges would be required in those years.

The annual discharges (potentially up to 130 ML/yr in the wettest of seasons) are small compared to the average annual discharge of the Avon River (as measured at the Waukivory gauge) which is approximately 110,000 ML/yr. Treated water discharges (on average) would represent an additional 0.04% of the average annual flow and would represent an even lower percentage during wetter periods when AGL are proposing to discharge.

5.7. Sensitivity to Variation in Rainfall Conditions

The sensitivity of the extracted water management strategy to variations in rainfall conditions has been investigated. In particular, variation in rainfall may affect the extracted water management system in the following ways:

› Rainfall onto storage catchments contributes to the total volume of water to be beneficially reused or discharged.

› Rainfall limits the potential for crops to uptake treated water via irrigation (and hence more water would be stored or sent for discharge).

› Catchment rainfall produces runoff which may lead to higher flows in local waterways.

Historical rainfall data was sourced from the Bureau of Meteorology's gauge at Gloucester Post Office (gauge number 60015). Records at the gauge extend back to 1888, providing approximately 126 years of daily-read rainfall data. Annual rainfall totals were ranked to determine the 90th percentile annual rainfall. The 90th percentile annual rainfall is the smallest annual rainfall total which exceeds 90% of the annual rainfall records. The 90th percentile annual rainfall represents a particularly wet year. Similarly, the 10th percentile annual rainfall was determined to represent a particularly dry year.

A summary of the rainfall scenarios considered is provided in **Table 5.1**.

Table 5.1 Annual Rainfall Scenarios

Statistic	Annual Rainfall (mm)
90th Percentile Annual Rainfall (P90)	1324.1
Average Annual Rainfall (mean)	981.9
10th Percentile Annual Rainfall (P10)	641.2

The sensitivity of the estimated daily rate of irrigation using treated water to variations in rainfall is presented in **Figure 5.8**. The sensitivity of the estimated annual rate of irrigation using treated water to variations in rainfall is presented in **Figure 5.9**. The figures show that during particularly wet years (as represented by the P90 rainfall), there is generally less potential to reuse treated water for irrigation. This is because direct rainfall onto the irrigation crops contributes a higher proportion to the potential crop uptake of water.

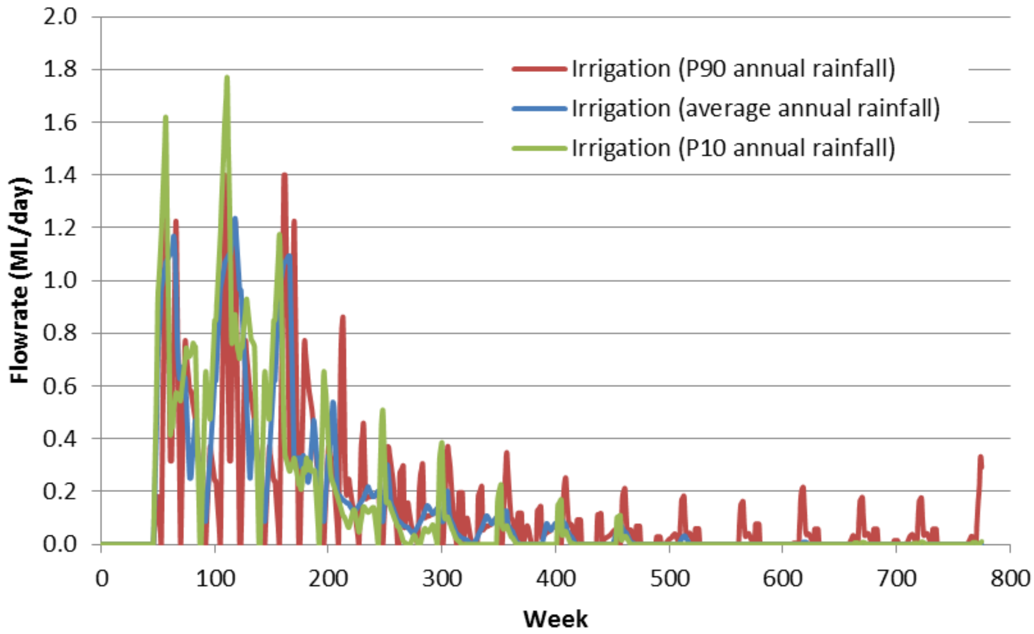


Figure 5.8: Variation in Estimated Daily Irrigation Rate using Treated Water

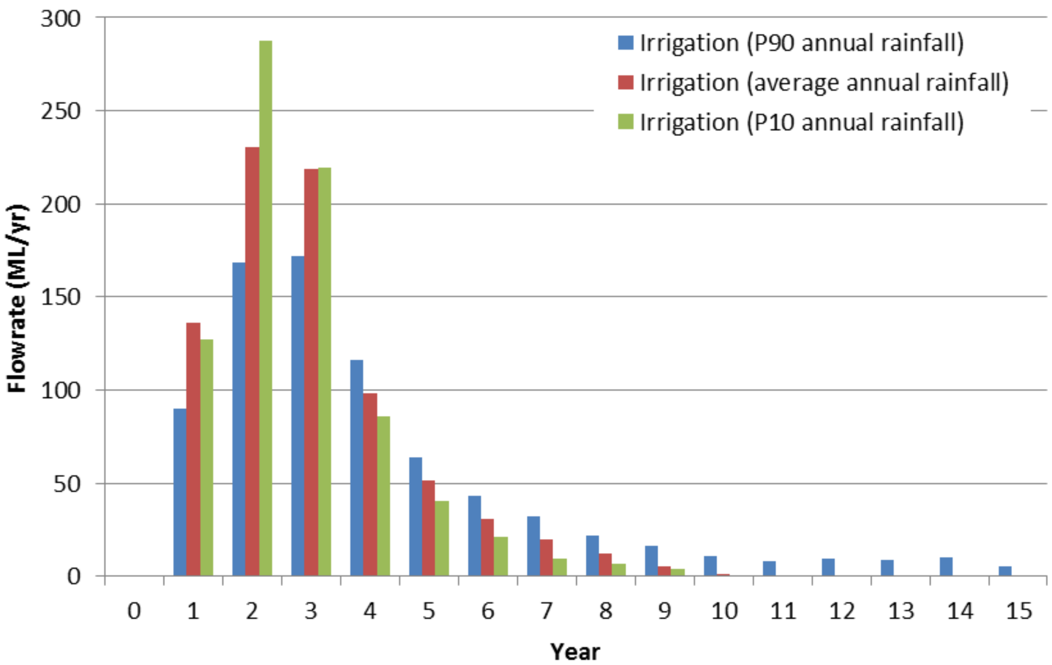


Figure 5.9: Estimated Annual Irrigation Rate Using Treated Water

5.8. Future Water Opportunities for the Community

Over the course of the project, it is anticipated that new opportunities will arise for the beneficial use of untreated and treated extracted water. AGL will call for 'Expressions of Interest' from third parties for use of both water (treated and untreated) and salt, and will also continue to identify potential third party users.

There is the opportunity to supply farming properties close to the proposed reticulated water pipelines. Treated water will be suitable for both stock and irrigation uses so there will be potential for farmers along the pipeline routes to be supplied with additional water or replacement water during periods of drought. However the ongoing availability and quantity of this water for external consumptive uses will diminish with time and it must be noted that reliability is uncertain. Stock water is more important than irrigation water and hence it is expected that stock supplies would be maintained in preference to irrigation.

There is also an opportunity to expand the number of properties that could benefit by discharging treated water to the Avon River via Dog Trap Creek. However the volumes would be small and the reliability uncertain.

Gloucester Shire Council's Agricultural Working Group (AWG) is also assessing potential new industry opportunities for the Gloucester area. If good quality water is available (even for start-up periods of around 5 years) then new opportunities such as industrial hemp, saline aquaculture and silviculture may emerge. Further details are provided in RPS 2014.

Expansion of the existing dairy and beef industries depends on the availability of improved pastures and/or fodder crops. Water for irrigation is limited from surface water sources and any additional water at appropriate cost could be utilised by existing operations if the quality, quantity and delivery of water was acceptable.

An increase in dairy production through increased irrigation (even modest increases due to the availability of treated water that may decline over time) could assist in the development of a milk processing plant that is being considered in the Gloucester Shire. Such a plant would also benefit from the availability of gas energy at the site.

6. Extracted Water Quantity and Quality Characteristics

The target coal seams will be fracture stimulated to increase gas flow. Initially, fresh water (or stored produced water) will be used for fracture stimulation operations. A large proportion of this fracture stimulation fluid is recovered during dewatering. This recovered fracture stimulation fluid is termed "flowback water".

During dewatering, the extracted water composition will change from flowback water to natural groundwater composition (i.e. the natural formation water in the coal seams). The extracted water quality and quantity will be monitored. Flowback will be deemed complete when the extracted water volume is equivalent to 100% of the injected water volume and water composition matches the coal seam groundwater composition. Subsequent extracted water is termed "produced water".

6.1. Flowback Water Volumes

Based on AGL's estimates, between 0.5 and 1.5 ML of water will be required to fracture stimulate each well depending on the final well designs. For the life of the drilling and fracture stimulation program for the Stage 1 GFDA approximately 100 ML of water will be required. It is expected that approximately 30% of flowback will be recovered within seven days of dewatering and that the remaining flowback would be recovered within approximately eight weeks of dewatering.

6.2. Flowback Water Quality

The quality of flowback water will depend on the composition of the fracture stimulation fluid and the quality of the coal seam groundwater. A detailed Fracture Stimulation Management Plan (FSMP) will be developed and approved prior to any fracture stimulation taking place in the Stage 1 GFDA.

The typical fracture stimulation fluid gel types include:

› Conventional linear gels: These gels are formulated with a wide array of polymers in an aqueous base. Polymers used to formulate linear gels include cellulose derivatives, guar or its derivatives. These polymers are dry powders that hydrate or swell when mixed with water and form a viscous gel.

› Borate cross-linked fluids: Borate cross-linked fracturing fluids utilise borate ions to crosslink the hydrated polymers and to provide increased viscosity. The polymers most often used in these fluids are guar and hydroxypropyl guar (HPG). These gels have high viscosity at upwards of pH 9 and are used to carry proppants. Following fracture stimulation, the pH is reduced to between 3.0 and 4.0 so that the cross-links are broken and the gel is less viscous and can be readily pumped out.

A linear gel system has been adopted for the Waukivory Pilot program. A Human Health and Ecological Risk Assessment (HHERA) was undertaken for the complete list of chemicals (including concentrations and volumes) used in fracture stimulation operations at the Waukivory Pilot program (ERS, 2012).

6.3. Produced Water Volumes

Typically, dewatering rates are initially high and decrease over the life of the project. This means that the peak rate of produced water is produced early in the project life and may be significantly higher than typical rates later in the project life. An indicative well depressurisation profile is shown in **Figure 6.1** including produced water (shown in blue) and gas (shown in red). This is generic profile and not necessarily applicable to any gas well or grouping of gas wells at Gloucester.

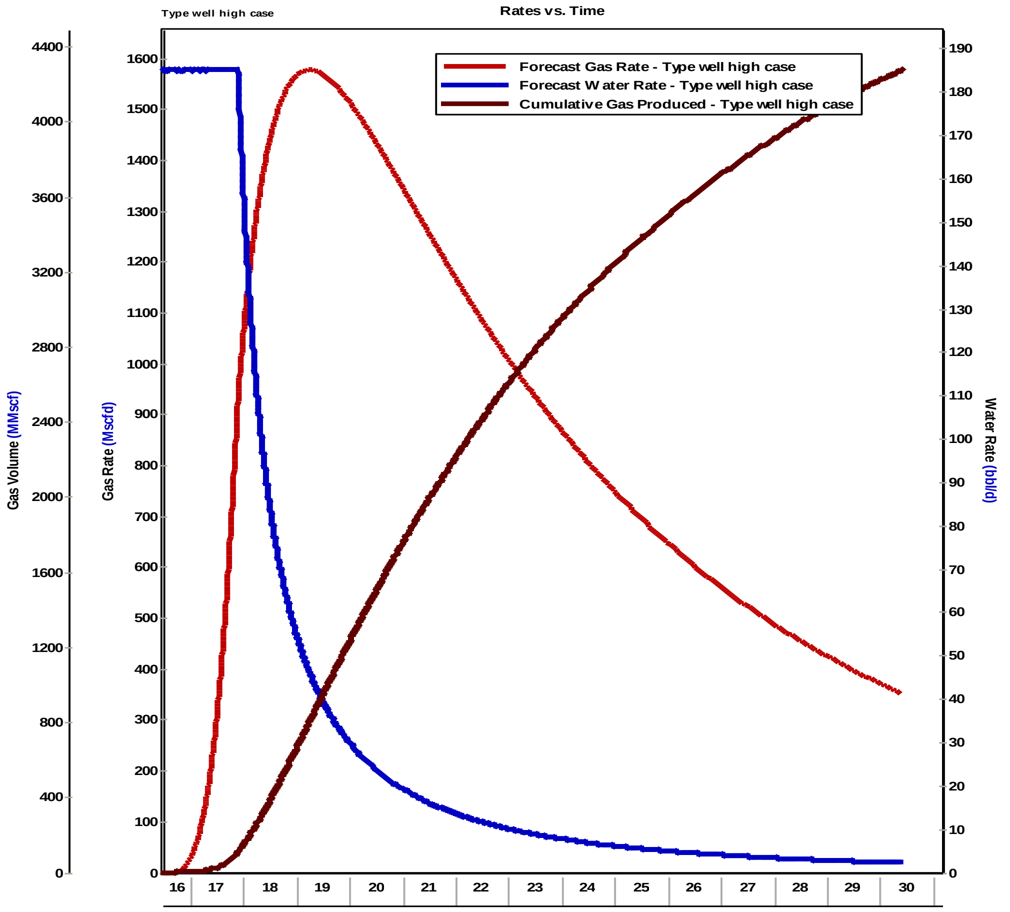


Figure 6.1: Indicative Well Depressurisation Profile

AGL has project approval to extract up to 730 ML of produced water per year across the Stage 1 GFDA at a rate of 2 ML/d on average across the year. It is expected that actual dewatering rates will be lower as the wells will be commissioned progressively.

6.4. Produced Water Quality

The quality of the produced water varies according to the geology of the region. Water quality data is available from historical flow testing programs across the basin with the most recent testing programs on Waukivory 03 (WK03) located towards Gloucester and Craven 06 (CR06) located south of the Stage 1 GFDA. Water testing undertaken at the CR06 well to the south of the Stage 1

GFDA provides an indication of expected produced water quality in the average to maximum water salinity range. The results from this well are therefore considered representative and are being used for the design of the WTP at the CPF.

The CR06 well is located near the centre the Gloucester Basin. Wells which are located more centrally within the basin are expected to produce water with a higher salinity than wells which are located further east. This is due to the groundwater recharge which mostly occurs along the eastern coal seam outcrop area.

The CR06 well was on production test for approximately 12 months. Six water samples were taken and a range of detailed analyses conducted on water extracted from this well in 2013/14 (Parsons Brinckerhoff 2014c). **Table 6.1** provides an overview of the results of the analyses, including key quality parameters in relation to the design of the WTP.

Table 6.1 also provides the suggested minimum and maximum range of produced water quality parameters to be adopted for the WTP basis of design. This range of parameters is based on an anticipated minimum water quality with a Total Dissolved Solids (TDS) of 3,000 mg/L (based on the Waukivory 03 water quality data) and a worst case maximum TDS of 9,000mg/L (not yet seen in basin from a gas well). CR06 is mid-range at around 4,500 mg/L TDS.

Table 6.1: Produced Water Quality for Water Treatment Plant Design

Item	Parameter	Unit	CR06 (Sample Date 13/08/2013)	Minimum and Maximum Range of Water Quality Parameters adopted for WTP Basis of Design
1	pH (field)	pH units	9.63	7.5 – 9.6
2	pH (lab)	pH units	7.84	-
3	EC (field)	µS/cm	6,746	4,700 – 13,500
4	EC (lab)	µS/cm	7,200	-
5	Temperature	^{0}C	13.9	13 - 25
6	Dissolved oxygen	% sat	8.02	6 - 16
7	TDS	mg/L	4,385	3,000 – 9,000
8	TSS	mg/L	276	200 - 550
9	Turbidity	mg/L	153	100 - 300
10	Hydroxide Alkalinity as $CaCO_3$	mg/L	< 1	< 1
11	Carbonate Alkalinity as $CaCO_3$	mg/L	< 1	< 1
12	Bicarbonate Alkalinity as $CaCO_3$	mg/L	2,020	1,400 - 4,000
13	Total Alkalinity as $CaCO_3$	mg/L	2,020	1,400 - 4,000
14	Sulphate as SO_4-	mg/L	< 1	< 1
15	Chloride	mg/L	1,270	900 – 2,500

Item	Parameter	Unit	CR06 (Sample Date 13/08/2013)	Minimum and Maximum Range of Water Quality Parameters adopted for WTP Basis of Design
16	Calcium	mg/L	9	6 – 18
17	Magnesium	mg/L	4	3 – 8
18	Sodium	mg/L	1,710	1,200 – 3,400
19	Potassium	mg/L	12	8 - 18
20	Silica	mg/L	13.7	10 - 27
21	Fluoride	mg/L	1.4	1 - 3
22	Total Anions	me/L	76.2	-
23	Total Cations	me/L	75.5	-
24	Ionic Balance	%	0.52	-
25	Aluminium	mg/L	0.01	0.01 - 0.05
26	Arsenic	mg/L	0.001	0.001 - 0.005
27	Barium	mg/L	< 0.001	< 0.001 - 0.005
28	Beryllium	mg/L	4.3	3 - 8
29	Cadmium	mg/L	< 0.0001	< 0.0001 – 0.0005
30	Chromium	mg/L	0.004	0.004 – 0.010
31	Cobalt	mg/L	< 0.001	< 0.001 – 0.005
32	Copper	mg/L	0.001	0.001 – 0.005
33	Lead	mg/L	< 0.001	< 0.001 – 0.005
34	Manganese	mg/L	0.475	0.3 – 1.0
35	Molybdenum	mg/L	0.005	0.005 – 0.01
36	Nickel	mg/L	0.001	0.001 – 0.005
37	Selenium	mg/L	< 0.01	< 0.01 – 0.05
38	Strontium	mg/L	3.06	2 - 6
39	Zinc	mg/L	0.006	0.006 – 0.01
40	Boron	mg/L	0.27	0.2 – 0.5

Item	Parameter	Unit	CR06 (Sample Date 13/08/2013)	Minimum and Maximum Range of Water Quality Parameters adopted for WTP Basis of Design
41	Iron	mg/L	37.8	30 - 70
42	Bromine	mg/L	2.8	2 - 6
43	Ammonia as N	mg/L	na	na
44	Nitrite as N	mg/L	< 0.01	< 0.01
45	Nitrate as N	mg/L	< 0.01	< 0.01

6.5. Produced Water Characteristics

Based on the available water quality data and existing groundwater salinity classifications, deep groundwater in the Gloucester Basin may be classified as brackish to moderately saline. Most produced waters from the CSG field development are expected to be either brackish or slightly saline.

Produced water is not toxic.

The proposed water treatment plant will ensure this naturally occurring salt is removed, resulting in treated water that is suitable for stock and irrigation use or if required, discharge to surface waters.

Salinity

The produced water is generally dominated by sodium, chloride and bicarbonate.

The produced water salinity can be reduced via various desalination processes, such as reverse osmosis (RO) or electrodialysis (ED), which are proven desalination technologies and are commercially available. These desalination methods will remove 85% to 99% of the salts from the produced water source, depending on its water chemistry.

Sodium and Chloride

Sodium and chloride are two of the most common elements in produced water (ranging from 1,200 mg/L to 3,400mg/L for sodium with CR06 showing a concentration of 1,710 mg/L and chloride levels ranging from 900 mg/L to 2,500 mg/L with CR06 showing a concentration of 1,270 mg/L). High sodium levels will be taken into consideration during the design of the WTP.

The high chloride content is unlikely to pose any problems for the WTP recovery and performance.

pH

The pH of water supply describes how acidic or alkaline it is.

The pH of most natural waters ranges between 5.0 and 8.0. The pH of produced water at Gloucester is slightly alkaline (7.5 – 9.5) and will be able to be handled by the RO plant since pH is taken into consideration in the design of the WTP.

Alkalinity

Alkalinity is the measure of water's ability to neutralise acids. Carbonate ions (CO_3^-) from dissolved salts such as calcium carbonate ($CaCO_3$), bicarbonate ions (HCO_3^-) from dissolved salts such as calcium bicarbonate ($Ca[HCO_3]_2$), sodium bicarbonate ($NaHCO_3$), and magnesium bicarbonate ($Mg[HCO_3]_2$) are the major chemicals contributing to alkalinity in the produced water.

For the produced water at Gloucester the calcium and magnesium content is relatively low. Calcium is predicted to range from 6 mg/L to 18 mg/L with CR06 showing a concentration of 9 mg/L whereas magnesium is predicted to range from 3 mg/L to 8 mg/L with CR06 showing a concentration of 4 mg/L.

Hydroxide ions (OH^-) are a minor contributor in most cases which is the case for the Gloucester water with a hydroxide alkalinity figure of <1 mg/L expressed as $CaCO_3$.

The bicarbonate levels in the produced water are predicted to range from 1,400 mg/L to 4,000 mg/L (expressed as $CaCO_3$) with CR06 showing a figure of 2,020 mg/L indicating a high alkalinity. This will be taken into consideration in the design of the WTP.

Suspended Solids

Suspended solids or total suspended solids (TSS), is a measure of the concentration of solid particulate matter present in water (expressed as mg/L).

The TSS level in the produced water (at the wellhead) is predicted to range from 200 mg/L to 500 mg/L with the CR06 sample showing a figure of 276 mg/L. Although these are elevated TSS levels, it is not likely to be of concern since detention and pre-treatment at the CPF will deal with all particulate matter.

It is anticipated that after the wellfield establishment phase the TSS will settle down to a low to moderate level. Also any TSS in the raw produced water will settle out in the receiving water pond. Water transferred from the receiving water pond to the pre-treatment process will be low TSS and should not have any detrimental impact on the proposed physio-chemical clarification Pre-treatment process.

Calcium

The low calcium content of produced water poses a potential constraint to the recovery of the RO system and to the operation of the downstream brine treatment process. It will be need to be addressed in the pre-treatment design.

Magnesium

Similar to the comment above for calcium, the low magnesium content of produced water poses a potential constraint to the recovery of the RO system and to the operation of the downstream brine treatment process. It will be need to be addressed in the pre-treatment design.

Silica

The silica levels in the produced water are predicted to range from 10 mg/L to 27 mg/L (with CR06 showing a figure of 13.7 mg/L). If the current silica level is representative of the produced water quality, over the long term, silica should not pose a constraint to high recovery RO or to the performance of the RO system. In the event that the silica level is found to be higher (i.e. up to the predicted maximum of 27 mg/L) this would pose a constraint for high recovery RO due to the potential for silica precipitation and fouling of the RO membranes. This would have to be addressed in the pre-treatment design.

Manganese

The manganese levels in the produced water are predicted to range from 0.3 mg/L to 1.0 mg/L with CR06 showing a figure of 0.475 mg/L. This is a relatively high manganese concentration. It would need to be removed by the pre-treatment system. The RO membrane manufacturers recommend that the manganese content in feed water be less than 0.1 mg/L to avoid RO membrane fouling.

Potassium

The potassium levels in the produced water at Gloucester are low with a predicted range of 8 mg/L to 18 mg/L, with CR06 showing a content of 12 mg/L. This potassium level is typical of produced water and should not pose any concern for the design and operation of the WTP.

Iron

The iron levels in the produced water are predicted to range from 30 mg/L to 70 mg/L, with CR06 showing a content of 37.8 mg/L. This is a high iron concentration but typical of natural groundwater. Iron would need to be removed by the pre-treatment system. The RO membrane manufacturers recommend that the iron content in feed water be less than 0.1 mg/L to avoid RO membrane fouling.

Strontium

The strontium levels in the produced water are predicted to range from 2 mg/L to 6 mg/L, with CR06 showing a content of 3.06 mg/L. High strontium levels in the RO feed water can limit the RO recovery and cause severe RO membrane fouling. This will need to be addressed in the process design for the pre-treatment to ensure a reduction of strontium in the RO feed water to trace levels.

Other Trace Metals & Inorganics

The arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, mercury, molybdenum, nickel, selenium, uranium and vanadium content of CR06 well water were below the limit of reporting for the particular metal, and do not present any issues with regard to WTP or to the target treated water quality requirement.

The aluminium, calcium, barium, copper, and zinc content of CR06 were at low levels and do not exceed the threshold values for irrigation water or stream discharge. However the barium content has the potential to cause scaling on RO membrane process so will need to be addressed by the technology provider in the design of the RO pre-treatment system.

Trace metals and inorganics are found in negligible concentrations in the produced water from the Gloucester Basin groundwater systems.

Fluoride

Fluoride is found in most natural waters at low concentrations 0.01 mg/L to 0.5 mg/L. The fluoride present in the produced water is predicted to range from 1.0 mg/L to 3.0 mg/L, with CR06 showing a content of 1.4 mg/L. The fluoride content in the treated water after RO desalination would be at negligible levels (say less than 0.03 mg/L) so fluoride would not be of concern for the proposed beneficial uses of treated water.

Boron

The boron present in the produced water is predicted to range from 0.2 mg/L to 0.5 mg/L with CR06 showing a content of 0.27 mg/L. The boron content in the treated water after RO desalination is expected to be at levels less than the adopted irrigation and aquatic ecosystem threshold levels so boron should not be of concern for the proposed reuses.

In the event that the boron content in the produced water is elevated, the reduction of boron, using RO membranes that have been specifically developed for produced water to achieve a higher boron removal (i.e. boron rejection greater than 90%) than conventional RO membranes (i.e. boron rejection nominally ranging from 70% to 80%) could be utilised in the RO desalination plant to ensure that the boron content is below the threshold level for aquatic ecosystems.

7. Stakeholder Consultation

Under Condition 3.12 of the Part 3A Project Approval, AGL must consult with the:

- Department of Industry and Investment (DII) - now Department of Trade and Investment (DoTI) – Division of Resources and Energy (DRE) and the Office of Coal Seam Gas (OCSG);
- NSW Office of Water (NOW);
- Hunter-Central Rivers Catchment Management Authority (HCRCMA) - now Hunter Local Land Services (HLLS);
- Department of Environment, Climate Change and Water (DECCW) - now Office of Environment and Heritage (OEH) and Environment Protection Authority (EPA); and
- relevant Councils.

The development of the EWMS must be to the satisfaction of the Director-General.

In addition to those nominated in the Project Approval, AGL has identified a number of key stakeholders who will be consulted during the development of the EWMS. The key stakeholders and their interest in relation to extracted water management are described in Sections 7.2 to 7.10.

Once the consultation is completed, the final EWMS will be submitted to the Department of Planning and Environment (DoPE) for information and to ensure that it is to the satisfaction of DoPE. Under Condition 21 of the EPBC Approval, the Commonwealth Minister will also be provided a copy of the EWMS.

7.1. Consultation Strategy

The proposed consultation strategy involves:

- Publishing and exhibiting the Consultation Draft of the EWMS on AGL's website;
- Holding workshops with Council, regulators and other government agencies;
- Releasing a Consultation Draft to the public via AGL's website;
- Organising community information sessions for the general public;
- Being available (via mail, phone or drop in to the local office) to answer any queries during the development of the EWMS;
- Finalising the EWMS and submitting it to the NSW and Commonwealth Government for their assessment/approval; and
- Publishing the final EWMS after it satisfies the expectations of DoPE.

AGL will also proactively inform the media and community about the strategy for produced and flowback water in order to address any concerns in the community regarding:

- Salinity/salt loads from produced water;
- Potential impacts from our operations e.g. water affecting local river systems;
- Differentiating ongoing activities from the current Tiedman irrigation program, which is using blended water; and
- The sustainability of the preferred practices.

The proposal and timetable is to:

- Present a full consultation draft EWMS to the NSW regulatory agencies and local government (Workshop 1 – 13 August);
- Exhibit the consultation draft publicly for 28 days (from the 21 August);
- Allow 5 weeks for all comments to be received (to 19 September);
- Analyse submissions and produce a final draft of the EWMS (in October);
- Hold a follow up workshop with regulatory agencies for comments (Workshop 2 – in early October);
- Finalise EWMS (in November);
- Submit EWMS to DoPE for their assessment (in December);
- Submit to Commonwealth Minister for Environment for their assessment (in December); and
- Publish the EMWS on AGL's website (after State and Commonwealth assessments).

7.2. Division of Resources and Energy (DRE)

NSW Department of Trade and Investment (DoTI) is the lead economic development agency in New South Wales responsible for driving sustainable economic growth across the state. The Division of Resources and Energy (DRE) is an integral part of the DoTI and is responsible for delivering policy, programs and compliance for the NSW Government across the minerals and energy sector. Its functional responsibilities are:

- Mineral Resources;
- Energy;
- Strategic Policy and Coordination;
- Mine Safety Performance; and
- Investment Attraction & Development.

In regard to CSG activities, DRE is responsible for geological mapping, exploration activities, and is the repository of all the geological data collected across NSW (including well completion reports and data).

It is expected that the DRE will provide minimal advice on the Draft EWMS and how it relates to the Petroleum (Onshore) Act and title requirements.

7.3. Office of Coal Seam Gas (OCSG)

In early 2013, the NSW Government set up the Office of Coal Seam Gas (OCSG) within the DoTI. The OCSG is responsible for:

- administering CSG titles and activity approvals granted under the Petroleum (Onshore) Act 1991 and associated assessments under the Environmental Planning and Assessment Act 1979;
- monitoring and auditing title compliance, including in relation to rehabilitation and security deposits;
- the application of workplace health and safety requirements under the Petroleum (Onshore) Act 1991 and the Work Health and Safety Act 2011 (WHSA) to petroleum operations; and

- general enforcement and compliance of CSG operations within these acts.

There is a single PEL 285 across the whole of the Gloucester Basin and AGL has made application for two PPLs across the approved Stage 1 GFDA.

Under the renewed PEL 285, there is a requirement to have a Produced Water Management Plan (PWMP) for prospecting operations with the potential to generate more than 3 ML/yr of produced water. A similar condition is expected to apply to each of the PPLs when granted.

This EWMS will be the PWMP (or the basis for the PWMP) for the new Stage 1 PPLs when granted.

It is expected that the OCSG will provide advice on the Draft EWMS in relation to compliance requirements associated with the PPLs that will apply across the Stage 1 GGP area.

7.4. Land and Water Commissioner

The New South Wales Land and Water Commissioner was appointed by the NSW Government in 2013 to provide independent advice to the community regarding exploration activities on Strategic Agricultural Land throughout the state.

The role of the Land and Water Commissioner is to build community confidence in the processes governing exploration activities in NSW and to facilitate greater consultation between government, community and industry.

The Land and Water Commissioner has shown a strong interest in the Gloucester Gas Project, currently chairs the Gloucester Dialogue, and advocates stronger discussion with the community on land use practices and water reuse opportunities as outlined in this EWMS. A copy of this Draft EWMS has been sent to the Land and Water Commissioner for information.

7.5. Chief Scientist and Engineer (CSE)

In 2013, at the request of the NSW Government, the NSW Chief Scientist and Engineer (CSE) conducted a review of coal seam gas (CSG) related activities in NSW, with a focus on the impacts of these activities on human health and the environment. One of the key terms of reference was to:

- Identify and assess any gaps in the identification and management of risk arising from coal seam gas exploration, assessment and production, particularly as they relate to human health, the environment and water catchments

An initial report and a number of background papers have been prepared the Office of the CSE. Several of these relate to produced water and produced water management. The CSE will be invited to provide comment on the Draft EWMS.

7.6. Environment Protection Authority (EPA)

The EPA is the lead regulator of environmental and health impacts of CSG activities across NSW with responsibility for compliance and enforcement. All CSG activities, from exploration, assessment to production are now required to hold an environment protection licence (EPL) issued by the EPA. This is additional to the approval process and the requirements of the OCSG, NOW and the DRE.

EPA will need to grant an amended EPL required to implement the EWMS e.g. the criteria for the reuse of treated water for irrigation and the criteria for the discharge of treated water to streams.

The expected focus will be on locational principles and soil/water monitoring aspects of the EWMS proposal.

7.7. NSW Office of Water (NOW)

The NSW Office of Water (NOW) is part of the Department of Primary Industries and is responsible for the investigation and management of surface water and groundwater resources across NSW. They administer the Water Sharing Plans across the state and specifically the necessary licensing requirements under the Water Management Act (2000) and Water Act (1912).

Under the Aquifer Interference Policy, NOW is tasked with assessing water reuse and disposal methods of produced water associated with CSG developments (specifically in relation to impacts to surface water and groundwater).

It is expected that NOW will provide advice on the Draft EWMS in relation to general catchment (water resource) attributes in the vicinity of the reuse and disposal infrastructure and any implications under our existing industrial and irrigation licences and works approvals.

7.8. Hunter Local Land Services (HLLS)

Hunter Local Land Services (HLLS) have a role to play in natural resource management, water and soil management issues on a catchment scale. HLLS consult with local communities, including landholders and Aboriginal groups, to develop strategies for natural resource management for the 11 respective regions across NSW. Until Local Strategic Plans are developed, existing Catchment Action Plans that were developed under the previous Catchment Management Authority model continue to apply.

It is expected that HLLS will provide advice on the Draft EWMS in relation to general catchment attributes, health, and environmental receptors in the vicinity of the reuse and discharge infrastructure.

7.9. Gloucester Shire Council (GSC)

Gloucester Council represents the interests of the rate payers of the shire and has a strong interest in these projects and the associated impacts on ratepayers and the local environment.

Gloucester Council has employed a Water Scientist to undertake a Water Study Project which includes managing a number of specialist studies under a cooperation agreement that commenced in October 2013. The components of the Water Study are:

› Baseline water study;
› Flood study;
› Produced water study; and
› Peer reviews.

Council is also looking at encouraging new industries and investment under its Economic Development Committee initiative. The primary objective of this Committee is to promote sustainable economic growth within the Gloucester Shire.

The recently released produced water study is the background evaluation of produced water management options that is described in Section 4.1. Council is actively providing an important link and encouraging dialogue between industry and community on a range of matters associated with the GGP. Council is also identifying potential opportunities for the use of treated water to encourage economic growth in the local government area. It is expected that Council will provide a detailed submission on this Draft EWMS.

7.10. MidCoast Water (MCW)

MidCoast Water (MCW) is the water supply authority delivering reticulated supplies to consumers across the Manning and Karuah River basins. Their Mission Statement is to manage the provision of sustainable water related services to meet community needs. In regard to the environment, MCW is all about conserving resources, protecting and enhancing the natural environment and is particularly focused on water cycle management.

It is expected that MCW will provide advice on the Draft EWMS in relation to their water supply infrastructure and protecting the health and attributes of surface water resources and groundwater resources that are protected and used (or have the potential to be used) for public water supply.

7.11. NSW Health

NSW Health is responsible for the public health system across NSW.

A copy of the EWMS will be sent to NSW Health for comment.

7.12. Broader Community

The broader community are also invited to comment on the Consultation Draft of the EWMS. The document once publicly released, will be exhibited for a period of 28 days, and will be placed on our Gloucester Project web site with a call for submissions. AGL will advertise that the document can be downloaded from this site.

www.agl.com.au/gloucester

The following organisations will also be advised that the document is available for comments:

- Gloucester Community Consultative Committee (GCCC);
- Gloucester Dialogue; and
- Advance Gloucester.

'Drop in' sessions are also being organised for interested parties to ask AGL staff questions regarding the EWMS and AGL's preferred reuse strategies.

Submissions on this Draft EWMS can be sent to:

Postal address:

AGL Upstream Investments Pty Ltd
Submission – Gloucester Gas Project EWMS
Locked Bag 1837
St Leonards NSW 2065

Email address:

gloucester@agl.com.au

AGL is also seeking early "Expressions of Interest" for the reuse of desalinated water and mixed salt.

8. Existing Water Management Infrastructure

AGL has some existing infrastructure to gather, store and treat fresh water and produced water. Existing water management infrastructure is located on the Tiedman and Pontilands properties and includes the following:

› Three 20 ML lined water storage ponds;
› An underground pipeline network linking the local pilot wells to the ponds;
› A pump station located on the Avon River and pipeline to the Tiedmans ponds;
› Pontilands Dam (50 ML storage) and associated pumps;
› A pipeline from the Pontilands Dam to the Tiedmans ponds;
› A pump station between the two western Tiedman ponds to transfer water between dams and to the irrigator;
› A pipeline to transfer river water to the ponds; and
› Irrigation infrastructure.

8.1. Water Supply Pumps and Ponds

Avon River Pumping Station

AGL holds a Water Access Licence (WAL), which allows extraction of up to 32 ML per year from the Avon River. A pump station licensed under a combined works approval for irrigation purposes has been constructed to extract water from the Avon River under this license (refer **Figure 8.1**).

Figure 8.1: Pump Site on the Avon River (Fodder King, 2013)

Pontilands Dam

AGL holds a WAL, which allows extraction of up to 20 ML per year from this large dam on an unnamed gully that drains to the Avon River. A new combined works approval has been lodged with NOW to use this water for industrial, irrigation and stock purposes.

Water Gathering Network

Produced water is separated from the CSG gas at each wellhead. Locally, the produced water from the pilot wells is conveyed to the Tiedman property via a buried pipeline network. For more remote sites, produced water is brought to site by road tankers.

Water Storage Ponds

AJ Lucas constructed two 'turkey nest' ponds at the Tiedman property to store fresh water and extracted water. An additional storage (Tiedman East Dam – TED) was constructed by AGL in 2013 and is a double lined dam with seepage control.

Each pond is fully enclosed within above-ground embankments. Each has a full supply capacity of 20 ML and each is lined with a high-density polyethylene (HDPE) membrane. A list of the ponds and their function is provided in **Table 8.1**. The ponds at the Tiedman property will be utilised in the proposed irrigation water management strategy.

Table 8.1: Summary of Existing Water Storage Ponds at the Tiedman Property

Name	Volume (ML)	Current Function	Proposed Function	Lining
Tiedman North Dam (TND)	20	Storage of extracted water from pilot wells	Storage of freshwater from the Avon River or treated water from the CPF	Single lined with a HDPE membrane
Tiedman South Dam (TSD)	20	Storage of blended water	Storage of freshwater from the Avon River or treated water from the CPF	Single lined with a HDPE membrane
Tiedman East Dam (TED)	20	Storage of fresh water	Storage of extracted water from pilot wells	Double lined with a HDPE membrane

The ponds are only filled by reticulation and direct rainfall within the embankments. Therefore the ponds have minimal impact on surface runoff and do not reduce catchment flows.

8.2. Irrigation areas

AGL is currently undertaking the irrigation of (blended) produced water and fresh water at the Tiedman property across two small areas known as Stage 1A (12 ha) and Stage 1B (4 ha). Details are provided in Section 3.1. The approved stages under the Tiedman Irrigation Program REF are described in

Table **8.2**. The Stage 2 area (also covered under the existing approval) is unlikely to be developed at this time.

Under the broader irrigation scheme for the Stage 1 GFDA both the Stage 1A and 1B areas will be expanded. Treated water would be used for irrigation rather than blended water which will mean that low salinity desalinated water will be used for irrigation rather than blended water.

Table 8.2: Approved Irrigation Stage at the Tiedman Property

Name	Active Irrigation Area (ha)	Likely to be Expanded as part of Stage 1 GFDA	Viable Irrigation Area (ha)	Current Irrigation Method
Stage 1A	12	Yes	~20	Linear-move irrigator
Stage 1B	4	Yes	~20	Travelling irrigator
Stage 2	Nil	No	Would need to be assessed	None

The irrigation program at the Tiedman property currently uses produced water from AGL's exploration activities blended with fresh water. AGL has approval to irrigate up to 70 ML of produced water over a period of two years. The current approval expires on 30 April 2015.

An aerial view of the Tiedman property is shown in **Figure 8.2**.

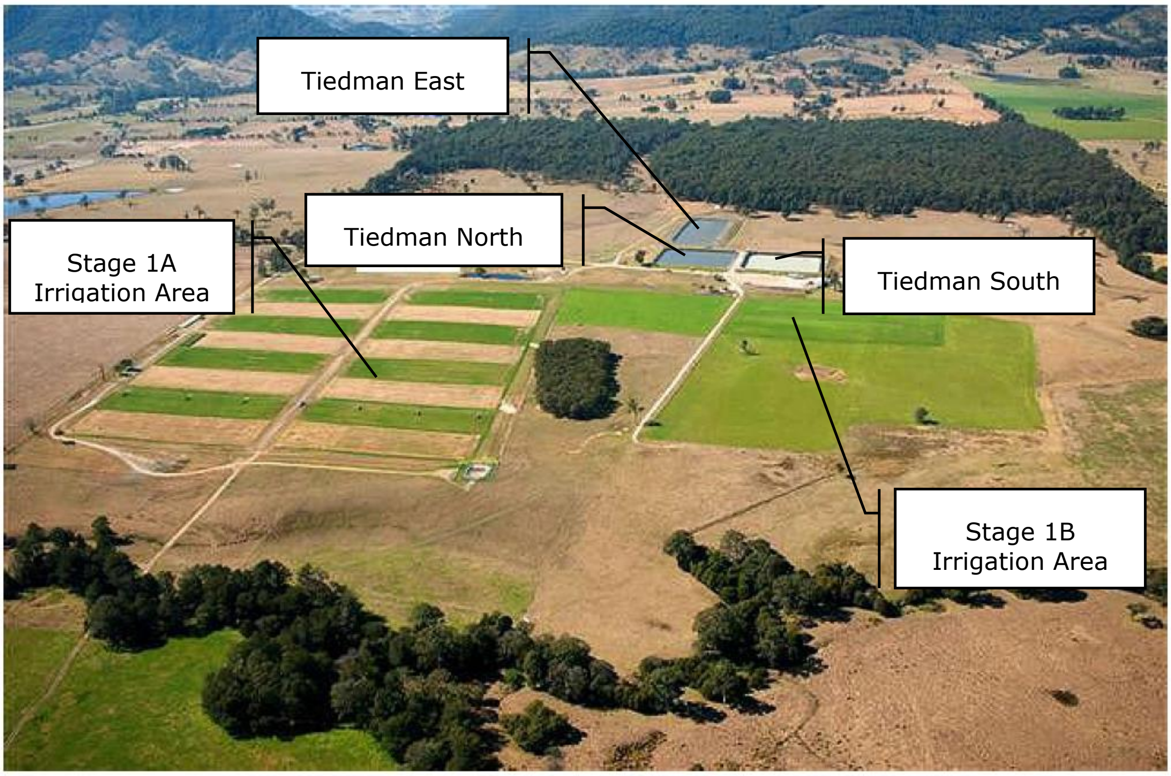


Figure 8.2: Aerial View of the Tiedman Property showing Pond Locations and Irrigation Areas Stage 1A & 1B (Fodder King, 2013)

9. Proposed Water Management Infrastructure

The EWMS detailed in Section 5 requires additional infrastructure to gather and store produced water, and to treat, reuse, and dispose of desalinated water. There are also additional infrastructure requirements associated with the many beneficial reuse options and opportunities. Key additional infrastructure requirements include:

- Gathering and distribution pipelines;
- Receiving water pond;
- Pre-treatment facility;
- Water treatment plant;
- Brine treatment plant;
- Treated water pond;
- Discharge water pond;
- Irrigation infrastructure; and
- Stream discharge infrastructure.

The location of the proposed CPF site relative to the Tiedman property is shown in **Figure 9.1.** An indicative footprint of the CPF site with the highlighted WTP infrastructure is shown in **Figure 9.2**. The indicative location for the water storage ponds is south of Parkers Rd together with a small potential irrigation area.

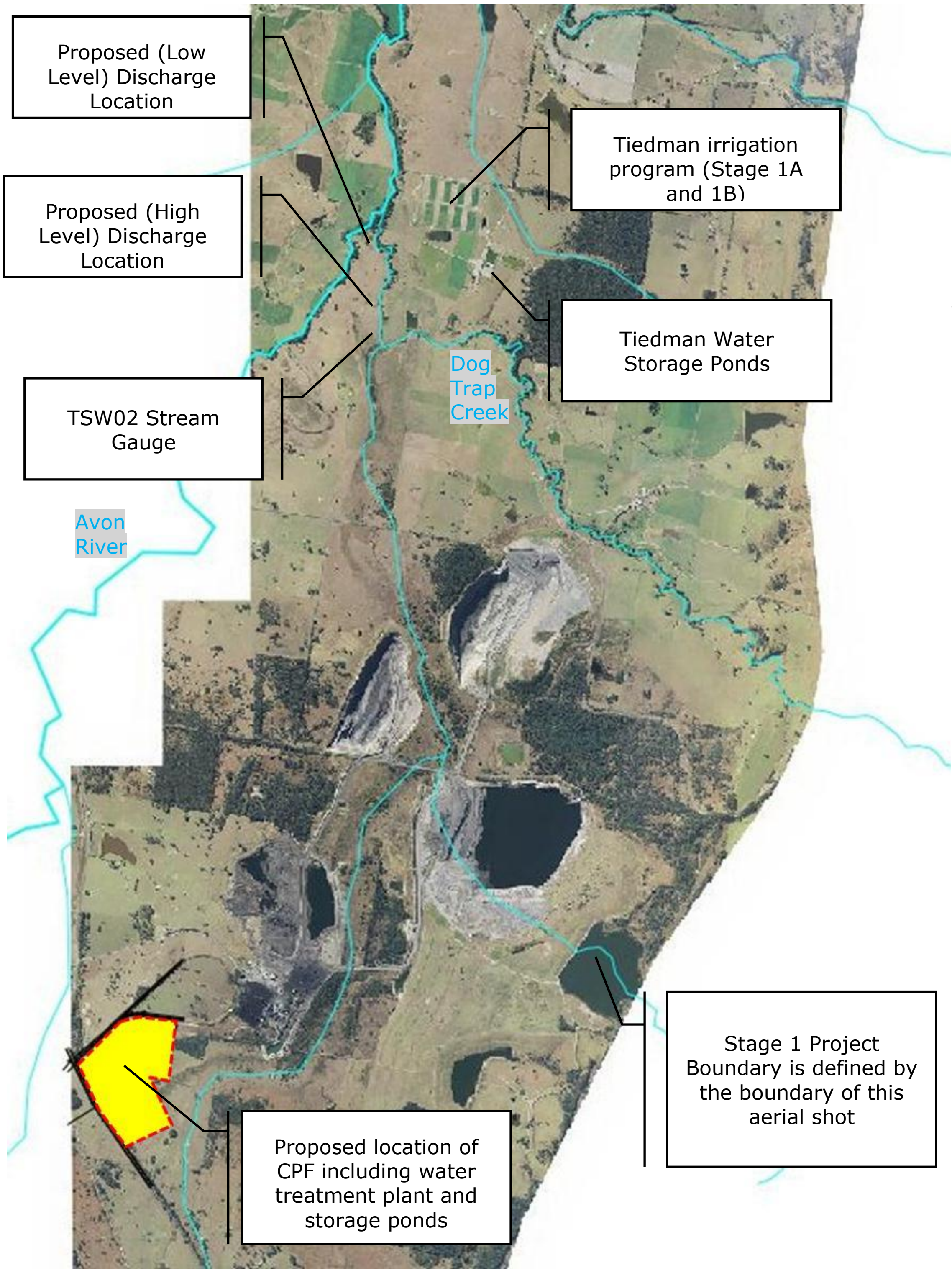


Figure 9.1: Proposed CPF Location Relative to the Tiedman Property within the Stage 1 GFDA

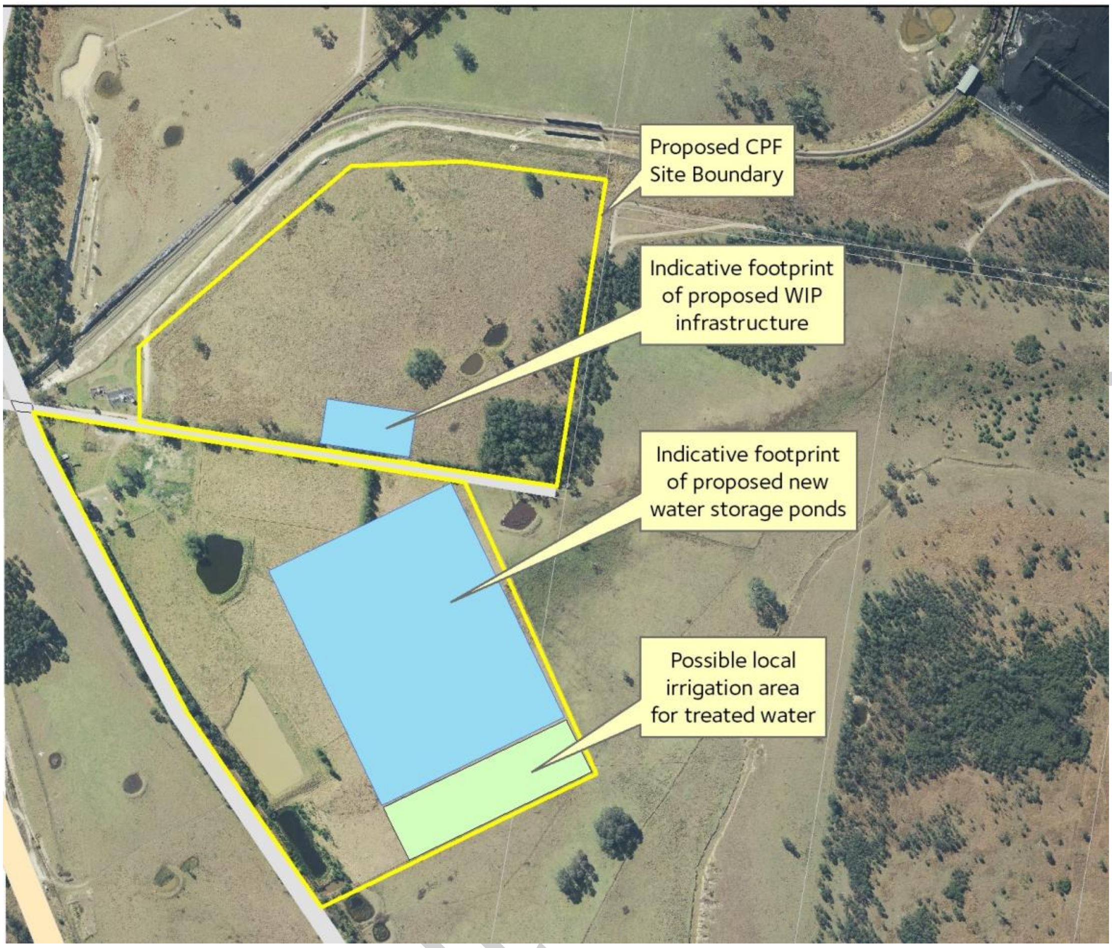


Figure 9.2: Indicative Layout of CPF Water Infrastructure
(layout is subject to final design and approval)

9.1. Water Infrastructure Flow Schematic

A simplified block flow diagram is provided in **Figure 9.3**, which gives an overview of all the water management infrastructure.

NODE	DESCRIPTION
1	PRODUCED & FLOWBACK WATER
2	WTP FEEDWATER
3	WORKING WATER
4	WTP TREATED WATER
5	IRRIGATION WATER
6	RIVER DISCHARGE
7	PROCESS WATER TO CPF
8	REUSE FOR STOCK

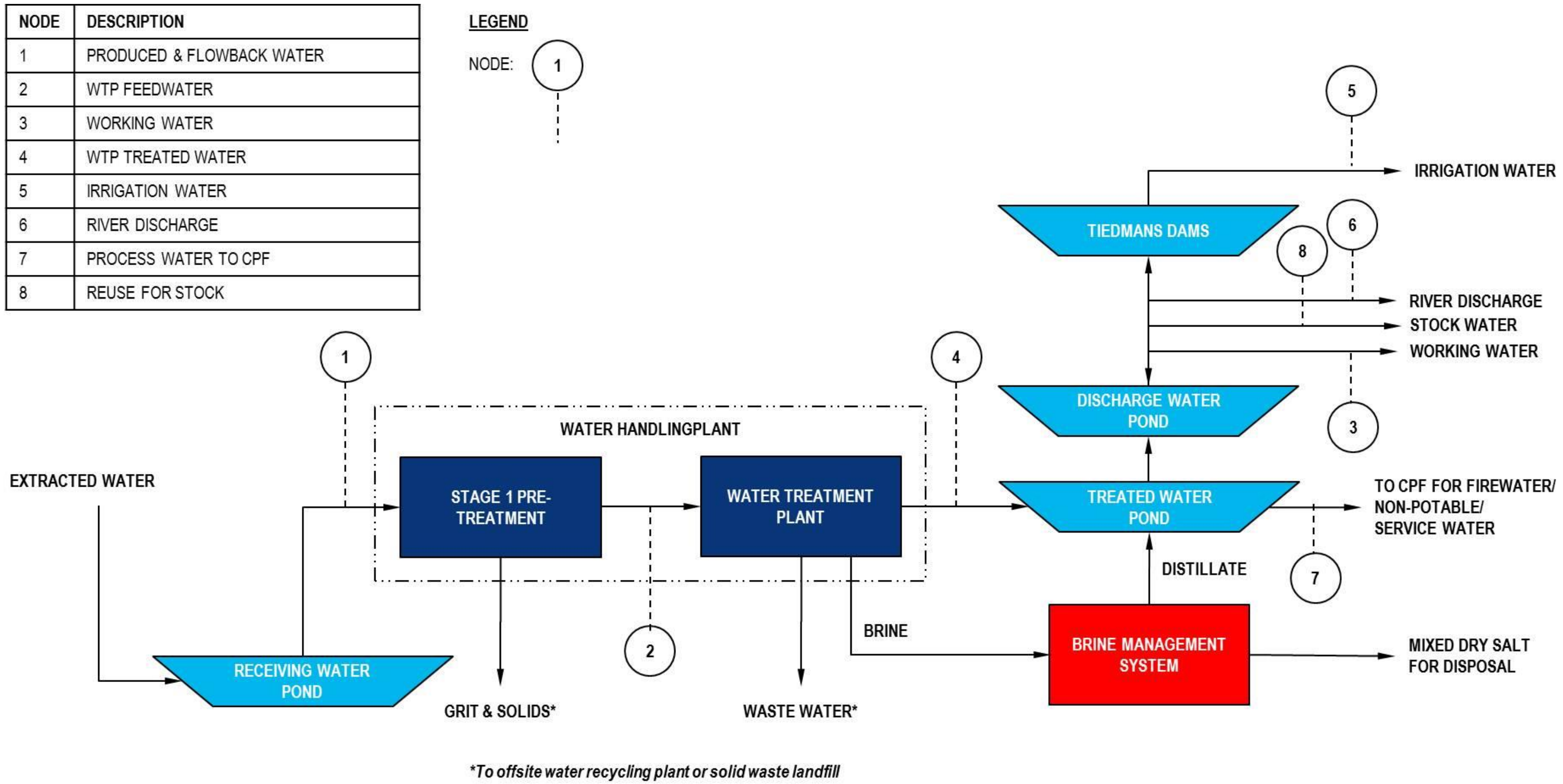


Figure 9.3: Water Infrastructure Flow Schematic

9.2. Storage Ponds and Tanks

Additional water storage ponds and tanks will be required as part of the extracted water management strategy. The additional ponds and tanks will be located at the CPF and will store the following:

- Extracted water;
- WTP feedwater (pre-treatment water);
- WTP treated water (RO treated water); and
- WTP discharge water (RO conditioned water).

AGL has approval to construct up to three new ponds at the proposed CPF site. Each pond may have a full supply volume of up to 25 ML.

The following new ponds and tanks are proposed:

- Receiving Water Pond (25 ML);
- Treated Water Pond (25 ML);
- Discharge Water Pond (25 ML); and
- Brine Storage Tank (2 ML).

The three existing ponds and irrigation infrastructure at the Tiedman property will be retained. None of the water storage ponds at either the CPF site or at the Tiedman site are located within the floodplain of the Avon River and its tributaries.

The three proposed ponds will be constructed by cut and fill excavation up to 3 m deep and embankment surrounds up to 3 m high. New ponds will be double lined with an HDPE membrane to reduce the potential for seepage. There will be a filter mesh between the dual layers of each of the dams, together with seepage control, inspection sump and pump out capability.

New ponds developed as part of the GGP will be lined and have level detection systems and will be designed to a 1-in-100 year flood design standard. A description of the proposed new ponds and tanks is provided below.

9.2.1. Receiving Water Pond (25 ML capacity)

The Receiving Water Pond (RWP) will receive extracted water delivered in from a water gathering network. The RWP will also receive process water that has been treated by an oily water separator in other parts of the CPF. Process water inflows are expected to be relatively minor (less than 0.01 ML/d). A floating pontoon pump station will be installed in the RWP to transfer water to the pre-treatment system.

The RWP would be operated to reduce storage and maximise capacity to store inflows. The expected daily inflow to the RWP is approximately 2 ML/d although there could be small periods in excess of 2 ML/d when new wells are brought online. The WTP would have a treatment capacity of greater than 2 ML/d. The RWP will therefore have a capacity to detain extracted water inflows for up to 10 days during the high water production period (and for much longer periods during low water production periods) should there be any disruption to WTP operations.

9.2.2. Treated Water Pond (25 ML capacity)

The Treated Water Pond (TWP) will receive treated water from the WTP. The TWP is expected to receive a peak inflow of less than 2 ML/d. A floating pontoon pump station will be installed in the treated water storage pond to transfer treated water to the Discharge Water Pond for irrigation, discharge to the Avon River, or for other uses at the CPF. Water for fracture stimulation purposes (initial field development only) will be taken directly from the treated water pond.

9.2.3. Discharge Water Pond (25 ML capacity)

The Discharge Water Pond (DWP) will receive treated water from the TWP. The DWP is expected to receive a peak inflow of around 1.8 ML/d.

There may be two cells within the DWP to separate treated water for irrigation and for stream discharge as this will require different water qualities. Stock water could be taken from either cell.

If there is any final adjustment of water quality required for either irrigation or stream discharge (e.g. to minimise any residual sodium hazard) then it would occur at this pond.

A floating pontoon pump station will be installed in the DWP to pump water to the Tiedman irrigation area and to the surface water discharge outfall as required.

9.2.4. Brine Storage Tank (2 ML nominal capacity)

The brine storage tank (BST) will receive RO concentrate from the WTP. The RO brine concentrate will be highly saline with a predicted TDS concentration in the order of 60,000 mg/L which is about 50% more saline than sea water. The maximum RO brine concentrate flow received by brine storage tank is expected to be approximately 0.2 ML/d. This maximum flow rate is expected to occur towards the end of the initial development phase, as more wells come online.

The BST has been sized for a 10 day detention time at maximum production rate to allow for any variations in received flows and for brine concentrator plant outages.

9.3. Extracted Water Treatment System

The WTP will operate 24 hours a day seven days a week and will be upsized/downsized as required.

9.3.1. Pre-treatment System

A pre-treatment system with a 2 ML/d maximum design flow rate will be provided to treat flowback water and produced water. This will remove physical and biological contaminants to provide appropriate quality water suitable as feed water to the WTP.

9.3.2. Water Treatment Plant (WTP)

A WTP is proposed to desalinate extracted water via RO. The WTP is a key component of the extracted water management strategy. The WTP would be designed with a modular configuration to accept a flow rate of 2 ML/d with a high degree of redundancy. For the majority of the production phase period, the WTP would operate at less than 50% of its design capacity and therefore provide redundancy. The proposed WTP modular design allows the facility to be flexible, contractable/expandable, and easily reconfigured, so that it can adapted to meet the changing needs over time.

The WTP would treat extracted water that has been through the pre-treatment system to a raw water quality suitable for working water as well as the preferred beneficial reuse and disposal options, namely:

› General domestic (for the CPF);
› Stock;
› Irrigation; and
› Managed discharge to surface waters.

Some final water conditioning may be required at the discharge water ponds to ensure that the water quality is suitable for stock, irrigation and stream discharge and is within the adopted thresholds proposed by this EWMS.

The brine resulting from the WTP will be further treated as discussed in Section 9.5.

As shown in the **Figure 9.2**, the WTP will be located within the CPF off Parkers Road in close proximity to the intersection point of Bucketts Way and Parkers Road.

9.4. Brine Treatment

Based on the composition of produced water and the design of the WTP, it is estimated that several hundred megalitres of brine will be produced from the WTP over the life of the project.

A preliminary review of a wide range of brine management and treatment options was undertaken which identified thermal evaporation technology as the preferred brine treatment process option for the GGP to produce a dry mixed salt. The brine management plant (with a nominal design capacity of 0.2 ML/d RO brine concentrate feed flow rate) will comprise a brine concentrator and brine crystalliser, and be capable of treating the entire brine stream.

The salt produced from the thermal brine management system will be handled on site by an appropriate salt handling system. The dry mixed salt will be contained in 1 tonne nominal capacity bulkabags for truck transfer for off-site disposal by road transport to a licensed landfill. It is expected that a maximum of two trucks per week would be required at peak production but this would reduce to one truck per fortnight for the longer term.

9.5. Gathering and Distribution Systems

The type of pipelines required for managing the production, treatment and distribution of extracted water are described below:

9.5.1. Water Gathering Pipelines

A low pressure water gathering system will connect each well to the CPF. Extracted water will go directly into the RWP. During the field development period, all collected flowback water/produced water will be transferred to the RWP for sediment removal and treatment.

These lines will be co-located with the gas gathering network.

9.5.2. Transfer Pipelines

Transfer pipelines, including associated pumps and controls will be constructed to connect ponds located within CPF treatment facilities.

All water and transfer systems required by the CPF (or generated by the CPF such as domestic sewage and stormwater) will be dealt with onsite as part of the detailed design.

9.5.3. Transfer of Treated Water to Wells and to the Tiedman Property

A separate line will also be installed to deliver working water to new wells for fracture stimulation and existing wells for workovers. This return line will be parallel to the water and gas gathering system. This line may also deliver stock water.

Treated water from the WTP will be stored in the TWP and then transferred to the DWP for any final water conditioning. This water will be transferred from the DWP via a pontoon mounted pump station and pipeline for the following uses:

› Irrigation Water: To the water storage ponds on Tiedmans via a separate distribution line.

› Discharge to Avon River: An offtake from the distribution pipeline (delivering treated water to Tiedman property for irrigation) will deliver treated water for discharge to the Avon River.

These lines will be collocated with the gas gathering network where possible.

9.5.4. Miscellaneous Distribution Pipelines

It is envisaged that the following additional transfer pipelines will be required:

› Upgrade of irrigation network: As a result of new irrigation area development, the irrigation network will need to be upgraded and expanded. This will require the addition of pumps and pipelines to supply treated water to the irrigation areas at Avondale, Tiedman, Pontilands and Rombo.

› Future offtakes for private agricultural and industrial/commercial users: There may be a future demand for treated water for private agricultural and industrial customers. As a consequence, provision may be made for the 'tees' to be installed in the treated water pipeline (with blanked flanges) to allow connections for offtake pipelines in the future.

9.6. Reuse and Discharge Infrastructure

9.6.1. Irrigation

Some 60 ha of irrigation area has been identified at the start of the project for the irrigation of treated water, although a slightly larger area may be developed to allow for crop rotation. A number of irrigation areas on AGL-owned properties have been identified as being prospective. It is expected that there will be several irrigation areas that are between 10 ha and 20 ha in size and spread across the AGL-owned properties of Avondale, Tiedman, Pontilands and/or Rombo. There may be some rotation between irrigation areas.

The final agricultural layout, crop types and irrigation strategy will be described in a farm master plan that focuses on the possible irrigation areas. Other properties in the vicinity of the CPF will also be considered for irrigation.

The possible irrigation areas on AGL-owned properties are shown on **Figure 9.2** (CPF at Rombo) and on **Figure 9.4**.

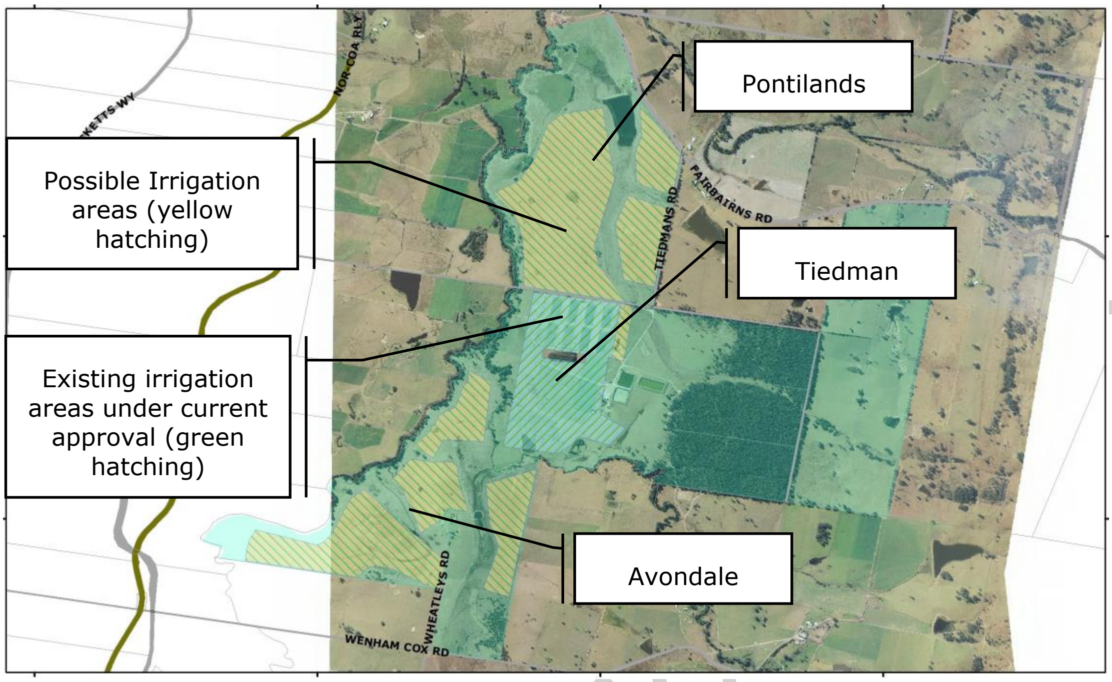


Figure 9.4: Existing and Proposed AGL Irrigation Areas for Treated Water

9.6.2. Stream Discharge

Discharge of high quality treated water to streams (when no other options are available) generated the greatest amount of regulator and water supply authority discussion. Importantly, water quality for any stream discharges will either mimic stream water quality or drinking water quality (subject to negotiations with EPA and approvals under AGL's EPL).

Stream discharge of high quality treated water is proposed in those seasons with very high rainfall events. This option is a last resort if irrigation and stock watering are not possible and all water storages are full. Discharges will be to Dog Trap Creek near the confluence with the Avon River. Two locations have been identified (see **Figure 9.1**) near the proposed water gathering and water distribution network. The low level discharge location is proposed for releases during low or zero stream flow periods. The second location is approximately 100 m upstream and is proposed for releases during extreme wet periods when irrigation is not possible.

AGL treated water releases are expected to be no greater than 1.5 ML/d and mostly during high flow situations. The proposed sites have been selected as they have the following characteristics:

› Low gradient from river bank to stream bed;

› Stable bank characteristics; and

› Works will not to impede flows.

Discharge and flows will be across gravel or rocky bedload materials so as not to cause gullying or erosion.

9.7. Aquifer Storage and Recovery

The following is a review of reinjection of produced water that is provided in response to Condition 21 of the EPBC Act (EPBC 2008/4432) approval for Stage 1 of the GGP.

Aquifer Storage and Recovery (ASR) is a prospective reuse/disposal strategy for treated and untreated produced water when the geology and hydrogeological characteristics of a sedimentary basin are suitable. If there are suitable conditions, the potential opportunities are:

› Deep Disposal - Disposal of untreated water/brine to deep groundwater systems when there is sufficient storage/confining layers and there is no connectivity to beneficial aquifers and environmental receptors; and

› Shallow Storage and Recovery - Recharge of treated water to shallow beneficial aquifers when there is sufficient storage and permeability characteristics for later recovery and use.

At Gloucester neither the geology nor the hydrogeology are suitable for deep disposal or shallow storage and recovery. From a geological perspective:

› The rock types are mostly coal seams, and consolidated siltstones, mudstones and conglomerates;

› There are no known permeable formations (such are porous sandstones);

› The basin is deformed with many high dip areas and faulted compartments;

› There are no (conventional) deep structural reservoirs with competent cap rocks over large areas where containment could be guaranteed;

› All rock types are consolidated with faults and fractures the main defects in the rock mass; and

› The rocks would have to be hydraulically fractured to create any reasonable storage for injected water.

From a hydrogeological perspective:

› The groundwater system storage characteristics are low;

› All the rock permeabilities are low;

› The groundwater systems are full (there are no depleted storage areas);

› The water quality is poor in all aquifers and water bearing zones;

› There is minimal groundwater use therefore storing fresh water in shallow aquifers and then trying to reuse this water is unlikely to be taken up by local landowners;

› If untreated/brine water was injected under pressure into deeper groundwater systems, the formations would not accept much water because of the required high pressures, low storage and low permeabilities;

› If treated water was injected into the shallow fractured rock groundwater systems (beneficial aquifers to ~ 75 m depth) then again there is limited storage and any injected volume would displace a similar volume of slightly saline water into the landscape. It is also uncertain as to what degree of mixing would occur and whether water quality could be maintained; and

› If treated water was injected or drained into the shallow alluvial aquifers again there is limited storage and any recharged water would drain into the Avon River or displace a similar volume of brackish to slightly salty water into nearby rivers (mainly the Avon River).

There are other impediments to ASR type schemes including:

› The construction of additional bores/wells that may require fracture stimulation;

- Reinjection of produced water to deep water bearing zones and shallow beneficial aquifers would require additional environmental approvals;
- Reinjection into groundwater systems is specifically banned under the Part 3A approval for Stage 1 of the GGP; and
- Re-pressurising the intermediate and deep coal seams would diminish gas production.

In conclusion, there are negligible prospects of being able to dispose of moderate volumes of untreated produced water, brine or treated freshwater to any of the groundwater systems within the Gloucester Basin. If produced water volumes reduced to very low volumes (say less than 0.1 ML/d) then ASR could be re-evaluated (together with other low volume options) to access its suitability on a local scale. Disposal schemes rather than reuse schemes would be the focus given there is negligible groundwater use across the basin at this time and the likelihood of groundwater development occurring (given the reliability of rainfall and surface water runoff) is low.

9.8. Management of Excess Produced Water

There are two potential issues associated with the unlikely possibility of having to deal with produced water volumes in excess of 2 ML/d. Exceedances of this rate for a few days or weeks as new wells are commissioned is not an issue as there is sufficient storage capacity at Tiedmans and at the CPF for the higher flows. However there may be resource and longer term storage issues if the higher rate of extraction occurred for an extended time. The associated extracted water management issues are:

- Lack of water treatment capacity at the CPF;
- Lack of storage capacity with the wellfield; and
- Insufficient irrigation area.

The WTP at the CPF will be sized to treat a produced water flow rate in excess of 2 ML/d. This is because some day to day variability is expected and some excess capacity is planned to ensure that the water treatment system is fully functional at all times.

A contingency allowance will be made in the WTP design, to cater for produced water flows greater than 2 ML/d such that the WTP would be able to accept a higher produced flow rate. Such a short term event would have minimal impact on operations. It is expected that the average produced water flow would not be exceeded over a one year period. If it was going to exceed this annual volume then AGL would need to apply for a project modification and for an increase in groundwater allocation. It is more likely that newer wells would be shut in or not brought on-line until water production rates diminished at existing sites.

There is also buffer storage for extracted water in-field at Tiedmans and within the large RWP at the CPF.

The WTP will be of a packaged modular flexible system that would be designed with adequate redundancy (e.g. 3 x 50% capacity process treatment unit trains) primarily to provide redundancy but would also enable it to readily accept higher than design produced water flow rates.

A lack of irrigation area is also an unlikely scenario as more than 60 ha of irrigable area will be available (although it is unlikely that more than 60 ha will be utilised at any one time) as well as the storages at the CPF and Tiedmans. If there was insufficient irrigation area and the flow conditions in the Avon River were suitable, then treated water could also be discharged to the stream to relieve the pressure on having to store treated water for an extended period.

9.9. Control Measures for Wildlife Access

The storage of produced water as part of the GGP infrastructure has the potential to impact on wildlife that could access the storage ponds. Wildlife access to ponds can also have detrimental impacts on the storage itself by damage to the pond lining and degradation of water quality.

The following control measures will be implemented for the water management ponds planned to be constructed at the CPF to prevent access of wildlife:

› Ponds will be fenced with a 2 m chain linked fence with 250 mm of the bottom fence buried to prevent animals digging below for access. Human and vehicle access will be provided with suitable locked gates.

› The ponds will be constructed as deep ponds to reduce the footprint and surface area.

With these control measures in place, wildlife and livestock, will not be able to access the ponds and will ensure that the produced water ponds do not pose a significant risk to wildlife.

Given the availability of alternate water sources in the area, including farm dams, creeks and rivers, and due to the presence of infrastructure and personnel at the CPF, it is considered unlikely that birds would preferentially utilise the new water storage ponds. Birds have not been an issue at the three similarly sized ponds at Tiedman to date. Netting of the dams will be considered as a contingency response if birds are wanting colonise any of the dams.

10. Treated Water Quality Targets

The water quality from the proposed desalination technologies will most likely be between 100 mg/L and 200 mg/L TDS although some desalination plants can achieve even lower salinities. The desalinated waters can be corrosive and dominated by ions such as sodium and chloride. To soften and rebalance the ionic ratios, some chemical additives are required depending on the final end water uses. These chemical adjustments add calcium, magnesium and carbonate ions back into the treated water to make it more suitable for different uses.

Water for beneficial reuse and stream discharge can be grouped according to the following five categories:

› Working water (for drilling, fracture stimulation and workover of wells);

› CPF process water;

› Stock water;

› Irrigation water; and

› Surface water discharge water.

For the purposes of this EWMS, a salinity level of 150 mg/L TDS has been assumed to be the most likely treated water salinity after desalination but with chemical dosing this salinity could increase to a maximum of 500 mg/L TDS. Less than 500 mg/L TDS is drinking water quality. Stock water qualities could be higher if required although it is likely that all water for all uses would have a salinity less than 500 mg/L. A summary of the target water quality criteria for the produced water reuses and discharge water is provided in **Table 10.1**.

Table 10.1: Target Water Quality Criteria for the Treated Water - Reuse and Discharge

Node	Description	Water Quality Criteria							
		Conductivity (µS/cm)	TDS (mg/L)	pH	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	Alk (mg/L)	SAR
1	Expected WTP Feed water	6,000 Initial 7,500 Ave 11,000 Max	4,800 Initial 6,000 Ave 9,000 Max	7.5 to 9.5	1,500 Initial 1,800 Ave	9 initial 12 Ave	4 Initial 6 Ave	2,000 Initial 2,500 Ave	Various
2	Working Water	200* to 7,000	150* to 5,000	6.0 to 9.0	-	-	-	-	-
3	CPF Process Water and Fire Water	200* to 650	150* to 500	6.5 to 8.0	To be determined				-
4	Stock water	200* to 2,000	150* to 1,500	6.0 to 8.0	To be determined – is dependent on type of stock				-
5	Irrigation Water	200* to 650	150* to 500	6.0 to 9.0	The criteria for these parameters cannot be defined at this time as this will depend on the agricultural conditioners which would be required (and the quantities of the conditioners) for maintaining or improving the soil.$^{\Delta}$				8 – 15
6	River Discharge Water	200* to 650	150* to 500	6.5 to 8.0	49 to 84	9 to 16	14 to 16	20 to 70	-

Notes: * Lower expected limit from the desalination plant but the actual target water quality may be slightly higher depending on amount of chemical conditioning required

Δ Irrigation water may not be required to meet nominated SAR requirements for crops since the soil may be conditioned at some sites. This would negate the need for the irrigation water to be within SAR target requirements for the specific crops.

10.1. Target Water Quality for Working Water

Extracted water will be treated in the pre-treatment system and then pass through the main WTP to produce a high quality treated water. Water at this low salinity will be delivered as working water even though higher salinity waters up to 5,000 mg/L TDS would be suitable for drilling, fracture stimulation and well workovers. **Table 10.2** shows the target water quality for working water.

Table 10.2: Working Water Quality Targets

Parameter	Unit	Range or Upper Limit
pH	pH units	6.0 to 9.0
Temperature	°C	5 to 38
Bicarbonates and Carbonates	mg/L	< 300
Hardness	mg/L	< 2,000
Iron	mg/L	< 10
Phosphates	mg/L	< 5
Sulphates	mg/L	< 1,000
TDS	mg/L	< 5,000

tbd – to be determined

10.2. Target Water Quality for CPF Process Water

Treated water will be used to meet the following non potable demands at the CPF:

- General use (e.g. toilets);
- Process water for compressors and cooling systems;
- Service water for wash down, maintenance, landscaping and dust suppression; and
- Fire water systems.

Minimal water conditioning is expected for this low volume reuse. Target water quality for these CPF process water demands are listed in **Table 10.3**.

Table 10.3: CPF Process Water Quality Targets

Parameter	Unit	Range or Upper Limit
TDS	mg/L	< 500
pH	pH units	6.5 to 8.0
Turbidity	NTU	< 5
Total Hardness	mg/L	< 200
Iron	mg/L	< 1
Manganese	mg/L	< 0.5
Aluminium	mg/L	< 0.2

10.3. Target Water Quality for Irrigation

It is anticipated that the treated water will require further conditioning by chemical addition (e.g. lime addition) to make the desalinated water suitable for irrigation. In particular the sodium adsorption ratio (SAR) is expected to be adjusted by adding calcium and/or magnesium to render this water suitable for long term irrigation. pH adjustment may also be required.

The RO desalination technology and the required conditioning will achieve a treated water quality that will meet irrigation water targets as shown in **Table 10.4**. For other analytes not listed the threshold values for irrigation water will apply (see **Table 2.5**).

Table 10.4: Irrigation Water Quality Targets

Parameter	Unit	Range or Upper Limit
TDS	mg/L	< 500
pH	pH units	6.5 to 9.0
Bicarbonate	mg/L	< 100
Fluoride	mg/L	< 1
Sodium	mg/L	< 460
Boron	mg/L	< 0.5
SAR		< 15

Conditioning of the treated water will be required to counteract the sodium content in the water and to ensure that the treated water SAR is less than 15.

Adding calcium and magnesium has been assumed as being required for the purposes of this EWMS, however it may be more economical and agronomically desirable to add calcium by surface application of lime and gypsum. Advantages include:

- calcium can be more evenly spread throughout the whole soil profile, than if it is applied in the irrigation water; and
- the use of lime and gypsum will avoid any potential problems of calcium carbonate precipitation in the spray irrigation equipment.

However the disadvantage is that the effectiveness of lime and gypsum soil applications will diminish over time and it will become uneven across the irrigation areas.

The final decision on whether to condition the water or the soils being irrigated has not been made.

No untreated produced water, which is likely to have much higher levels of salinity and SAR, will be used for irrigation.

10.4. Target Water Quality for Stream Discharge

It is anticipated that the treated water may require further conditioning by minor chemical addition to adjust the final water quality to render this water compatible with the water quality in the stream at the time of stream discharge.

The salinity of extracted water will be reduced by RO desalination technology to achieve a treated water quality that will meet stream discharge targets as shown in **Table 10.5**. For other analytes not shown, the ANZECC threshold values will apply (see **Table 2.6**).

Table 10.5: Stream Discharge Water Quality Targets

Parameter	Unit	Range or Upper Limit
TDS	mg/L	< 500
pH	pH units	6.5 to 8.0
Sodium	mg/L	< 84
Calcium	mg/L	< 16
Magnesium	mg/L	< 16
Alkalinity	mg/L	< 70

11. Irrigation

The application of treated (desalinated) water to irrigate crops and pasture has been identified as a preferred extracted water management option. Irrigation is a preferred option for the following reasons:

- It will provide a new source of water which is valued by the community and which will have tangible benefits to the agricultural products of the district;
- It offers sustainable, beneficial reuse of extracted water;
- It is a recognised extracted water management option;
- It may be scaled to respond to changing volumes and seasonal conditions;
- It is a proven technology; and
- It is cost effective (for a CSG project of this size).

Irrigation will be undertaken on hillside and alluvial flat locations (well away from water courses) at the Tiedman, Avondale and Pontilands properties and potentially at Rombo adjacent to the CPF.

Treated water that has been desalinated will be conditioned and used for irrigation rather than blended water, as has been recently used for the Tiedman irrigation program (see Section 3.1).

11.1. Benefits and Constraints of Irrigation

Benefits

The potential benefits associated with irrigation are to:

- allocate a high proportion of the treated water for irrigation (after the essential requirements of process water and stock water);
- provide economic benefits to landholders in the vicinity of the GGP;
- reduce pressure on existing water resources; and
- minimise the cost of transportation of water given that:
  - the pipework is part of the gas gathering and working water pipeline network; and
  - the proposed irrigation area is located in close proximity to the CPF and the Tiedman storage ponds.

Constraints

The constraints associated with irrigation are:

- irrigation rates are dependent on weather conditions (especially rainfall and runoff) which may fluctuate significantly; and
- irrigation application rates and usage is generally lower in winter when crop and pasture requirements are less.

Technical Considerations

To meet the water quality target for irrigation (see Table 10.4) the following technical factors will need to be taken into consideration:

- pH adjustment to maintain the pH of treated water to be within the desired pH range for irrigation of crops;
- The maximum treated water salinity will not exceed 600 µS/cm (i.e. a TDS of approximately 500 mg/L);
- The maximum SAR will need to be identified for site specific conditions but should not exceed 15;
- The maximum bicarbonate ion concentration will not exceed 100 mg/L (expressed as $CaCO_3$);
- The maximum fluoride concentration will not exceed 1 mg/L;
- The water application rate shall not exceed the water deficit in the soil profile;
- Irrigation will not be undertaken in circumstances where soil erosion is likely to occur; and
- Irrigation will not be undertaken at a rate that results in water run-off to permanent water courses.

11.2. Site Characteristics

Location

To manage the development of the Stage 1 GFDA, an expanded irrigation scheme of approximately 60 ha is proposed to be developed on AGL owned properties or nearby agricultural properties. An additional area of 40-50 ha is proposed to the existing 16 ha under irrigation on AGL's Tiedman property. Potential irrigation areas are shown on **Figures 9.2 and 9.4**.

Sizing of the individual irrigation areas will be determined using the following criteria:

- Efficient irrigation design and layout;
- Conflicts with existing and future gas infrastructure;
- Soil suitability, including; depth and soil nutrient deficiencies;
- Slope;
- Presence of rock outcrops; and
- Environmental considerations, including potential for soil erosion and drainage.

Soil structure

Soil structure describes the aggregation of soil particles (sand, silt, clay) and the pore spaces. Soil structure decline is a detrimental change in these soil characteristics as a result of land use. Soil structure decline increases run-off and the potential for soil erosion, which may reduce water quality. Soil compaction is one of the causes of structural decline and may have other impacts as well as reduced infiltration, such as poor crop establishment and poorer root systems.

Soil structure can be adversely affected by an increase in sodium levels compared to calcium (i.e. high SAR levels). This can occur as a result of high sodium being applied as irrigation water. Water and/or soils will be conditioned with extra calcium and magnesium to ensure that SAR is less than 15.

Crop selection

Crops such as lucerne, triticale and forage sorghum and pasture that includes kikuyu, ryegrass, clover and chickory are currently being trialled as part of the Tiedman Irrigation Program. These crops together with improved pasture are under consideration as they have been found to be suitable for the prevailing conditions. Even though the treated water that is going to be applied is high quality (i.e. low salinity), salt tolerant species are still under consideration because of the sodic and saline nature of the underlying soils.

The specific crops grown will be reviewed on an annual basis and may be modified to optimise water use and land management practices as well as in response to market demand.

Other issues that need to be taken into consideration are:

- **Water optimisation** - cereals can be planted in April/May each year and will utilise water over the winter period, while grain and sorghum crops can be planted in September/October and use water in the spring-summer period.
- **Crop rotation** - legume crops can provide a rotation break from cereal crops and fix nitrogen, thereby reducing the total requirement for nitrogen fertiliser.
- **Given market conditions** - other salt tolerant crops may be appropriate depending on the economics of supply and demand. It is expected that an annual review will be undertaken considering adjustment in response to market factors.

The balance between cropping and pasture is still to be decided.

11.3. Irrigation Methods

Methods

There are several irrigation methods which have control over the water application rates including drip, centre pivot and linear/ lateral move irrigators.

A small travelling irrigator and a large linear move irrigator have been used to date to intensively irrigate (up to 4 to 5 ML/ha/yr) the current irrigation area. A mixture of centre pivot, linear move and travelling irrigators is proposed for the expanded irrigation scheme.

No direct application of water to land by flood irrigation is proposed.

Reticulation and Storage

The three existing water storage ponds at Tiedman property (and current irrigation infrastructure) will be retained to provide operational storage and water balance capacity required for the containment of treated water, fresh water and produced water.

The TSD and TND storages will allow treated water from the WTP to be matched to crop demand. These storages will also allow water to be stored over winter or during wet periods if water is unable to be irrigated. If there is a demand for fresh water for fracture stimulation or other industrial uses then this may also be stored in either of these dams (although water is most likely to be taken from the large Pontilands farm dam).

The TED will (most likely) remain as an in-field storage for flowback water and produced water, although if there is no requirement for in-field storage, this dam may also be used to store treated or fresh water.

11.4. Irrigation Demand

Based on the irrigation program results to date to grow both summer and winter crops, approximately 4 ML/ha/year of irrigation water is required in an average season.

Irrigation demand has been determined based on average monthly rainfall and evaporation data and represents typical irrigation demand in a given year. There is potential for actual irrigation demand to vary significantly from the estimated average seasonal demand. The following data was used in determining the estimated average monthly irrigation demand:

› Average monthly rainfall (Gloucester Post Office – station number 060015);

› Average monthly pan evaporation (Chichester Dam – station number 061151); and

› Annual crop uptake of 4ML/ha (note based on the irrigation program results there appears to be little variability in the application rates for cropping compared to permanent pasture).

Based on the above parameters, typical monthly irrigation application rates are presented in **Table 11.1**.

Table 11.1: Estimated Monthly Irrigation Rates (average years)

MONTH	MONTHLY IRRIGATION (ML/ha)	MONTH	MONTHLY IRRIGATION (ML/ha)
January	0.5	July	0.2
February	0.3	August	0.3
March	0.1	September	0.5
April	0.2	October	0.5
May	0.1	November	0.6
June	0.0	December	0.6
		TOTAL	**4.0**

Note: Highest demand is in Spring and Summer.

11.5. Irrigation Management

A well designed irrigation system will provide good application efficiency and distribution uniformity. The irrigation systems will be routinely monitored (using local weather station data and feedback from soil moisture sensors) and maintained to ensure the efficiency of the irrigation system.

Water management

Annual volumes of irrigation water have been determined from site water balance modelling. Assuming an irrigation area of 60 ha and being able to achieve irrigation application rates of 4 ML/ha/year, typical annual rates of irrigation are presented in **Figure 11.2**.

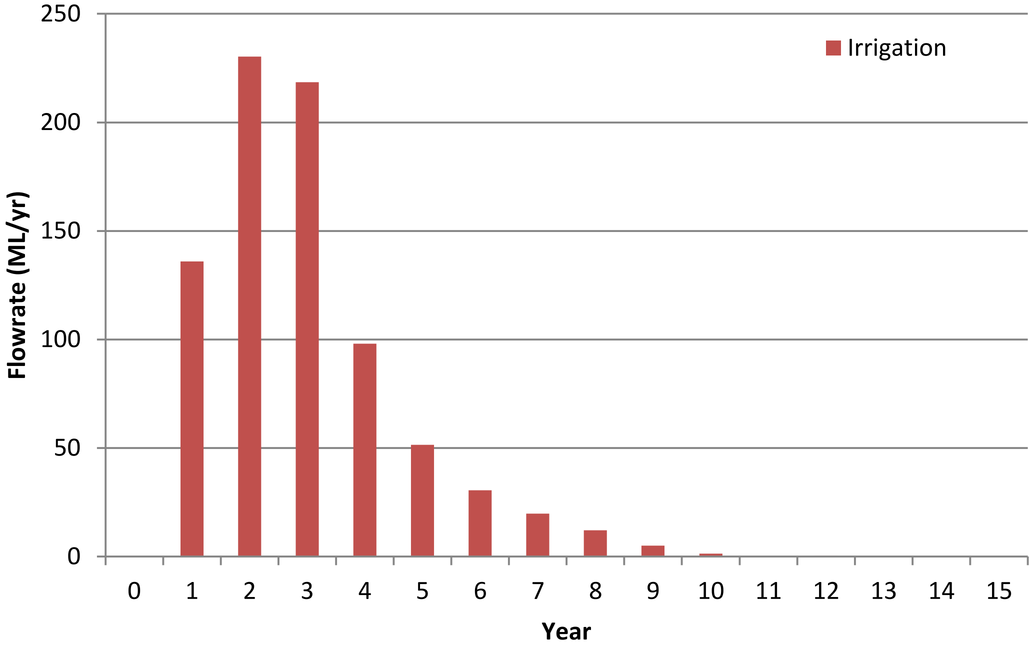


Figure 11.2: Estimated Annual Irrigation Rates for the Stage 1 Project

Soil management

Soil erosion can lead to loss of nutrients and a decline in the soil structure. Ground cover is the most important factor in minimising soil erosion, with soil movement possible wherever soil is bare during land preparation. As the crops/pastures grow, they will provide ground cover which will be maximised and maintained by controlled traffic and zero tillage farming systems which represent best practice in today's farming environment.

Erosion management during land preparation will include maintaining surface roughness and stubble cover from the ploughed out grass as much as possible.

Improvement of soil structure and good infiltration is important for the control of soil erosion. Soil cover and mulches will help this process. Compaction from machinery may also significantly affect structure and infiltration. Machinery operations will be limited, as much as possible, to times when the soil is dry and operated with appropriate tractor tyres, pressures and loadings to minimise compaction.

The combination of heavy crop residues from irrigated farming, zero-tillage, controlled traffic and the use of an intensive cropping program which grows three crops in two years or two crops in one year, will have a growing crop or heavy stubble cover on the ground at all times and erosion will be minimal.

Establishment and irrigation of improved permanent pasture is also an opportunity for the reuse of treated water. Improved pasture has the advantage over cropping of not requiring any substantial soil treatment and provides full vegetation cover thereby minimising the potential for soil loss and erosion.

12. Discharge to Surface Waters

As the second component to managing extracted water, AGL proposes to discharge treated water to local waterways when it is not possible to irrigate, and treated water storages are full and there is no capacity in the system to store any additional water. It is proposed to only discharge treated water from the discharge water pond at the CPF that has been conditioned to meet the surface water quality target identified in Section 10.4.

Modelling has indicated that based on 60 ha of irrigation, discharge to surface waters will not occur very often (see Section 5.6). Discharge is only likely:

- In the initial years of dewatering when water production rates are high; and
- If there were very wet seasons that precluded irrigation reuse for periods of more than a month.

While AGL's philosophy is to discharge water during and immediately after high flow river events, there may be some community and environmental benefit for also allowing discharges during very dry periods to maintain water for stock use and environmental flow purposes.

At the present time the primary proposal is to discharge to surface water in combination with a high flow event in the catchment when Dog Trap Creek and the Avon River are flowing. A high level discharge location is proposed along Dog Trap Creek (downstream of stream gauge TSW02).

If there was community support (and discharges were allowable under our EPL), AGL would consider discharging treated water during lower flow conditions if it was deemed appropriate to provide small environmental flows or water for stock water supply during periods of drought. A lower level discharge location is proposed along Dog Trap Creek near the confluence with the Avon River should this option be supported by stakeholders and local community.

In both instances, discharges are likely to be small and unlikely to exceed a maximum of 1.5 ML per day. Discharge to these locations would be managed such that the creek geomorphology and the pre-development environmental flows in Dog Trap Creek and the Avon River are preserved. This approach would reduce the potential for harm to aquatic ecology.

Water quality will be tested and checked at the DWP prior to discharge (see Section 14.4).

12.1. Benefits and Constraints of Discharge to Surface Water

Benefits

The following benefits associated with the managed discharge of treated water to surface waters have been identified:

- Low risk of environmental harm;
- Readily implemented with minimal stream bank/river bed impact; and
- Sustainable with low risk of long-term impact.

Whilst discharge would primarily be managed in a manner which mimics existing/current environmental flows, there is flexibility for the managed discharge to supplement natural stream flows. This would only be undertaken in response to community and stakeholder support and with subsequent licensing approvals from the relevant authorities and in accordance with those licensing conditions.

Constraints

If discharges occurred during periods of higher flow then the potential of harm to the stream, the bed load and the aquatic ecology are considered to be negligible.

The following constraints associated with the managed discharge of treated water to surface waters have been identified for low flow discharges:

- Potential change to aquatic ecology;
- Potential to change stream geomorphology; and
- Potential scour and erosion at the discharge location.

12.2. Discharge Site Characteristics

Location

The following factors were considered in the selection of a suitable discharge location:

- River geomorphology: flat banks with stable soils are preferable to steep banks so as to reduce the potential for erosion and sediment mobility;
- Stream bank and bed sediment type (particularly with regard to dispersive qualities); and
- The presence of riparian and aquatic vegetation which may stabilise the channel.

Two discharge locations are proposed to manage discharge to surface waters:

- High level outfall; and
- Low level outfall.

A section of Dog Trap Creek, between approximately 0.25 and 1 km upstream of its confluence with the Avon River has been identified as the best location for the proposed outfall/s. Two stream discharge locations have been identified (see **Figure 9.1**).

Both outfalls would be located downstream of the Dog Trap Creek stream gauge TSW02 (see **Figure 9.1**). The high level discharge location would lie at an elevation above a nominal design flood level to allow efficient discharge when levels in the waterways are elevated. The proposal is that treated water discharge to the streams would only occur when flows of at least 5 ML per day are naturally occurring within Avon River (as measured at the NOW Waukivory Gauging Stn - 208028).

The low level discharge location would be located at a lower elevation near the confluence with the Avon River and would only be utilised if low level flows were approved to maintain environmental flows or provide water for basic rights (stock use).

Technical Considerations

The managed discharge outfalls would be structures designed to appropriately convey the treated water into the receiving surface waters without creating scour or erosion. The structure would address the following key design principles:

- Dispersion of treated water so it mixes with existing flows within a relatively short distance;
- Compatibility with upstream and downstream water quality;
- Dissipation of energy associated with the new inflow; and
- Appropriate scour protection on the creek river banks, the receiving water bed local to the outlet, and immediately downstream of the outlet.

12.3. Proposed Method of Treated Water Discharge

Subject to agreement by the EPA and NOW, it is envisaged that the discharge of treated water to Dog Trap Creek will be conducted through an appropriately engineered discharge structure in the bed of the creek designed to dissipate energy from the flow and minimise flow velocity prior to entry into the main Avon River channel according to the specific needs of the final release location.

The structure will be engineered with consideration given to the specific geomorphology, and soil types at the release location and the volume of water to be discharged. The creek flow volumes and velocities during flood events will also be a consideration.

12.4. Proposed Flow Regime

AGL is advocating flows greater than 5 ML/d for the discharge of treated water from the WTP. These flow rates are preferably measured at AGL's stream gauge location TSW01 but in the interim without there being a good rating curve for this site, the flows are deemed to be at the NOW Waukivory Gauging Station 208028 located just downstream of the confluence with Waukivory Creek.

Stream discharge would only occur when there was at least a 5-fold mixing factor. That is, when existing flows in the stream are at least 5 times greater than the proposed rate of discharge. It is expected that the maximum discharge rate would be around 1.5 ML/d and would average less than 1 ML/d, representing around 0.001% of the flow during a typical flood event.

A typical flow duration curve for stream flow in the catchment is provided in **Figure 12.1** (NOW Gauging Station 208028).

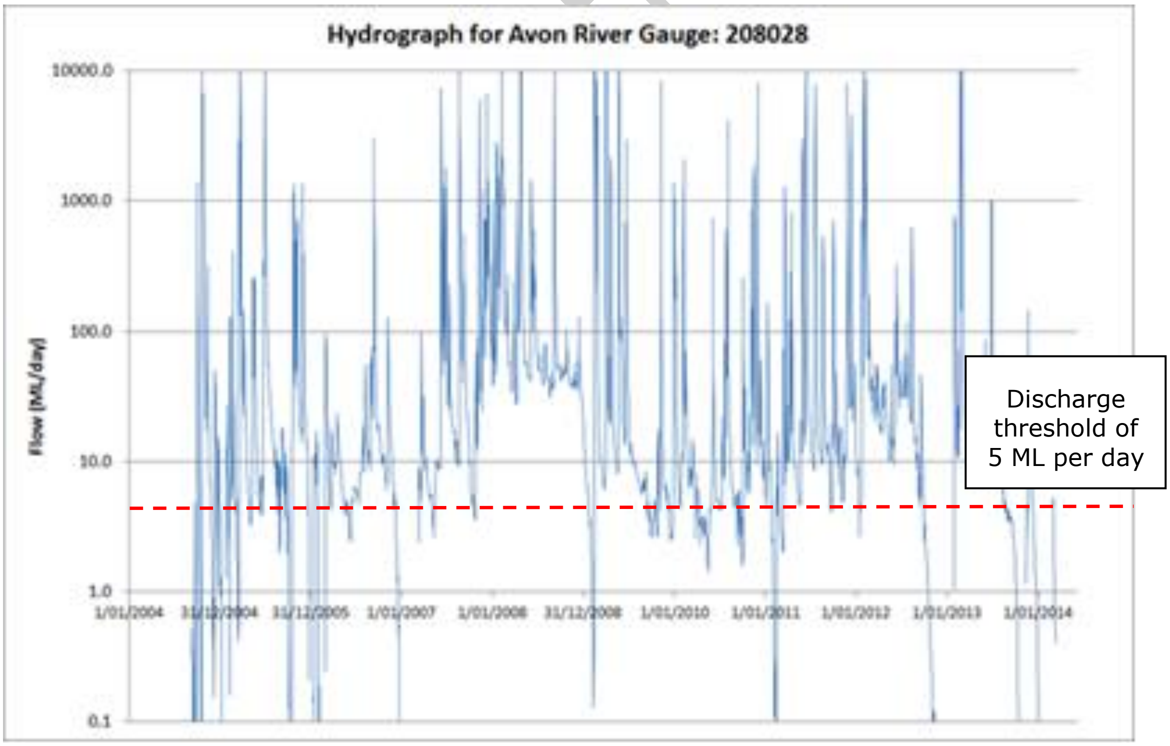


Figure 12.1: Streamflow Data for the Avon River (Gauge 208028)

The treated water will be discharged to Dog Trap Creek in a controlled manner, taking into consideration the sensitivity of the receiving watercourse. A discharge event will be conducted in accordance with specific (approved) parameters including discharge volumes, flows, durations and water quality. Appropriate monitoring will be undertaken to ensure that the released water does not cause any adverse effects on the receiving aquatic environment.

Discharge Rate and Frequency

River discharge will be managed to avoid environmental degradation of the receiving Dog Trap Creek and Avon River. Discharge will most likely only occur during relatively high flow conditions. Discharge to streams is expected to only be required when alternative water management measures, such as irrigation and stock use, are unavailable.

Indicative daily rates of discharge to Dog Trap Creek are presented in **Figure 12.2** for all types of seasons. Discharge rates would typically be less than 1 ML/d and only occur in the early years of production. Annual volumes would typically be less than 130 ML/yr (see Section 5.6).

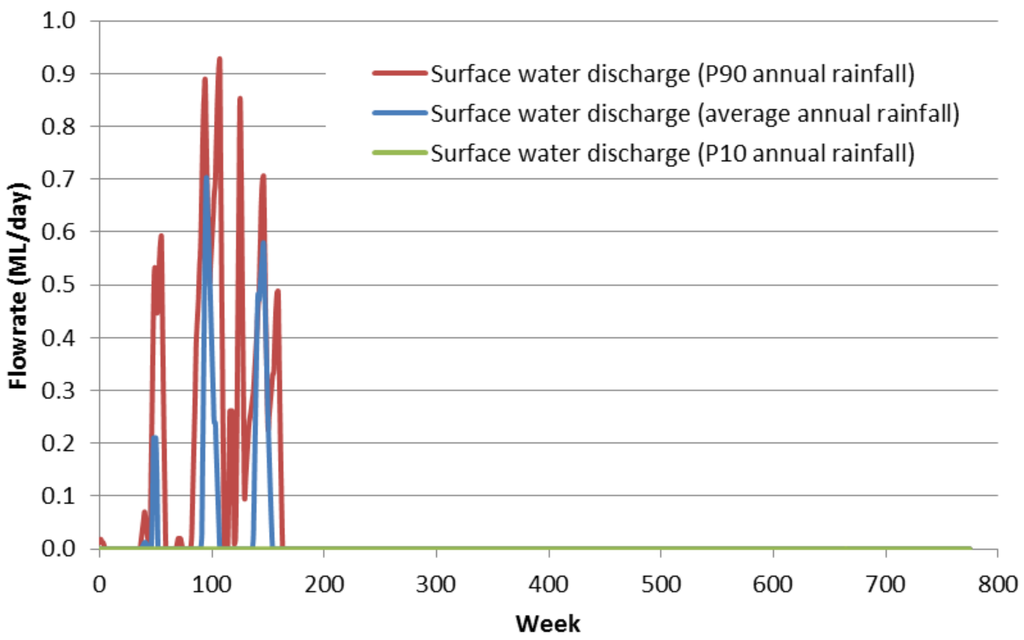


Figure 12.2: Variations in estimated annual discharge to Dog Trap Creek

Receiving Waterway

The Avon River has a total catchment area of approximately 290 km^2 and is one of approximately 30 sub-catchments that contribute to the greater Manning River system (Parsons Brinckerhoff, 2014b).

Figure 12.3 highlights the flow contributions from each of the sub-catchments within the Avon River catchment area. The main contributing sub-catchment is Waukivory Creek sub-catchment with about 31% of the average annual flow in the Avon catchment. Dog Trap Creek provides about 14% of the Avon River flow.

About 46% of the average annual flows occur upstream of the confluence of the Avon River and Dog Trap Creek (the approximate proposed discharge locations), with the Waukivory Creek catchment contributing another 31% to bring the total flows at the NOW gauging station about 77% of the total flows to the Avon River (Parsons Brinckerhoff, 2014b).

The proposed discharge locations are considered to be located in an intermediate catchment area where the discharge of an extra 1 -1.5 ML/d for relatively short periods will not compromise the natural flow regime.

Figure 12.3 Proportional contribution of tributaries to the Avon River

13. Waste and Brine Management

Several waste water streams will result from operations associated with managing extracted water. This waste water is expected to originate from the following sources:

› Pre-treatment process; and

› WTP process steps.

The WTP will also generate brine as a by-product of the desalination process.

13.1. Pre-treatment Waste Management

The pre-treatment facility will generate grit and sediment from the clarification process or float if dissolved air flotation is employed instead of a clarifier.

Dewatering of this sediment would be undertaken to reduce the quantity of this waste material for disposal off-site by road transport to licensed industrial waste facility. The chemical composition of the waste material is expected to be similar to the extracted water quality with an increased concentration of suspended solids (TSS).

13.2. WTP Waste Management

The WTP processes generate several waste streams. An overview of these streams for a plant capacity of 2 ML/d is provided in **Table 13.1**. These indicative waste quantities are the maximum residual volumes of materials that would be sent for disposal after all the water recycling processes and after the maximum amount of treated water has been recovered from all processes. Backwash from the UF system is expected to accumulate the largest volume of suspended solids.

Table 13.1: WTP Waste Streams and Quantities

Waste Stream	Treatment	Indicative Quantity (m^3/day)	Quality	Disposal
UF backwash wastewater	Dewatering	2	High TSS concentration	Off-site waste facility
UF membrane CIP wastewater	Dewatering and pH neutralisation	0.1	Variable pH	Off-site waste facility
IX regenerant wastewater	Dewatering and pH neutralisation	1	Variable pH	Off-site waste facility
RO CIP wastewater	pH neutralisation	0.1	Variable pH	Off-site waste facility

The chemical composition of the salt and its variability from different gas wells and over the life of the project will confirm the waste classification and will determine the landfilling requirements. The information provided in **Table 13.2** provides a summary of the issues relating to regulatory approval, long term environmental compliance, and environmental factors and risks related to the disposal of mixed salt to an off-site landfill.

Table 13.2: Issues relating to Mixed Salt Disposal to Off-site Landfill

Item	Criteria	Off-site Landfill
1	Regulatory Approval	Landfill Operators - Assuming this material is classified as a GSW (C&I waste), disposal to an appropriately licensed landfill could occur without additional approvals. EPA - The offsite disposal and landfilling of the salt would be reflected in the EPL for the GGP.
2	Long Term Environmental Compliance	None. The operator of the licensed landfill would accept responsibility for the material received at their landfill provided that the chemical concentration of the material does not significantly change from that which is initially approved and accepted by the licensed landfill operator. The licensed landfill operator will not take responsibility for contaminants that they are not aware of.
3	Environmental Factors and Risks	None. Once accepted by the landfill provider that the chemical concentration of the material does not significantly change from that which is initially approved and accepted by the landfill.

13.3. Brine Management

RO membrane desalination has been adopted as the preferred technology for this project. This will generate a brine concentrate stream that will contain the salts present in the extracted water, but at significantly elevated concentration levels.

Management of this saline brine concentrate stream is of critical importance to the GGP. In many cases the cost and technical challenges relating to brine management has a greater impact on the economic and technical feasibility of the desalination of produced water than that for the produced water desalination plant itself.

Storage of the brine concentrate in brine evaporation ponds at the project site has been eliminated due to NSW Government rules that ban the use of evaporation ponds for the CSG industry. Salt recovery and reuse of brine and salt streams is AGL's preferred management strategy, however given the known variability in the produced water quality within the Gloucester Basin and the salt being a mixed sodium-chloride-bicarbonate salt, the reuse opportunities appear limited.

For the large scale CSG produced water schemes in Queensland, the brine management option incorporating brine treatment to recover product (salts) is currently under consideration as is the production of mixed salts.

There is also the trend towards brine treatment technology for smaller scale exploration schemes where innovative technologies for brine management are being be trialled. For small scale salt production applications, such as is the case for the GGP, the technology providers have developed pre-engineered, modular packaged systems specifically for the CSG industry market.

13.4. Brine Production

The RO desalination process will produce a highly concentrated brine stream (estimated to have a salinity of around 60,000 µS/cm or 50% higher than seawater) which will be further treated using a thermal technology (i.e. brine concentration and crystallisation or if technically appropriate brine crystallisation without preceding brine concentration) to produce a mixed salt suitable for disposal off site as a registered solid waste residue by road transport to a licenced landfill.

13.5. Brine Management Option Selection

A preliminary review was conducted of the following brine management options which were regarded as potentially suitable for the GGP. These options include:

- Option 1 – Minimal or No Treatment with the following sub options:
  - Sub Option 1.1 - Deep Well Brine Injection;
  - Sub Option 1.2 - Brine Discharge to Ocean Outfall; and
  - Sub Option 1.3 - Option Solar Evaporation for Encapsulation.
- Option 2 - High recovery RO with further concentration of the RO brine concentrate using thermal mechanical evaporation together with brine crystallisation technology to produce a mixed salt for transporting off-site to a licensed landfill.
- Option 3 - High recovery RO with further concentration of the RO brine concentrate using thermal mechanical evaporation technology in conjunction with solar evaporation ponds to produce saline slurry for transporting off-site for disposal to a licensed landfill.
- Option 4 – Selective salt recovery.

Option 2 has been selected as the preferred option for the GGP.

Option 1 – Minimal or no treatment

The sub options in Option 1 have been determined to be unviable. However, for the purpose of completeness, a discussion on these options is provided below.

Option 1.1 - Deep Well Brine Injection

Brine is injected into below ground geological formations that are confined, such that the brine has no possibility of contaminating aquifers, reporting to surface water, or being used for some other purpose. This would require deep wells to be drilled and fracture stimulated. Further discussion is provided in Section 9.7.

The main risk associated with either deep or shallow well injection is the potential for contamination of groundwater resources. There is also concern where groundwater feeds surface waters. The quality of brine material injected is probably of more significance than the quantity in relation to groundwater contamination.

In addition there are no suitable deep aquifers with sufficient permeability or storage to accept the re-injected brine waste at Gloucester (see Section 9.7).

This option has not been pursued further because the Part 3A Project Approval does not authorise re-injection of groundwater.

Condition 1.6 states:

"To avoid any doubt, this approval does not authorise the following activities or works unless the subject of additional assessment and approval as part of a modification application under section 75W of the Act:

a) construction or operation of a transmission line connection between the central processing facility (15 megawatt gas-fired electricity generating facility) and existing electricity grid; and

b) direct re-injection of groundwater produced during gas well development, back into groundwater aquifers as a water disposal option"

Option 1.2 - Brine Discharge to the Ocean

The distance to the ocean from the GGP project site is in the order of 70 km which renders the economic feasibility for such a relatively small volume of brine disposal unattractive. This option would incur the highest capital cost of these four sub-options given the significant distance to the ocean and the need for an outfall at the ultimate destination on the coast. This option would also not be aligned with either regulatory requirements or local community wishes and so is most unlikely to receive environmental regulatory approval or community acceptance. For these reasons disposal of brine to the ocean has not been considered further in this study.

Option 1.3 - Solar Evaporation for Encapsulation

Solar evaporation brine ponds is potentially a low cost option for produced water brine concentrate. However, the NSW Government's position on brine evaporation ponds is outlined below:

> *"The NSW Aquifer Interference Policy (NSW Office of Water, 2012) states that the method for the disposal of extracted water should not involve the use of evaporation ponds. The Policy further states that "This issue will be primarily dealt with via a prohibition of evaporation ponds under the Petroleum (Onshore) Regulation 2007".*

While no such prohibition is currently reflected in legislation, the solar evaporation for encapsulation option has been discounted for this GGP.

Option 2 – High recovery RO with mixed salt to landfill

This is the preferred option has the benefit of removal of the RO brine concentrate from site after crystallisation and bagging as a mixed salt.

An assessment was undertaken to identify potential locations of licensed waste facilities that could receive mixed salt. Although the specific quality of the mixed salt generated from the proposed WTP is yet to be determined, it is expected that the salt will be acceptable for classification as GSW – Commercial and Industrial (C&I) waste.

The production of a mixed salt of a quality that would render it suitable for transport from site to a licensed landfill is considered to be the best solution for brine management. This approach by removing the salt from site would avoid the legacy of land at the GGP being rendered unusable in the future as it would have contaminated waste encapsulated at the site.

Option 3 – High recovery RO with concentrated slurry to landfill

This option has the benefit of removal of the RO brine concentrate from site in the form of highly saline slurry, which would eliminate the legacy of retaining this material on site.

One approach for highly saline slurry disposal that might be worthwhile considering transporting the RO brine concentrate slurry to a liquids recycling plant.

Due to the high level of uncertainty relating to highly saline slurry disposal, this option is not pursued further at this time.

Option 4 – Selective Salt Recovery

Thermal processes have been widely used for brine treatment. Thermal process technology is commercially proven for both brine concentration and to achieve a salt product using crystallisation.

In the Surat Basin in Queensland, the major CSG producers are evaluating selective salt recovery (SSR) options to produce saleable salt products (such as sodium chloride (NaCl) and/ or sodium carbonate (more commonly known as soda ash Na_2CO_3) from the RO brine concentrate. The Queensland Government has indicated that SSR is their preferred approach to brine management (Ref: Queensland Government's 2012 CSG Water Management Policy).

For this project, SSR is not considered to be a viable option due to:

› the relatively small quantity of SSR product that would be generated makes it uneconomic;

› the produced water salinity is a mixed sodium-chloride-bicarbonate ($Na\text{-}Cl\text{-}HCO_3$) water type; and

› the potential variability of the source water quality, making it impossible to determine the technical feasibility of producing a specific selective salt for the GGP.

As a consequence, we have not included SSR as one of the brine management options for further consideration for this project.

Preferred Salt Disposal Option

Due to the high level of uncertainty relating to both the highly saline slurry disposal Option 3 and to the SSR Option 4, AGL has adopted Option 2 as the preferred brine management solution for the GGP. This preferred option is shown in the flow schematic diagram provided in **Figure 13.3**).

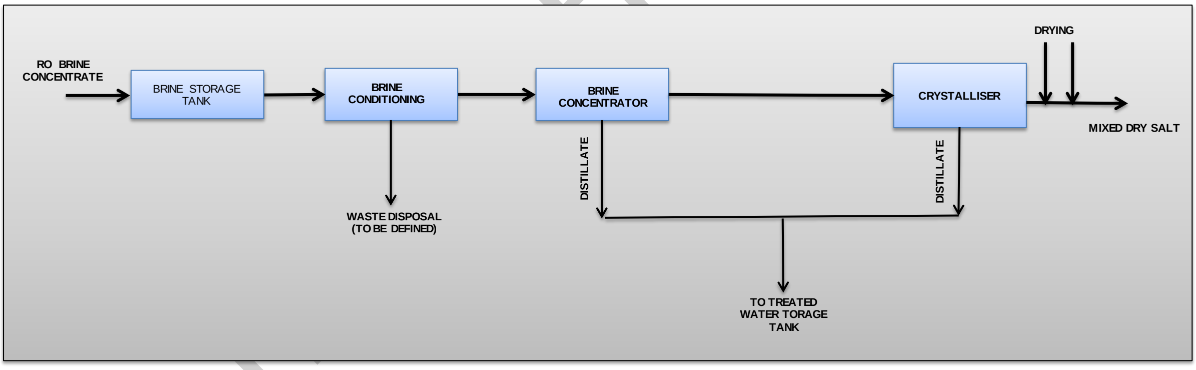


Figure 13.3: Preferred Brine Management Option

The mixed salt content of the produced water precludes its production as a saleable salt. However, the design of the WTP and brine management system will be such that new treatment technologies could be 'bolted on' over time to provide more sustainable salt management solutions.

Due to the relative low capacity of the proposed brine treatment system it is feasible that innovative thermal technology solution could be suitable for the GGP. Recognised thermal technology original equipment manufacturers (OEMs) have proposed consideration of modified brine crystallisation technology (i.e. utilising a brine crystalliser without a brine concentrator as an alternative option to the conventional combined brine concentrator and salt crystalliser technology). This alternative option has the potential benefit of providing a simpler robust lowest energy demand solution.

13.6. Mixed Dry Salt Production

The estimated weekly production of mixed salt is presented in **Figure 13.4**. The peak rate of salt produced is estimated to be in the order of 42 t per week. Salt production will decrease rapidly over the life of the project. Average salt production is estimated to be less than 8 t per week over the life of the project. Estimated annual salt production is presented in **Figure 13.5**. It is expected that (on average) less than 400 t per annum of mixed salt per annum will be disposed of over the life of the project.

Salt would be trucked from the CPF to an appropriate waste disposal facility. It is estimated that a maximum of two truck movements per week would be sufficient to transport the salt from the CPF in the initial years of production. Longer term, less than one truck movement per fortnight would be required to manage the disposal of salt.

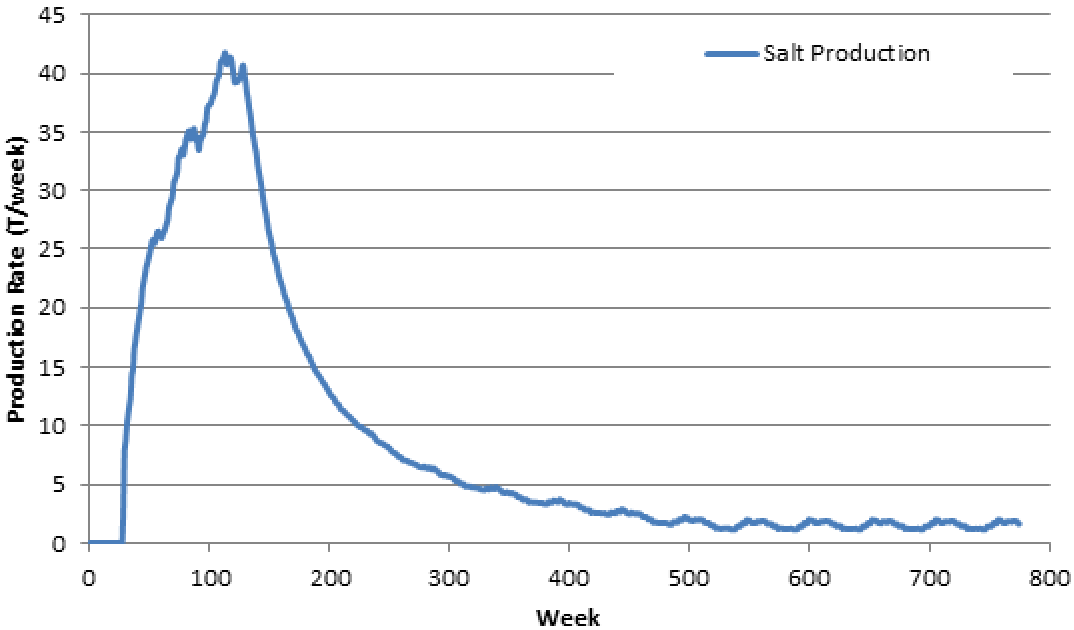


Figure 13.4: Estimated Weekly Rate of Salt Production from the WTP

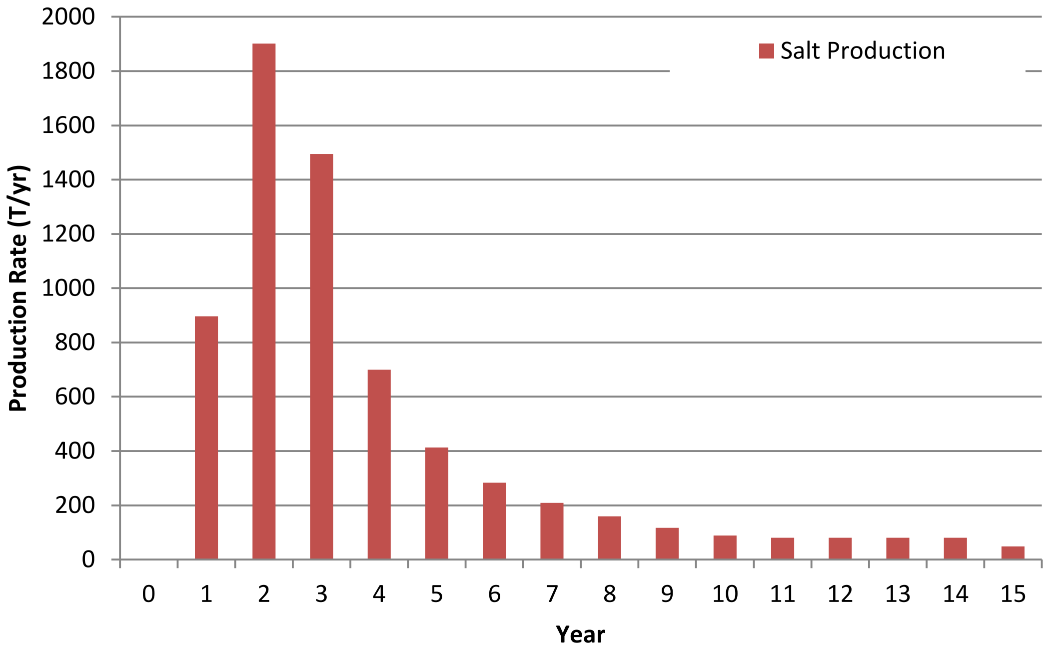


Figure 13.5: Estimated Annual Rate of Salt Production from the WTP

13.7. Final Salt Disposal

To summarise, the total identified capacity to receive this general solid waste (GSW) in the Newcastle/Sydney Basin is approximately 2.3 Mt per annum. Peak salt production from the GGP could be as high at 1,900 t per annum, but the long term average is expected to be about 400 t per annum. This average compared to the regional capacity to receive such waste represents around 0.02% of the general solid waste stream. The relative percentages are shown in **Figure 13.6**.

The salt generated from the brine stream will be a mixed Na-Cl-HCO_3 salt. Sodium chloride (NaCl) is table salt while sodium bicarbonate ($NaHCO_3$) is bicarbonate of soda (used for a variety of household uses including cooking (baking), cleaning, and personal health).

The crystallised salt by-product would most likely be classified as General Solid Waste (GSW) (Commercial and Industrial category) under the NSW *Waste Classification Guidelines* (Department of Environment and Climate Change, 2009). AGL has identified seven landfills operated by major waste disposal companies in the Newcastle/Sydney Basin region that are licensed to receive crystallised salt as General Solid Waste.

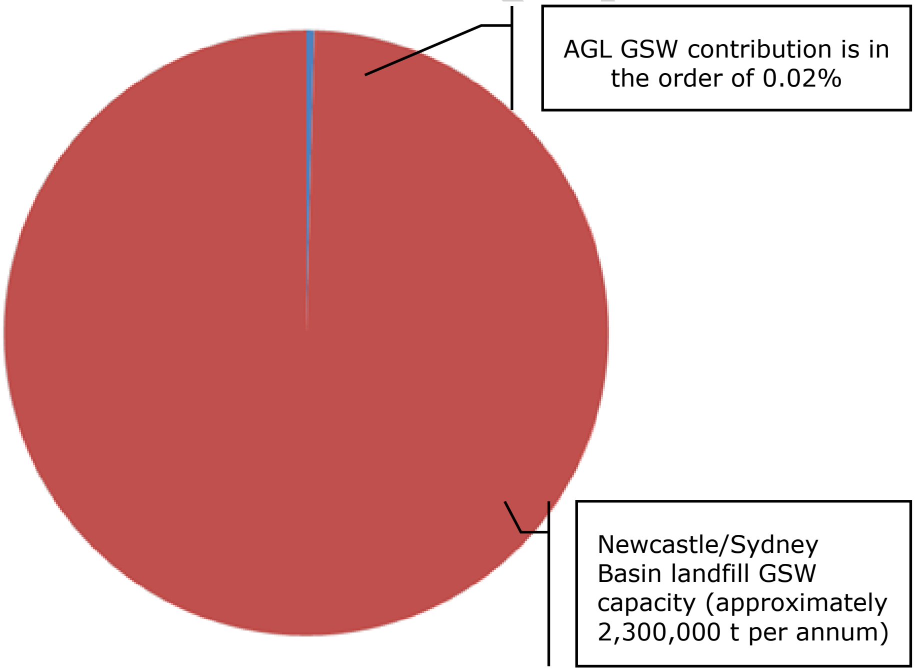


Figure 13.6: AGL's Estimated Contribution to Commercial and Industrial - GSW received in Newcastle/Sydney Basin Region

On a state-wide basis, all solid waste streams fall into the following categories (note that (subject to final testing and classification) the GGP salt is considered GSW - Commercial and Industrial):

- NSW (Municipal Solid Waste) - MSW generation is about 4.8 Mt per annum;
- NSW (Commercial and Industrial) - C&I waste generation is about 5.5 Mt per annum; and
- NSW (Construction and Demolition) - C&D waste generation is about 6.9 Mt per annum.

These quantities are an estimate of what is produced prior to recycling and recovery. They are not necessarily what is finally disposed of to landfill.

To summarise, the total identified capacity to receive this GSW waste across NSW is approximately 2.6 Mt per annum. Peak salt production from the GGP could be as high at 1,900 t per annum, but the long term average is expected to be about 400 t per annum. This average compared to the state-wide capacity to receive such waste represents just 0.015% of the general solid waste stream.

14. Monitoring Plan

A Produced Water Management Plan (PWMP) will be written for the Stage 1 GFDA that reflects the requirements of this EWMS, the Stage 1 project approval, and the respective conditions imposed on the PPL (to be issued by OCSG) and EPL (to be modified by EPA). The following sections outline the monitoring principles and the expected requirements of this PWMP. The plan will:

- Detail inspection procedures for assessing and maintaining the integrity of the respective pond liners;
- Identify the water monitoring network;
- Detail the locations of monitoring points, parameters to be measured, frequency of monitoring, and monitoring methodology;
- Identify trigger values, or the process for developing trigger values, for the measured parameters;
- Assess the level of impact caused in the event of leakage to underlying groundwater from the monitored infrastructure; and
- Detail additional hydrogeological investigations to assess the extent and significance of any water level or water quality impact that occurs.

The current Water Management Plan that applies to the blended water irrigation program that is the Tiedmans irrigation program will expire with the expiry of the approval for that exploration activity.

Produced water management for the Stage 1 GFDA is totally separate to AGL exploration activities and a completely new PWMP will apply.

14.1. CPF WTP Infrastructure

The ponds, tanks and liners and associated pipework will be physically inspected on a monthly basis to assess the integrity of these structures and associated liners.

Water quality monitoring is proposed at each of the following locations on a quarterly basis for a comprehensive suite of analytes:

- Receiving water pond;
- Treated water pond;
- Brine water tank; and
- Discharge water pond (if there are multiple cells then samples will be taken from each cell).

In addition, it is proposed to place continuous salinity (EC) loggers in the:

- Receiving water pond; and
- Discharge water pond (if there are multiple cells then a logger in each cell).

Salinity measurements will be taken every hour and the loggers will have a live feed back to the CPF control room. Loggers would be checked and calibrated quarterly.

A water monitoring network (both water levels and water quality) will be installed around the new water storage infrastructure and brine storage areas that have the potential to impact on underlying groundwater resources. Even though the ponds will be double lined with seepage detection, inspection and control, additional monitoring is proposed downgradient of each of the three new water storages and downgradient of the brine storage tank. In addition, the two existing Rombo monitoring bores (RMB01 and RMB02) which are located downgradient of the proposed WTP infrastructure will be included in the PWMP.

This monitoring network will:

- Identify background perched water levels and quality in the weathered rock zone; and
- Identify background shallow groundwater levels and quality.

It is expected that a very shallow monitoring bore (to around 6 m depth) and deeper monitoring bore (to the water table at around 30 m depth) will be constructed at each of the four new locations (three water ponds and the brine storage tank). There are no nearby surface water receptors so no surface water monitoring is proposed at the CPF site.

These five locations will monitor any unusual changes in water levels or water quality to ensure the integrity of site WTP infrastructure and to provide early warning of any impact to shallow groundwater from ponded water.

Water quality monitoring and testing will be undertaken quarterly for the first two years then revert to six-monthly for the groundwater sites. Only basic suite water sampling is proposed.

14.2. Tiedman Water Storage Infrastructure

The ponds and liners will be physically inspected on a monthly basis to assess the integrity of these structures and associated liners.

Water quality monitoring is proposed at each of the following location on a quarterly basis for a basic suite of analytes:

- Irrigation water pond (TSD);
- Irrigation water pond (TND); and
- Produced water storage pond (TED) – only if the storage of produced water occurred during the preceding quarter.

In addition it is proposed to place continuous salinity (EC) loggers in the two irrigation ponds. Salinity measurements will be taken every hour and the loggers will have a live feed back to the CPF control room. Loggers would be checked and calibrated quarterly.

There is already some water monitoring in place at the Tiedman water storage dams:

- Shallow perched water monitoring bores around each of the single lined dams (TND-TMB04 and TSD-TMB05); and
- Seepage inspection and control at the TED.

It is proposed to increase the amount of monitoring around each of these dams to be consistent with the monitoring proposals at the CPF. A deeper monitoring bore (to the water table at around 30 m depth) will be constructed at each of the two existing locations. In addition a very shallow monitoring bore (to around 6 m depth) and deeper monitoring bore (to the water table at around 30 m depth) will be constructed adjacent to the seepage inspection area of the double lined dam (TED).

There is also a nearby nested monitoring bore site (TCMB site with four individual monitoring bores) located adjacent to TSD and TND that will be included in the PWMP.

These four locations with 10 individual monitoring bores will monitor any unusual changes in water levels or water quality to ensure the integrity of irrigation site infrastructure and to provide early warning of any impact to shallow groundwater. There are no nearby surface water receptors so no surface water monitoring is proposed at the Tiedman water storage site.

Water quality monitoring will be undertaken quarterly for the first two years then revert to six monthly for the groundwater sites (all except for the deeper monitoring bores at the TCMB site where no water quality monitoring is proposed). Only basic suite water sampling is proposed.

14.3. Monitoring Network for Irrigation Areas

AGL will carry out monitoring during irrigation to ensure that water quality thresholds for the surface water receptor are not exceeded and the irrigation water quality target is being achieved. Water quality targets for treated water to be used for irrigation are set out in

Table **10.3**.

Water quality will be tested prior to release from the Discharge Water Pond (DWP) to ensure it meets the target water quality and it is below the nominated thresholds for irrigation and stream discharge. As the water quality will be monitored closely at the WTP, it is only proposed to monitor the water quality within each of the two irrigation ponds on Tiedmans. No additional monitoring of adjacent surface water or underlying groundwater receptors is proposed for the new irrigation areas (as shown in **Figure 9.4**). The monitoring of the existing surface water monitoring sites on the Tiedmans and Avondale properties will continue as outlined in the broader Stage 1 Groundwater Management Plan (AGL, in prep).

No additional water quality monitoring is proposed because the treated water is equivalent to or better than Avon River quality that others use for stock use and occasional irrigation of similar crops and pasture.

It is proposed that no catch dams or recycling of waters will be required. The two existing catch dams around the Stage 1A irrigation area will be removed once the current Tiedman irrigation approval expires. Also no soil sampling is proposed across any of the proposed irrigation areas because:

› There is natural variability in soils across the landscape; and

› Minimal salt loads will be applied in the irrigation of treated water.

Also no nutritional or trace metal crop monitoring is proposed given the low salinity water to be applied as irrigation water.

14.4. Monitoring Discharge to Surface Waters

AGL will carry out monitoring prior to stream discharge to ensure that water quality thresholds for the surface water receptor are not exceeded and the stream discharge water quality target is being achieved. There will be batch testing of water in the DWP prior to release. Water quality targets for treated water to be discharged to the environment (Dog Trap Creek close to the Avon River) are set out in

Table **10.4.**

As the water quality will be monitored closely at the WTP, it is only proposed to monitor the water quality upstream and downstream of the stream discharge location (sites TSW02 and TSW01 respectively) during periods of discharge. Additional grab samples will be taken at these two sites for a basic analysis on a monthly basis if stream discharge is occurring for an extended period. In addition there is continuous monitoring of salinity (EC) at both these sites as there are permanent dataloggers installed. The monitoring of the existing monitoring sites on the Tiedmans and Avondale properties will continue as outlined in the broader Stage 1 Groundwater Management Plan (AGL, in prep).

The monitoring network for irrigation and discharge of treated water (comprising existing and proposed monitoring sites) is set out in Table 14.1. Information is also provided in Table 14.1 on the water quality parameters that will be included for:

› Continuous monitoring;

› Quarterly monitoring; and

› Extra monthly monitoring (when required).

Table 14.1 Monitoring network for irrigation and discharge of treated water

Monitoring Site ID	Type - Location	Continuous Monitoring	Monthly Monitoring	Quarterly Monitoring
Irrigation Storage Ponds (Tiedmans)				
Tiedman North (treated water)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Basic suite
Tiedman South (treated water)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Basic suite
Tiedman East (extracted water)	Sampling of Water Storage Pond Water	None	Physical inspection of surrounding area	Basic suite (only if water transferred in)
TMB04a and b	Seepage – immediately east of Tiedman North Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
TMB05a and b	Seepage – immediately south of Tiedman South Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on a quarterly basis. If inflow within 12 hours then basic suite
TMB06a and b (new site at TED)	Seepage – immediately south of Tiedman East Dam	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on a quarterly basis. If inflow within 12 hours then basic suite
TCMB01	Shallow groundwater	WLs - Yes WQ - No	None	Basic suite
TCMB02, 03, 04	Intermediate and deep groundwater	WLs - Yes WQ - No	None	None

Monitoring Site ID	Type - Location	Continuous Monitoring	Monthly Monitoring	Quarterly Monitoring
Stream Discharge location (Dog Trap Creek near Avon River)				
Downstream Gauge (TSW01)	Avon River	WLs - Yes Salinity - Yes	None	Comprehensive suite – if extra monthly samples are taken then basic suite
Upstream Gauge (TSW02)	Dog Trap Creek	WLs - Yes Salinity - Yes	None	Comprehensive suite – if extra monthly samples are taken then basic suite

Monitoring Site ID	Type - Location	Continuous Monitoring	Monthly Monitoring	Quarterly Monitoring
WTP Site and storage ponds (Rombo)				
Receiving water pond (RWP)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Comprehensive suite
Treated water pond (TWP)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Comprehensive suite
Discharge water pond (DWP)	Sampling of Water Storage Pond Water	Salinity	Physical inspection of surrounding area	Comprehensive suite
Brine Storage tank (BST)	Sampling of Water Storage Pond Water	None	Physical inspection of surrounding area	Comprehensive suite
RMB01 and RMB02 (existing)	Shallow and intermediate groundwater	WLs - Yes WQ - No	None	Basic Suite
RWPa and b	Seepage – immediately downgradient of RWP	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
TWPa and b	Seepage – immediately downgradient of TWP	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
DWPa and b	Seepage – immediately downgradient of DWP	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite
BSTa and b	Seepage – immediately downgradient of BST	WLs - Yes WQ - No	Physical inspection of surrounding area	Physical parameters then purge dry and assess inflows on quarterly basis. If inflow within 12 hours then basic suite

14.5. Water Quality Parameters for Monitoring Program

Water samples collected at the proposed monitoring sites will be analysed for either the basic or comprehensive suite of analytes as described in **Table 14.2**. The proposed parameters and analytes include the following physical parameters and laboratory analytes:

- Physical parameters:
  - pH;
  - Electrical conductivity (EC);
  - Redox (Eh);
  - Dissolved oxygen (DO); and
  - Temperature.
- Laboratory analytes:
  - Major ions;
  - Dissolved metals and trace metals;
  - Miscellaneous other analytes;
  - Nutrients;
  - Dissolved gases; and
  - Hydrocarbons.

Table 14.2 Laboratory analytical suites

Category	Suites			Parameters	
	Basic	Intermediate	Comprehensive		
Check on Field Parameters				EC, pH and TDS	
Major ions				*Cations* calcium magnesium sodium potassium	*Anions* chloride carbonate bicarbonate sulphate
Dissolved metals and minor / trace elements				aluminium arsenic barium beryllium boron bromide cadmium chromium cobalt copper iron	lead manganese mercury molybdenum nickel selenium strontium uranium vanadium zinc

Category	Suites			Parameters	
Other analytes				Fluoride Total organic carbon	Silica
Total Suspended Solids				TSS	
Nutrients				Nitrate Nitrite Ammonia	Reactive phosphorus Total phosphorus
Dissolved gases				Methane	
Hydrocarbons				Phenol compounds Polycyclic aromatic hydrocarbons (PAH)	Total petroleum hydrocarbons (TPH)/ benzene, toluene, ethyl benzene and xylenes (BTEX)

15. Conclusion

AGL is committed to maximising the reuse of extracted water from the Stage 1 GFDA of the GGP for beneficial purposes. Upon careful consideration of all the options, AGL's preferred strategy for extracted water and associated salt is:

- Treatment and RO desalination of extracted water to produce treated water and brine;
- Reuse of treated water for CPF, drilling, fracture stimulation and workovers (i.e. working water);
- Beneficial reuse of treated water for stock and irrigation purposes;
- Discharge of treated water to streams (when irrigation is not possible); and
- Landfilling of the mixed salt from the brine stream.

The engineering components of the preferred strategy at the CPF are:

- Centralised water treatment facility with a suite of treatment plants and process water storages;
- Pre-treatment to condition extracted water for desalination;
- Desalination of extracted water using various technologies but primarily RO for working water, beneficial reuse and surface water discharge;
- Brine concentration; and
- Crystallisation of brine water to form salt.

The preferred EWMS provides a flexible and sustainable water management approach that can readily incorporate available and proven water treatment technologies and appropriate water management practices.

The following extracted water beneficial use options are:

- Reuse for CPF operations;
- Reuse for working water (including drilling, fracture stimulation and well workovers);
- Reuse for stock water;
- Reuse for irrigation; and
- Discharge to the Avon River.

The investigation of new market opportunities for water and mixed salt will be further investigated, depending on 'Expressions of Interest' received for the available water and salt.

References

AECOM (2009), *Gloucester Gas Project Environmental Assessment*. Prepared under the Environmental Planning and Assessment Act 1979 Section 75F. 2009

AECOM (2010), *Gloucester Gas Project Submissions Report*. Prepared for AGL Gloucester L E Pty Ltd, 24 May 2010.

AGL (2012) Water Management Plan for the Tiedman Irrigation Program – Gloucester. 14 May 2012.

AGL (2014) Fracture Stimulation Management Plan Waukivory Pilot, Gloucester NSW, July 2014.

ANZECC (2000) Water Quality Guidelines for Fresh and Marine Waters (Australian and New Zealand Environment and Conservation Council

Department of Environment, Climate Change and Water (DECCW) (2003), Use of Effluent by Irrigation (Department of Environment and Conservation, NSW)

Department of Environment, Climate Change and Water (DECCW) (2008), NSW Waste Classification Guidelines.

Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia (2014) Context Statement for the Gloucester Sub region, Product 1.1 from the Northern Sydney Basin Bioregional Assessment, 28 May 2014

DIPNR (2004) (Draft) Avon River Catchment Dryland Salinity – Stratford Area Groundwater Investigations dated January 2004.

Environmental Risk Services (2012) Human Health and Ecological Risk Assessment – Hydraulic Fracturing Activities.

Fodder King Ltd (2012a) Tiedman Irrigation Program – Gloucester. Prepared for AGL Upstream Investments Pty Ltd. 14 May 2012.

Fodder King Ltd (2012b) Soil Quality Monitoring and Management Program Tiedman Irrigation Trial. Prepared for AGL Upstream Investments Pty Ltd, 9 October 2012.

Fodder King Ltd (2013a) Gloucester Stage 1A Irrigation Trial Evaluation of Design Elements and Cropping Results, Report 1 (all activities to 31 August 2013), Tiedman Irrigation Trial. Prepared for AGL Upstream Investments Pty Ltd, 30 September 2013.

Fodder King Ltd (2013b) Soil Quality Monitoring and Management, Report 2 - Irrigation (Activities 1 April 2013 to 30 June 2013), Tiedman Irrigation Trial, Prepared for AGL Upstream Investments Pty Ltd, August 2013.

Fodder King Ltd (2014) Gloucester Stage 1A Irrigation Trial - Soil Quality Monitoring and Management, Report 3 (Activities to 1 July 2014 – December 2014), Tiedman Irrigation Trial, Prepared for AGL Upstream Investments Pty Ltd, 31 January 2014.

Gordus, A.G., Shivaprasad, H.L. and Swift, P.K. (2002) Salt toxicosis in ruddy ducks that winter on an agricultural evaporation basin in California. Journal of Wildlife Diseases 38:124-131 in Arenal, C. and Ohlendorf, H. (2002) Salinity Effects on Birds. Technical Memorandum. Prepared for Schulze, R., Haislip, T. and Foster, L. December 11, 2002.

Khan, S. and Kordek, G. UNSW (2013) Background Paper, entitled: *Coal Seam Gas: Produced Water and Solids* prepared for Office of NSW Chief Scientist and Engineer (OCSE). 22 November 2013.

Mitcham, S.A. and G. Wobeser (1988) Toxic effects of natural saline waters on mallard ducklings. Journal of Wildlife Diseases 24:45-50 in Arenal, C. and Ohlendorf, H. (2002) Salinity Effects on

Birds. Technical Memorandum. Prepared for Schulze, R., Haislip, T. and Foster, L. December 11, 2002.

PAC (2011a) Concept Plan Approval

PAC (2011b) Project Approval for Stage 1

Parsons Brinckerhoff (2011), Gloucester Irrigation Review of Environmental Factors Amended

Parsons Brinckerhoff (2013), Water Balance for the Gloucester Basin. Prepared for AGL Gloucester L E Pty Ltd, July 2013.

Parsons Brinckerhoff (2013), 2013 Gloucester Groundwater and Surface Water Monitoring - Annual Status Report. Prepared for AGL Upstream Investments Pty Ltd, 11 October 2013.

Parsons Brinckerhoff (2014a) Tiedman Irrigation Program – Water Compliance Report for the Period 1 July to 31 December 2013 Gloucester Gas Project, report dated 31 January 2014.

Parsons Brinckerhoff (2014b) Gloucester Gas Project Hydrology Study Report dated 21 March 2014.

Parsons Brinckerhoff (2014c) 2013 Flow Testing of Craven06 and Waukivory03 Gas Wells report dated 13 February 2014.

Parsons Brinckerhoff (2014d) Tiedman Irrigation Program – Water Compliance Report for the Period 1 January to 4 July 2014 Gloucester Gas Project, Draft report dated 30 July 2014.

RPS Australia East Pty Ltd (RPS) (2012) Leewood – Produced Water & Brine Management Ponds Review of Environmental Factors. Prepared for Santos. December 2012.

RPS Group (2014) Gloucester Coal Seam Gas Produced Water Evaluation Study. Independent Report prepared for Gloucester Shire Council, 12 May 2014.

SKM (2012) Gloucester Coal Seam Gas Project, Peer Review of Groundwater Studies – Report to Gloucester Community Consultative Committee, 3 May 2012.

Windingstad, R.M., Kartch,F.X. and Stroud, R.K. (1987) Salt toxicosis in waterfowl in North Dakota. Journal of Wildlife Diseases 23:443-446 in Arenal, C. and Ohlendorf, H. (2002) Salinity Effects on Birds. Technical Memorandum. Prepared for Schulze, R., Haislip, T. and Foster, L. December 11, 2002.