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Gloucester Gas Project – Extracted Water Management Strategy

Final Draft

Date: 4 September 2015

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Document Revision History

Date	Version	Author	Comment
Consultation Draft			
23 June 2014	0.1	Worley Parsons	Draft to AGL
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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 the same as treated water. It is extracted water that has been through all the processes and conditioning 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	The return to surface of fracture stimulation fluids before transition to natural formation water (groundwater), after which water 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 (GSW)	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).
Produced water	Water that is taken in the course of a prospecting operation that is part of, or incidental to, that prospecting operation, including water that is encountered within and extracted from boreholes, petroleum wells or excavations.
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	***Freshwater 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 slightly saline 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 freshwater 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.
Target criteria	The water quality criteria that is being adopted for treated water for all beneficial uses and stream discharges.
Threshold criteria	The water quality criteria (based on established guidelines or site specific data) that is acceptable for different uses or different receptors.
Total dissolved solids	A measure of the total dissolved ions in water. It is often used (with EC) as a measure of water salinity.
Treated water	Treated water is the same as desalinated water. It is extracted water that has been through all the processes and conditioning 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.
Workover	Downhole refurbishment and/or clean out of a gas well to establish/re-establish gas flows.

ABBREVIATIONS

AGL	AGL Upstream Infrastructure Investments Pty Ltd
AI	Aquifer Interference
ANZECC	Australian and New Zealand Environmental Conservation Council
ASR	Aquifer Storage and Recovery
AWG	(Gloucester Councils) Agricultural Working Group
BMP	Brine Management Plan
BST	Brine storage tank
BTEX	Benzene. Toluene, Ethyl benzene and Xylenes
BTP	Brine treatment plant
bbl/d	Barrels per day
CoP	Code of Practice
CSE	Chief Scientist and Engineer
CSG	Coal seam gas
CPF	Central processing facility
DAF	Dissolved air flotation
DEC	Department of Environment and Conservation (now EPA) (NSW)
DECCW	Department of Environment Conservation, Climate Change and Water (now EPA) (NSW)
DEHP	Department of Environment and Protection (DEHP) (Qld)
DF	Disc filtration
DII	Department of Industry and Investments (now DoI) (NSW)
DoE	Department of Environment (Cth)

DoI	Department of Industry, Skills and Regional Development (NSW)
DoTI	Department of Trade and Investment (now DoI) (NSW)
DPE	Department of Planning and Environment (NSW)
DPI	Department of Primary Industries (NSW)
DRE	Division of Resources and Energy (NSW) within DOI
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)
EPC	Engineering, procurement and construction (contract)
EPL	Environment Protection Licence
EWMS	Extracted Water Management Strategy (required under Condition 3.12 of the Part 3A approval)
FSMP	Fracture stimulation management plan
FEED	Front End Engineering Design
GRL	Gloucester Resources Ltd
GFDA	Gas field development area
GGP	Gloucester Gas Project
GMP	Groundwater Monitoring Program
GMMP	Groundwater Monitoring and Modelling Plan (this is the Groundwater Monitoring Program required under Condition 4.1 of the Part 3A approval)
GSC	Gloucester Shire Council

GSW	General Solid Waste
ha	Hectares
IMP	Irrigation Management Plan
HCRCMA	Hunter Central Rivers Catchment Management Authority (now HLLS)
HLLS	Hunter Local Land Services
IX	Ion exchange
km	Kilometre
km²	Square kilometres
m	Metre
MEAB	Monoethanolamine Borate
mm	Millimetres
MCW	MidCoast Water
mg/L	Milligrams per litre
ML	Megalitre
ML/d	Megalitres per day
ML/yr	Megalitres per year
Mt	Megatonnes
NGSF	Newcastle Gas Storage Facility
NOW	NSW Office of Water (now DPI Water)
OCSG	Office of Coal Seam Gas (NSW) within DRE
OWS	Oily water separator
P10	10^{th} percentile or the water production profile that is only 20% of forecast water profiles
P50	50^{th} percentile or median value of the water production profile

P90	90th percentile or the water production profile that exceeds 80% of forecast water profiles
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
t/a	Tonnes per annum
TDS	Total Dissolved Solids
TED	Tiedman East Dam
THPS	Tetrakis (hydroxymethyl) phosphonium sulphate
TND	Tiedman North Dam
TPH	Total Petroleum Hydrocarbons
TSD	Tiedman South Dam
TSS	Total Suspended Solids
TWT	Treated water storage tank
UF	Ultra filtration

µS/cm	MicroSiemens per centimetre
µm	Microns
WAL	Water Access Licence
WM Act	Water Management Act 2000 (NSW)
WTreatP	Water Treatment Plan
WTP	Water treatment plant

Executive Summary

AGL is committed to maximising the reuse of extracted water from the Stage 1 Gas Field Development Area (GFDA) of the Gloucester Gas Project (GGP) for beneficial purposes.

The Extracted Water Management Strategy (EWMS) for the GGP has been developed after a Consultation Draft of the EWMS was prepared and released in August 2014. The Draft EWMS was presented at a workshop with key agencies and local government, and publicly exhibited between the 21 August and the 19 September 2014. Five agency submissions were received and two public submissions provided comment. There were eight initial 'Expressions of Interest' received for using the desalinated water for beneficial reuse.

Since September 2014, the Front-End Engineering Design (FEED) and specialist studies have been completed and water production data from the Waukivory Pilot have been obtained. The water balance in this EWMS is based on the development of 110 gas wells over a period of three years and extracted water being pumped from depths greater than 250m.

AGL's EWMS maximises the reuse of high quality treated water for local beneficial purposes. The EWMS is a framework and strategy document prepared to address the Part 3A project approval requirements in relation to the treatment of extracted water, and the reuse and discharge of treated water after desalination. The EWMS is not intended to provide the engineering designs for the water management infrastructure, specifications for the treated water plant or identify the final irrigation areas, stream discharges or repositories for solid wastes. Rather this document provides the overall strategy for extracted water management from source to final reuse. Detailed designs for the required infrastructure will be available after an investment decision is made to proceed with the project and the EPC contract for water treatment is awarded and delivered.

The preferred extracted water management strategy provides a flexible and sustainable approach that incorporates available and proven water treatment technologies and water management practices.

This version of the EWMS has been updated from the Consultation Draft of the EWMS in the following ways:

› The predicted water production profile used for the water balance modelling is 40% less;

› There is one less holding pond proposed at the Central Processing Facility (CPF) water treatment plant (WTP);

› The proposed river discharge location has changed from Dog Trap Creek to the Avon River based on completed environmental studies;

› Substantially lower volumes of treated water are proposed to be discharged to the Avon River; and

› No discharge of treated water is proposed during low flow periods to augment Avon River baseflows.

AGL received Project Approval 08_0154 for Stage 1 of the 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 Secretary of the Department of Planning and Environment (DPE) in consultation with relevant government agencies prior to commencement of the construction of the project. There was a modification to the Part 3A approval in September 2014, however there was no material change to Condition 3.12.

This document is the EWMS for the Stage 1 Gas Field Development Area (GFDA). It is being submitted for the Secretary's satisfaction of the proposed water management approach prior to an investment decision to proceed with the GGP and the preparation of engineering scopes for tender.

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 associated waste streams are key considerations for Stage 1 of the GGP and important issues for government agencies and 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 pumped, treated and then either irrigated or disposed. Flowback water volumes are in addition to this volume. However with the benefit of additional flow testing programs since 2011, the extracted water volumes are now likely to be much less than these initial estimates. Water production rates (for extracted water) for the P50 water production profile are now expected to be around 0.6 ML/d at their peak diminishing to less than 0.1 ML/d after five years. For the P90 water production profile (expected worse case water volumes) the peak production is 0.9 ML/d diminishing to around 0.1 ML/d after 5 years.

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 storage tank
  - Discharge water pond
  - Brine treatment plant
  - Water reuse infrastructure within the CPF
- Associated ancillary infrastructure and works such as:
  - Existing and new irrigation infrastructure
  - River discharge infrastructure
  - Stock watering infrastructure

Preferred Strategy

AGL is committed to maximising the reuse of extracted water. Upon careful consideration of all the options, AGL's preferred strategy for extracted water management is:

- Treatment and desalination of extracted water to produce treated water and mixed salt;
- Reuse of treated water for CPF processes, and 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
- Disposal of the primary solids from the pre-treatment system and mixed salt from the brine management system at an offsite facility in accordance with regulatory requirements.

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 stream discharge;
- Brine concentration; and
- Crystallisation of brine water to produce salt.

Infrastructure will be sized and operated to meet the expected water production profile and it will include some redundancy to cater for short term peaks, maintenance, breakdowns and alike. The capacity of the WTP will initially be in excess of 1 ML/d so there will be capacity to cater for variable flows. As flowback water volumes diminish and produced water volumes decline, the desalination capacity of the WTP will be scaled back to reflect the production profile. This will also mean decreasing irrigation areas, fewer wet weather releases to the Avon River, and less crystallised salt waste. Treated water will be prioritised for working water, general consumption at the CPF and stock usage.

Irrigation areas of up to 60 ha are planned on local properties, however water volumes and irrigation areas will quickly decline after the first few years of operation. In dry to average seasons most water will be irrigated with no expected discharges to the Avon River. Water balance modelling suggests that no treated water is expected to be discharged after Year 3 of operations.

The treated water quality from the final discharge water pond (DWP) will be of low salinity and suitable for a variety of uses. Treated water after desalination is expected to be between 200 and 250 mg/L total dissolved solids (TDS). Heavy metal concentrations will be negligible or 'non detect' with barium, strontium, and zinc likely to be present in very low concentrations. There will be no or negligible methane or BTEX in the final treated water for reuse or stream discharge. The target water quality for different reuses and stream discharge is expected to be between 250 and 500 mg/L TDS depending on the conditioning required. Conditioning is expected to neutralise the pH and to lower the sodium adsorption ratio (SAR) so as to be suitable for irrigation and stream discharge (and as a raw drinking water supply source). Only one final water quality standard is proposed irrespective of the final treated water use.

The long term average salt production for the brine treatment plant (BTP) is expected to be less than 200 tonnes per annum. This equates to one truckload of salt per month for off-site disposal at a licensed facility in accordance with regulatory requirements.

New market opportunities for water and mixed salt will be further investigated, depending on 'Expressions of Interest' received for the available water and salt once a decision is made to proceed with the project. AGL has emphasised to potential users that the water production profile is likely to be highly variable and that treated water availability is not guaranteed. The desalinated water should be considered as a supplementary source of supply.

Consultation Process

The consultation process involved:

- Distribution of the Consultation Draft EWMS and inviting all the nominated agencies (Office of Coal Seam Gas (OCSG), NSW Office of Water (NOW), Environment Protection Authority (EPA), Department of Planning and Environment (DPE), Hunter Local Land Service (HLLS), Gloucester Shire Council (GSC) plus MidCoast Water (MCW)) specified in Condition 3.12 to a workshop in August 2014.

- Sending copies of the EWMS to other government agencies not directly involved in the development of the EWMS.
- Advertising the release of the EWMS and community information sessions.
- Holding a workshop with Council, MidCoast Water, regulators and other government agencies (13 August 2014).
- Launching the EWMS at the Gloucester Community Consultative Committee (GCCC) on the 21 August 2014.
- Publishing and exhibiting the Consultation Draft of the EWMS on AGL's website (21 August to 19 September 2014).
- Presenting to the Advance Gloucester meeting on the 20 August 2014.
- Organising and attending two community information sessions in August 2014.
- Being available (via mail, phone or drop in to the local office) to answer queries during the exhibition of the EWMS, and ongoing as water treatment queries have arisen.
- Preparing this final draft of the EWMS for agency review incorporating comments and feedback from consultation.

The general consensus of the agency submissions on the Consultation Draft was support for AGL's extracted water strategy and the availability of additional water that could provide additional drought security with some reservations surrounding low flow discharges and the stream disposal options.

The tasks remaining to be completed are:

- Circulate the Final Draft version of the EWMS for agency comment (in September 2015).
- Workshop with key agencies in mid-September 2015.
- Inform community representatives (in September 2015).
- Finalise EWMS (in October 2015).
- Submit Final EWMS to Secretary of DPE for her 'satisfaction' (in November 2015).
- Submit Final EWMS to Commonwealth Minister for Environment for his information/assessment (in November 2015).
- Publish the Final EMWS on AGL's website (after State and Commonwealth assessments).

AGL is seeking comment on the Final Draft EWMS from regulators and community throughout September 2015. Written submissions must be received by AGL by the **6 October 2015**.

Submissions on this Final Draft of the EWMS should be sent to the following email address:

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 GGP 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 (i.e. the returning injection water) 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 Secretary of the Department of Planning and Environment (DPE) in consultation with relevant government agencies prior to commencement of the construction of the project.

This document is the EWMS and 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 technologies and processes for extracted water management for the Stage 1 Gas Field Development Area (GFDA).

This plan is a strategy document and not a detailed Produced Water Management Plan (PWMP), Water Treatment Plan (WTreatP), Brine Management Plan (BMP) or Irrigation Management Plan (IMP) for the design, operation, management and monitoring of the water treatment infrastructure and reuse facilities of 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:
    » Gas production from 110 wells and associated infrastructure;
    » Pumping and treatment of flowback water and produced water.
    » Beneficial reuse of flowback water and produced water.
    » Maintenance and operation of a water monitoring network.
    » 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 96 km high pressure gas pipeline will be constructed and operated to transfer gas south from the CPF 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 operation, and maintenance of:

- A water gathering system and associated infrastructure within the Stage 1 GFDA;
- A water treatment plant (WTP) within the CPF for desalination of extracted water;
- A brine treatment plant (BTP) within the CPF for the crystallisation of salt;
- An oily water separator within the CPF for removal of oil-in-water emulsions from the process water generated by the gas compression process;
- Three new storage ponds, each of up to 25 ML capacity located within the CPF to store extracted water and treated 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 September 2014 to allow minor realignments to the STP corridor and to allow the connection of the pipeline to the Newcastle Gas Storage Facility (NGSF) at Tomago rather than the Hexham gas delivery station. Some of the conditions relating to the main Stage 1 development were also varied however there was no material change to Condition 3.12.

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**.

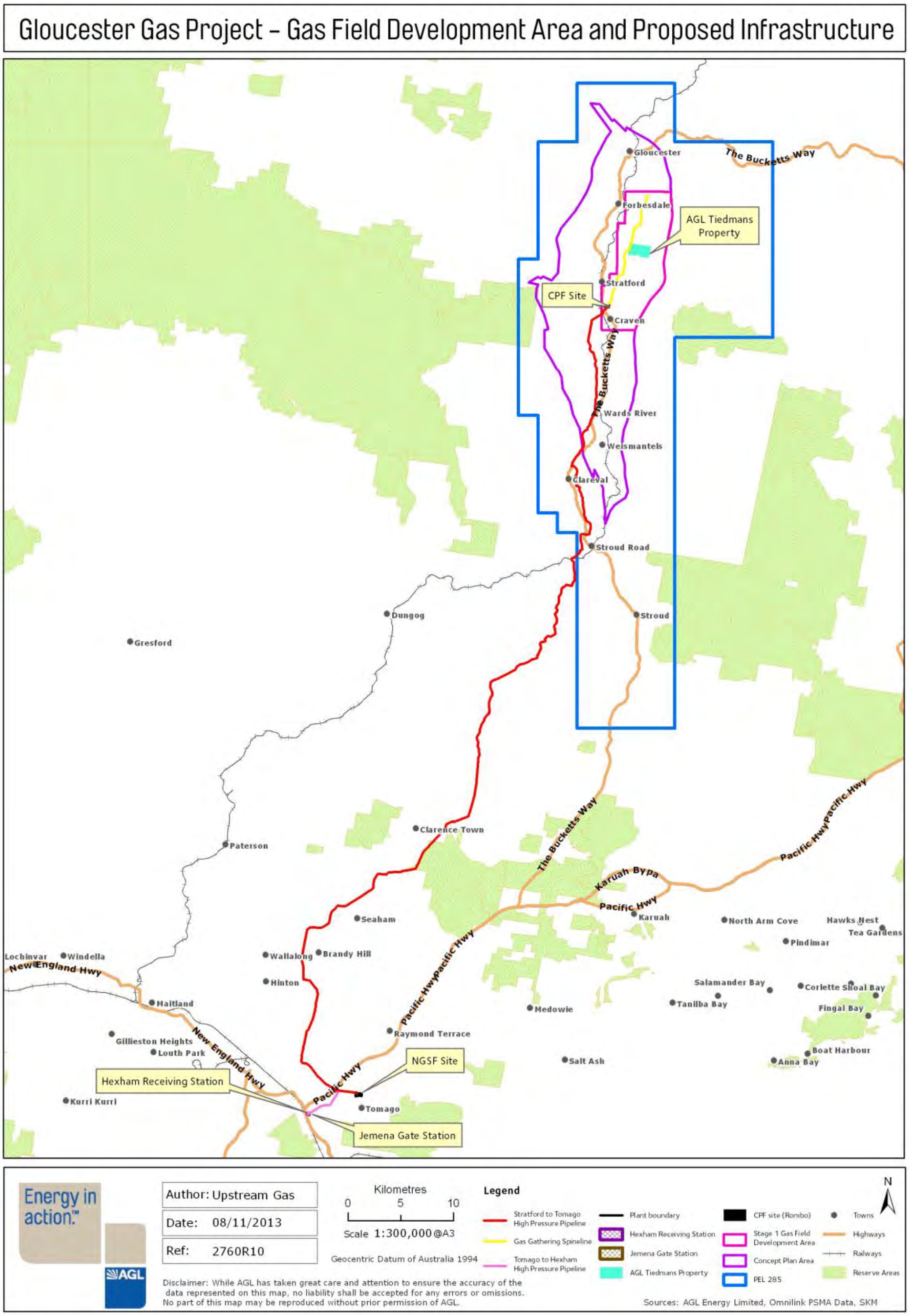


Figure 1.1: Gas Field Development Area and Proposed Infrastructure

1.3. Objectives

The objectives of this EWMS are to:

› Provide a framework for the capture, treatment and 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 target;

  » 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 an analysis of potential impacts to groundwater, surface waters, and associated groundwater dependent ecosystems; and

› Meet the requirements of the Part 3A Condition 3.12: Extracted Water Management and to obtain the approval of the Secretary of the DPE.

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 this 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 DPE, OCSG, NOW, EPA, Hunter Local Land Services (HLLS), MidCoast Water (MCW), Gloucester Shire Council (GSC), and the wider community. Stakeholder and community feedback was taken into account as part of the EWMS consultation process.

The EWMS is based on a sustainable approach to development and is 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 property, the environment and the communities within the project area.

The EWMS will 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 for both water and salt; and
- Regulations, licences, codes of practice, and industry standards change.

1.5. Inclusions and exclusions in the EWMS

The EWMS is a framework and strategy document prepared to address the Part 3A project approval requirements. It is consistent with the Environmental Assessment (EA) and Submissions Report exhibited in 2009 and 2010 respectively, and it includes a description of:

- The extracted water management options;
- AGL's preferred water reuse and discharge strategy;
- Extracted water quantity and quality characteristics;
- Stakeholder consultation process;
- Likely components of the water management infrastructure for water gathering, treatment and reticulation;
- Treated water quality targets for reuse and stream discharge;
- Waste and brine management;
- Contingency strategies for managing risks to the environment (focussing on water resources); and
- Proposed monitoring requirements.

There is also information included in the EWMS that confirms that reinjection and aquifer storage and recovery is not feasible for managing extracted water, treated water or brine given the geology and hydrogeology of the Gloucester Basin (Condition 21 of the EPBC approval).

The EWMS is not intended to provide the engineering designs for the required water management infrastructure, specifications for the treated water plant or identify the final irrigation areas, stream discharges or repositories for solid wastes. Also the EWMS does not provide specific detail relating to water treatment, brine management, irrigation management or water monitoring. Rather this document provides the overall strategy for extracted water management from source to final reuse or stream discharge.

Detailed designs for the required infrastructure will be available after an investment decision is made to proceed with the project and the Engineering, Procurement and Construction (EPC) contract for water treatment is awarded and delivered.

1.6. Summary of Submissions

1.6.1. Consultation Draft

A summary of the seven submissions received from government agencies, Gloucester Council, MidCoast Water and the public on the Consultation Draft of the EWMS is provided in **Appendix A**. Issues raised in submissions are summarised below together with an indication of where each particular issue is discussed in this Final Draft of the EWMS.

Many of the issues raised related to engineering and operational issues surrounding extracted water management. The issue of whether an approved PWMP and any other supporting plans are required and when will need to be resolved by Government. AGL proposes to develop a PWMP prior to commissioning of the CPF and therefore explicit details regarding all aspects of extracted water management are not included in this EWMS. As the detailed WTP, BTP and associated design aspects are not available at this time, details regarding these engineering components are not included in this strategy document.

Water treatment

- Engineering design detail for the WTP – not required to be included in the EWMS. Section 5.1 provides an overview.

Reuse water supply and stream discharges

- Provision of water to third parties (no commitments can be made at this stage - general discussion in Section 5.4.3).
- Stream discharge location (general discussion in Sections 11.6.2, 9.2 and **Appendix C**).
- Inclusion of water balance modelling (Sections 5.1 to 5.5, 11.1 to 11.4 and **Appendix B**).
- Contingencies to minimise stream discharge (Section 5.5 and **Appendix B**).
- Low flow discharges (no longer part of the EWMS) (see Section 5).

Management of wastes

- Brine disposal (general discussion in Section 5.1.3; Section 11.4 and Section 13.4).
- Salt encapsulation (encapsulation off-site at a licensed facility plus general brine management discussion in Section 13.4 and Section 13.5).
- Explore reuse opportunities (Section 13.4).

Water quality criteria

- Target values for reuse and discharge (Section 12).
- Site specific water quality criteria (Section 2.4.2).

Water monitoring locations

- Monitoring in the vicinity of the Tiedman storages (general discussion in Section 14 and then **Appendix E**).
- Monitoring frequencies at the WTP (**Appendix E**).
- Preparation of a Produced Water Management Plan (PWMP) – not required to be included in the EWMS.

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 which were identified in the EA:

- Stage 1 GFDA, including:
  - 110 coal seam gas wells and associated wellhead infrastructure;
  - existing holding ponds at the Tiedman property (except the Tiedman East storage (TED) which was constructed later under separate approvals);
  - water gathering lines;
  - water distribution lines;
- CPF with associated infrastructure, including:
  - receiving water pond;
  - pre-treatment system;
  - water treatment plant;
  - water treatment tank;
  - discharge water pond;
  - brine treatment plant;
  - water reuse infrastructure within the CPF;
- Associated ancillary infrastructure and works such as:
  - existing and new irrigation infrastructure;
  - river discharge infrastructure; and
  - stock watering works.

No further planning approvals are required to construct, commission and operate the proposed water infrastructure.

2.2. Legislative Requirements

The EWMS considered 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	DPE 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*	DRE within DoI
Dewatering and the pumping of groundwater to surface (where it becomes produced water) and reuse for beneficial uses (such as industrial, irrigation and stock)	Operation – Part V bore licences issued under the *Water Act 1912* (these will transition to a WAL under the *Water Management Act 2000*) 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	DPI Water
Reuse or discharge of (treated) 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 2014*	EPA
Supply of untreated or treated water to a third party	*Water Management Act 2000*	DPI Water

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 for extracting water for irrigation and industrial activities.

AGL currently holds 15 (production) bore licences under the *Water Act 1912* for the extraction of deep groundwater from the sedimentary rocks of the Gloucester Basin. These existing licences will be replaced by new licences for the gas wells proposed for the Stage 1 GFDA. These applications will be lodged in 2016 for 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 (AI) Policy will be applied to each of these licences.

Protection of the Environment Operations (Waste) Regulation 2014

Waste regulation regulations, classifications, and procedures were updated during the last 12 months. The Protection of the Environment Operations (Waste) Regulation 2014 commenced on 1 November 2014 and has been progressively implemented in 2014 and 2015.

Brine, crystallised salt, or solids resulting from the treatment of flowback water or produced water are classified in accordance with the NSW Waste Classification Guidelines (EPA, 2014) and have to be disposed of at an appropriately licensed facility. Salt is generally considered to be a General Solid Waste (non-putrescible) and is accepted at licensed solid waste landfills in NSW.

Under the provisions of the Protection of the Environment Operations (Waste) Regulation 2014, 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 the NSW Gas Plan, a number of CSG policies/guidelines and Codes of Practice (CoP). There are also a number of new and revised CoPs in preparation. The Exploration Code of Practice for Produced Water Management, Storage and Transfer (DOI, 2015) has recently been released however it has little relevance to this EWMS as it only applies to exploration programs. It also only applies to produced water storage and transfer, and not water reuse and disposal, nevertheless the principles outlined in this CoP will be addressed in the PWMP.

The AI policy is relevant given there are minimal impact considerations defined for groundwater systems that could be potentially impacted by the development and the capture, treatment, storage and reuse of extracted water.

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.

Several water quality guidelines were also taken into consideration to identify the appropriate level of treatment for the intended water reuse and disposal. The relevant policies, guidelines and codes are listed in **Table 2.2.**

Table 2.2 Policies, guidelines and codes 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 DPI Water	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
Code of Practice for Coal Seam Gas - Fracture Stimulation	September 2012	DoTI	Fracture stimulation activities UNDER REVIEW
Code of Practice for Coal Seam Gas - Well Integrity	September 2012	DoTI	Well design, drilling, completion, workover and abandonment activities UNDER REVIEW
NSW Aquifer Interference Policy	September 2012	NOW DPI Water	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
Groundwater Modelling and Monitoring Plans – information for prospective mining and petroleum exploration activities	February 2014	NOW DPI Water	Document to assist with the development of water monitoring networks to ensure the data requirements for: › Hydrogeological conceptualisation › Assessment of baseline and regional conditions › Time series data for any future groundwater model calibration
Waste Classification Guidelines	November 2014	EPA	Disposal and transport of liquid and general solid wastes
NSW Gas Plan	November 2014	NSW Govt	Plan outlining five priorities to developing NSW gas reserves including 'strong and certain regulation'
Exploration Code of Practice – Produced Water Management, Storage and Transfer	July 2015	DOI	Flowback water and produced water storage, handling, transfer and associated management activities FOR EXPLORATION PROGRAMS only

2.3. Environmental Approvals

The Environmental Assessment (EA) (*AECOM, 2009*) for the GGP 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*).

This EWMS is consistent with the proposed infrastructure and water treatment technologies in the EA (See Chapter 5 and Section 5.5.4).

Concept plan and project approvals were granted in February 2011 (Application 08_0154).

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 Secretary of the DPE. The EWMS is required to be developed in consultation with the OCSG/DRE 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 developed at the CPF or on the Tiedman site that are part of the extracted water proposals 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. In addition to the detail provided in this EWMS to address parts a) to i) of Condition 3.12, AGL will prepare a detailed PWMP prior to commissioning of the CPF.

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 Secretary, prior to the commencement of construction of the project, the Proponent shall develop an **Extracted Water Management Strategy** in consultation with OCSG, NOW, Hunter LLS, EPA and relevant Councils and to the satisfaction of the Secretary.	The process and outcomes of consultation with the relevant agencies and Councils are **summarised in Sections 1.4 and 1.6, detailed in Section 7, and discussed throughout the EWMS.**

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
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; and • salt products disposed to licensed facility as a general solid waste. **Details of these components are provided in Sections 5, 8, 9, 10, 11 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 12**. Treated water monitoring requirements are provided in **Section 14 (and Appendix E)**.

CONDITION	SECTION OF EWMS WHERE THE RELEVANT CONDITION IS ADDRESSED
<u>Condition 3.12 c)</u> 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 stored during extended wet periods, and only discharged to surface water (i.e. the Avon River) if an extreme wet weather period prevailed. 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 9**); • details of the receiving environment including water quality and flow conditions (**Section 9.2 and Appendix C**); • proposed discharge rate and frequency (**Section 9 and Appendix B**); and • practical measures to protect the environment from harm as a result of discharge to surface water (**Section 9 and Appendix C**).
<u>Condition 3.12 d)</u> 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 all treated water. The reuse of treated water for irrigation is proposed as the primary reuse opportunity. The following information regarding the reuse of treated water for irrigation is provided: • demand for the volumes of water to be generated (**Sections 8.1, 8.4, 8.5**); • 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) (**Sections 8.3, 8.4, 8.5 and Appendix B**); and • practical measures to protect the environment from harm as a result of irrigation of treated water (**Sections 8.4, 8.5, 14 and Appendix E**).

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 and eight others have indicated expressions of interest. It is expected that treated water will be available for community use. Prior to supply of treated water to the market, AGL will undertake a thorough investigation of market opportunities. This investigation is expected to have a long lead time (over 12 months) to enable consultation, negotiation and information gathering and sharing. It is expected that final arrangements will be described in more detail in the PWMP and commercial arrangements will either be included in Access and Compensation Agreements or new Water Supply Agreements.
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 (primarily Section 13.5).**
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.	This is highly unlikely and has a low consequence, and is therefore a low risk. A description of the contingency plan for the management of greater than 2 ML/d extracted water is provided in **Section 11.8**. Current modelling suggests that extracted water volumes will be less than 1 ML/d, and produced water volumes will be even less.
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 11.9**. 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 proposed reuses of treated water and stream discharges are provided in **Section 12 (Section 2.4.2 provides threshold information)**. Site specific water quality criteria will be developed during the preparation of the PWMP and in consultation with EPA.
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 water storage ponds for the GGP at the CPF/WTP will be double lined (i.e. dual layers) using high density polyethylene (HDPE) for leak detection and capture purposes (consistent with the Exploration Code of Practice for Produced Water Management, Storage and Transfer). The ponds will be designed consistent with a 1 in 100 year flood design standard and will be above the predicted PMF flood levels (BMT WBM, 2014). There is also an existing double lined pond for storing extracted water at Tiedmans. Once the stored produced water has been treated, the existing single lined ponds at the Tiedman property will be used to store treated water prior to stock and irrigation use (and stream discharge). The existing ponds are also above the predicted PMF flood levels (BMT WBM, 2014). Details of existing and proposed water storage ponds are provided in **Sections 10.1 and 11.2**.

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 11.7 of this report entitled *Aquifer Storage and Recovery*) which concluded that reinjection of produced water is not considered appropriate for the Gloucester Basin and the GGP. This conclusion is also supported by the NSW Office of Water in their submission. Details are provided in **Sections 7.7 and 11.7**.
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.	This condition relates to the produced water volumes which will be less than the extracted water volumes. Discussed in **various sections with additional details provided in Section 11.8.**
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.	**Sections 10.1 and 11.2** confirm this requirement.

2.4. Water Quality Criteria

There are two sets of water quality criteria described in this EWMS:

(i) **thresholds** which are the regulatory water quality criteria for different uses as defined by the appropriate ANZECC 2000 criteria; and

(ii) **targets** which define the water quality that can be achieved using the proposed water management and treatment processes.

In this section there is a discussion on the appropriate water quality thresholds while Section 12 discusses the proposed water quality targets for treated water (after desalination and required chemical conditioning).

2.4.1. Water Quality Thresholds for Irrigation and Stock Use

For the GGP development, AGL is planning to desalinate extracted water (see Section 5) rather than irrigate blended water which was the approved program for exploration phase produced water.

It is recognised that water quality alone does not define irrigation sustainability. Other factors such as soils, crop types, the vulnerability of adjacent and underlying water resources, rainfall, irrigation application rates, and management practices are also important considerations. However from a water quality perspective, the ANZECC guidelines (2000) for irrigation use have been adopted as the threshold values for the GGP.

The values in **Table 2.5** are the **threshold values** for treated water for irrigation and stock reuses (i.e. the adopted ANZECC water quality criteria that should not be exceeded). The **target values** that AGL plans to adopt for treated water will be much lower than these threshold values (these are discussed further in Section 12). The irrigation guideline 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 (up to 20 years).

Table 2.5 Water quality parameters and threshold values for irrigation and stock water

Parameter	Unit	Irrigation Guideline Value (1)	Stock Guideline Value (7)
pH (range)	pH units	6.0 – 9.0	-
EC (salinity)	µS/cm	1,000-3,000 (2)	3000-15000 (8)
Sodium	mg/L	230-460 (3)	-
Calcium	mg/L		1000
Chloride	mg/L	350-700 (4)	-
Sulfate	mg/L		1000
Boron	mg/L	2.0-6.0 (5)	5
Iron	mg/L	10.0	-
Manganese	mg/L	10.0	-
Nitrate/Nitrite	mg/L		400/30
Total Phosphorus	mg/L	0.8-12 (6)	
Fluoride	mg/L	2.0	2.0
Aluminium	mg/L	20	5
Arsenic	mg/L	2	0.5
Beryllium	mg/L	0.5	-
Cadmium	mg/L	0.05	0.01
Chromium (VI)	mg/L	1.0	1.0

Parameter	Unit	Irrigation Guideline Value (1)	Stock Guideline Value (7)
Cobalt	mg/L	0.1	1.0
Copper	mg/L	5.0	0.5
Lead	mg/L	5.0	0.1
Mercury	mg/L	0.002	0.002
Molybdenum	mg/L	0.05	0.15
Nickel	mg/L	2.0	1.0
Selenium	mg/L	0.05	0.02
Uranium	mg/L	0.1	0.2
Vanadium	mg/L	0.5	-
Zinc	mg/L	5.0	20.0

(1) ANZECC 2000 Water Quality Guidelines: Water quality for irrigation waters and general use, short-term trigger 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
(7) ANZECC 2000 Water Quality Guidelines: Water quality for livestock drinking water requirements (the most conservative values are quoted).
(8) Approximate conversion of the TDS limits for poultry – sheep at a conversion factor of 0.65. The dairy cattle EC limit is 6000 µS/cm

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 lowland river system as defined under the ANZECC 2000 guidelines for the protection of freshwater ecosystems as stream elevations within the GGP area are less than 150 mAHD. It is also a disturbed catchment and is generally referred to as a saline catchment because of sodic and saline soils that are derived from the underlying sedimentary 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. The catchment water quality is not typical of the ANZECC 2000 range of 200-300 µS/cm for NSW coastal lowlands although the guidelines recognise that some coastal catchments in south eastern Australia have salinities in the range 125-2200 µS/cm (Table 3.3.3 of Volume 1 of the ANZECC 2000 guidelines).

Currently there is insufficient available data to develop site specific values in accordance with the ANZECC methodology (ANZECC recommends a minimum of two years of contiguous monthly data at the reference site before a valid trigger value can be established). Quarterly data is available since October 2011, however given the variability in water quality with high and low flows, further discussions with EPA are required to confirm whether the methodology can/should be applied at this site, and whether the data requirements (quality data sets and length of data required) are sufficient.

When there is sufficient seasonal and high-low flow water quality data available, AGL proposes to develop site specific guideline values based on actual water quality data collected from the TSW01 stream gauge site, as long term data from this site are considered to more appropriately reflect local conditions than the ANZECC freshwater ecosystem criteria. The site is located downstream of the confluence of the Avon River and Dog Trap Creek, and is adjacent to the Tiedman irrigation areas. The gauge location is shown on **Figure 11.1**.

The ANZECC (2000) guidelines for the protection of freshwater ecosystems have been adopted as the default thresholds for the EWMS. The 95% trigger values for the protection of ecosystems (slightly to moderately disturbed systems) are considered the most appropriate guideline values. These values are provided in **Table 2.6**.

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

Analyte	Units	ANZECC 2000 guideline values 95% protection (1)
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	-
Aluminium	mg/L	0.055
Arsenic (As V)	mg/L	0.013
Barium	mg/L	-
Beryllium	mg/L	ID
Boron	mg/L	0.37
Bromine	mg/L	-

Analyte	Units	ANZECC 2000 guideline values 95% protection (1)
Cadmium	mg/L	**0.0005**
Cobalt	mg/L	ID
Chromium (Cr VI)	mg/L	**0.0025**
Copper	mg/L	**0.0035**
Iron	mg/L	ID
Manganese	mg/L	1.9
Molybdenum	mg/L	ID
Nickel	mg/L	**0.0275**
Lead	mg/L	**0.0136**
Selenium	mg/L	0.011 (total)
Strontium	mg/L	-
Vanadium	mg/L	ID
Zinc	mg/L	**0.02**
Mercury	mg/L	0.0006
Uranium	mg/L	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, lowland river ecosystems.
(3) ID – insufficient data to determine guideline.
(4) **Bold** values have been corrected for moderate water hardness (based on ANZECC 2000 Table 3.4.4).

2.4.3. Comparison with NSW Effluent Irrigation Guidelines

A guideline for the irrigation of effluent was prepared by the NSW Department of Environment and Conservation (now EPA) in 2004 (DEC, 2004). This guideline is educational and advisory in nature and relates to the irrigation of effluent. Extracted water is not captured under the current definition of effluent. It is not a mandatory or regulatory tool. The emphasis is on best management practices related to the management of effluent by irrigation, to be used to design and operate effluent irrigation systems, with the goal of reducing risks to the environment, public health and agricultural productivity.

The objective of the effluent guideline is to manage waste waters with high nutrient loads where that water is irrigated and beneficially reused. AGL's extracted water is mostly natural waters that are low in nutrients but high in salinity.

The effluent water quality and irrigation considerations outlined in the guideline are summarised in **Table 2.7.** The guidelines reference the ANZECC (2000) irrigation guidelines and the long term (100 years) threshold values for metals.

Table 2.7 Effluent Water Quality Guidelines and Suggested Trigger Values

Analyte	Units	Effluent Irrigation Guidelines
pH	pH units	5.0 - 8.5
Aluminium	mg/L	5
Arsenic	mg/L	0.1
Beryllium	mg/L	0.1
Cadmium	mg/L	0.01
Cobalt	mg/L	0.05
Chromium (Cr VI)	mg/L	0.1
Copper	mg/L	0.2
Iron	mg/L	0.2
Manganese	mg/L	0.2
Mercury	mg/L	0.002
Molybdenum	mg/L	0.01
Nickel	mg/L	0.0275
Lead	mg/L	2
Lithium	mg/L	2.5
Nickel	mg/L	0.2
Selenium	mg/L	0.02
Zinc	mg/L	0.2

These trigger values are lower than the short term (20 year) threshold values proposed in **Table 2.5** for irrigation reuse.

It is proposed to adopt the values in **Table 2.5** as the threshold values for irrigation and stock reuse under AGL's EWMS given the relatively short periods that treated water will be available for reuse.

3. Background Studies

3.1. AGL Irrigation Program Studies

AGL irrigated produced water from historical exploration (mostly pilot testing) programs ahead of the commencement of the GGP. The Tiedman Irrigation Program (TIP) approval recently expired and was for 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 ponds, was blended with freshwater sources to provide a water quality suitable for irrigation use.

The 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 program ensured that the quality of the water used for irrigation met the ANZECC irrigation criteria (refer **Table 2.5**) and that the application of irrigated water did not result in impacts on the local surface water or groundwater resources. Water level and water quality data were evaluated for each monitoring period together with periodic soil sampling reports for the irrigation area.

Blended water irrigation occurred 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**.

Monitoring of the TIP has indicated that marginal to brackish irrigation water can be irrigated successfully in this high rainfall landscape. The TIP ended on 30 April 2015 with the reuse of 54 ML of the original 55 ML of produced water that was in storage. During the irrigation program period from April 2013 to April 2015, approximately 130 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 and productivity was high;

› There was some salt exported in crops; and

› There was some slight build-up of sodium in the soil profile, but the loading was small.

A series of six-monthly water compliance reports were prepared as part of the approval requirements of the Division of Resources and Energy (DRE) and Office of Coal Seam Gas (OCSG). These are:

› The baseline and the initial irrigation period to 30 June 2013 (PB 2013c);

› The period 1 July 2013 to 31 December 2013 (PB, 2014a);

› The period 1 January 2014 to 4 July 2014 (PB, 2014d);

› The period 5 July 2014 to 31 December 2014 (PB, 2015a); and

› The period 1 January 2015 to 30 June 2015 (PB, 2015c).

The findings of the most recent water compliance report were that monitoring during the approval period to 30 April 2015 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 shallow groundwater.

These studies have confirmed that deficient irrigation with appropriate monitoring is a suitable reuse approach for produced water. The studies have demonstrated the beneficial reuse of produced water through irrigation.

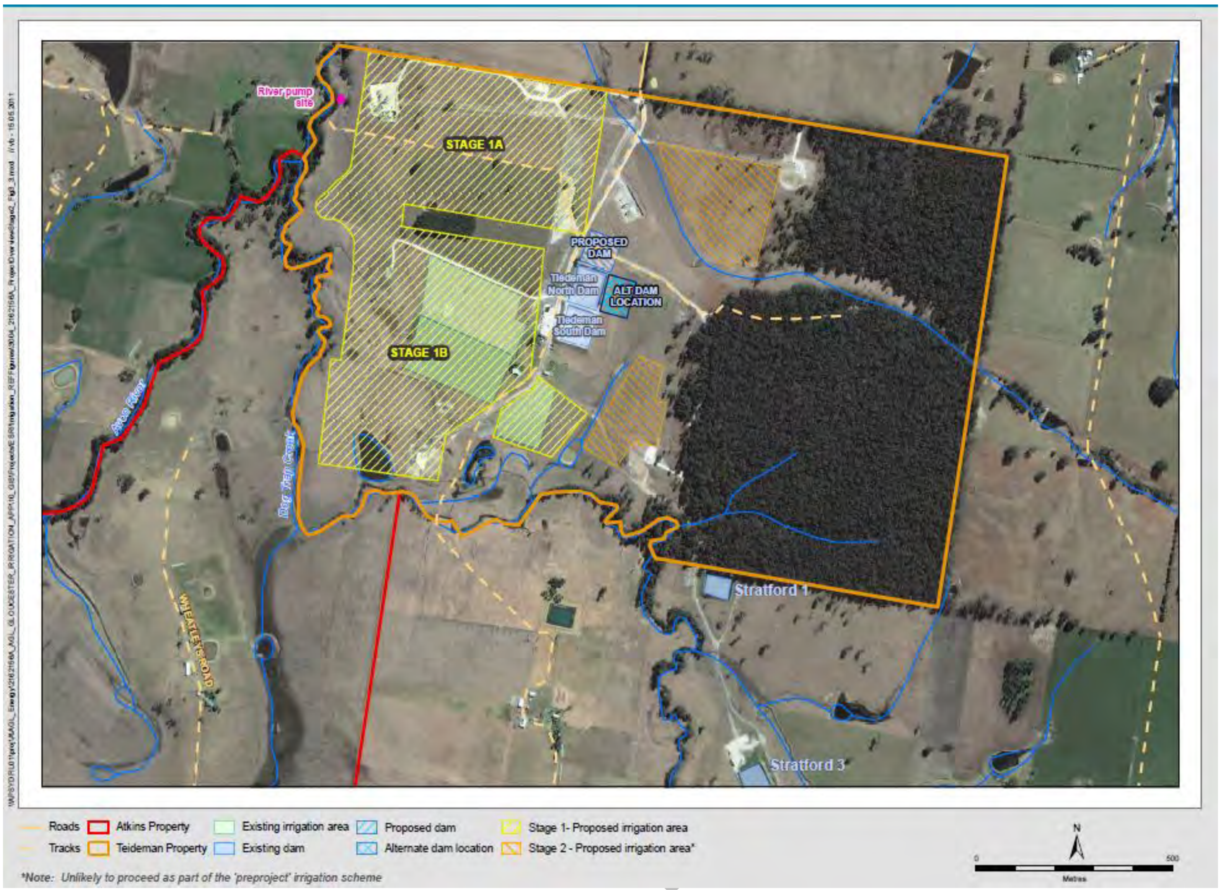


Figure 3.1: Tiedman Irrigation Areas

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 across the Stage 1 GFDA is 40 groundwater and ten surface water monitoring sites (plus there is more monitoring across the remainder of the basin). Three annual monitoring reports (for years 2012, 2013 and 2014) have been published for the groundwater monitoring data for the period January 2011 to June 2014. The 2015 report will be released in October 2015. There is currently more than 54 months of baseline project and exploration project water data. PB 2014e focuses on the last monitoring period (July 2013 to June 2014). These reports are available on AGL's project website at http://www.agl.com.au/about-agl/how-we-source-energy/natural-gas/natural-gas-projects/gloucester-gas-project/gloucester-gas-project .

The status reports highlighted that groundwater level trends in the monitoring bores vary depending on the climatic conditions, the lithology and depth of the screened interval. These reports provided the following observations:

- Groundwater levels in monitoring bores screened in the alluvial deposits respond rapidly to significant rainfall events.
- Groundwater levels in shallow rock monitoring bores decreased slightly during 2014 in response to the below average rainfall. There are no strong responses to individual rainfall events in the shallow rock monitoring bores.

- Groundwater levels in interburden and deep coal seam monitoring bores show minimal change over the monitoring period, and groundwater levels do not respond to individual rainfall events.
- 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 deep 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 and surface water sites in accordance with the existing program. In addition to the annual status reports there are quarterly updates prepared on water level trends. All results are published periodically on AGL's Gloucester website.

Some of these monitoring locations will be key site locations for where AGL is undertaking irrigation reuse or controlled stream discharge. Further details will be provided once AGL's Groundwater Monitoring and Modelling Plan (GMMP) for Stage 1 has been developed.

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 testing programs on Waukivory 03 and Craven 06 in 2013/14 (PB, 2014c, PB, 2015b) and the four gas wells that are the Waukivory pilot in 2014/15 (PB, 2015c and 2015d). The produced water quality from Craven 06 is slightly saline, is sodium-chloride-bicarbonate dominant, is low in trace metals and has few other analytes. Total BTEX and TPH concentrations were low. This water quality has been used extensively in this EWMS as being typical of expected produced water qualities across the Stage 1 GFDA. However a more conservative water quality range will be used for the purpose of desalination plant design.

The Waukivory fracture stimulation and flow testing program is providing additional information on water production profiles and water quality. Currently this program is in the flowback water phase so the water quality is still transitioning from flowback water quality to produced 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.

The average flow contribution of the Avon River downstream to the Manning River flow at Killawarra was found to represent approximately 8% of the total river flow. Based on water levels within the Stage 1 GFDA, a rapid response to rainfall events was recorded within the Avon River and Dog Trap Creek (except after extended dry periods) with large flow events occurring both in summer and winter.

Different water quality results were recorded during high and low flow events. Salinity and dissolved metal concentrations are generally lower during high flow sampling events (apart from an initial salinity spike) compared to routine water quality monitoring conducted during lower flows.

This information was useful in determining likely river locations and conditions for the discharge of excess treated water during high rainfall and high river flow periods.

Other hydrology and salinity studies conducted by others have similar catchment conclusions. 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 - Baseline Water Surveys

Gloucester Council (using consultants SMEC), under the Water Study Project initiative (see Section 7.9), completed baseline water surveys of properties in private ownership within and immediately adjacent to the Stage 1 GFDA in March 2014. 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 were sent to all landowners and summary information is available from http://www.gloucester.nsw.gov.au/environment/water-study-project-new/baseline-water-survey

The surveys did not locate any groundwater bores or shallow wells/excavations within the Stage 1 area (only two spring fed dams). Summary details are provided in **Table 3.1**.

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

Attributes	Number / Description
Number of properties surveyed	19
Number of bores and wells	Zero
Number of springs/spring fed dams	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 overland flow 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. Gloucester Shire Council – Flood Study

Gloucester Council (using consultants BMT WBM), under the Water Study Project initiative (see Section 7.9), completed a major flood study of the Avon and Gloucester River catchments in 2014/15. Both the CPF site and the Tiedman property where most of the above ground water infrastructure is sited, are located off the Avon River floodplain and beyond the 1:100 and PMF flood limits (BMT WBM, 2015).

3.7. 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 (BAP) being delivered by the Office of Water Science. The context statement for the Gloucester Sub Region was released in May 2014 (DoE, 2014a), the coal and CSG resource assessment statement in October 2014 (DoE, 2014b), and the water dependent asset register in January 2015 (DoE, 2015a).

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 dependent assets.

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

4. Evaluation of Extracted Water Options

4.1. 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 Environmental Assessment (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 from the EA for different reuse and disposal opportunities for produced water and brine are summarised in **Table 4.1.**

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 fewer (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 technologies 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.

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 EA proposed that the extracted water would be stored in a receiving water pond (maximum 25 ML). Post treatment the treated water would be stored in a maximum 25 ML treated water pond and 25 ML discharge water pond). Treated water would then be transferred to the Tiedman property prior to reuse or disposal. The capacity of the additional water storage (three holding ponds) at the Tiedman property was to be 60 ML. Management of the treated water was 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 preferred options align with those options in the recent GSC study (RPS, 2014) described in Section 4.2.

4.2. 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.
- 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 the preferred water management strategy outlined in AGL's Environmental Assessment (EA) (AECOM, 2009).

4.3. Re-evaluation of Options

A re-evaluation of preferred reuse options from the EA (AECOM, 2009) and options revisited in Councils independent options assessment (RPS, 2014) was completed as part of the finalisation of this EWMS. The 2014 EWMS consultation process has also confirmed these preferred reuses.

AGL's justification for adopting irrigation and stock usage is as follows:

› The Stage 1 GFDA is located with a primary production area (agriculture, grazing and mining) and reuse for irrigation and stock are appropriate local land uses.

› The availability of a supply of treated water (albeit small) will improve the drought security of local farms by providing new water and the opportunity to grow additional crops and improved pasture to provide additional stock feed.

› New business opportunities may arise if there is sufficient new water.

These reuses were supported in the agency and community submissions, and AGL has already received a number of 'Expressions of Interest' from local farmers for the use of this treated water.

In addition AGL has included industrial reuse for its own drilling and fracture stimulation programs. By reusing as much extracted water as possible, and recycling it for multiple drilling and fracture stimulation programs, this practice ensures there is a minimal take from town water and other freshwater sources. This reuse will be the predominant reuse of treated water during the initial years of the project.

The following reuses were discounted from the recommended combinations in the RPS study:

› Intensive livestock production – there are no intensive livestock operations located close to the Stage 1 GFDA and no new industries are likely in the short to medium term. Given the relatively small volumes of water likely to be available longer term, occasional stock use for beef and dairy cattle on existing properties is considered a better stock water supply option;

› Aquaculture – there are no existing aquaculture operations located close to the Stage 1 GFDA and no new industries are likely to emerge in the short to medium term. Also further investigations and research would be required to assess whether the variable water quality would be suitable for different fish and crustacean species;

› Silviculture (forestry) – there are no plantation forestry operations located close to the Stage 1 GFDA and no new industries are likely to emerge in the short to medium term;

› Mining – further discussions with the miners suggest they have sufficient freshwater and mine water for their process water applications at this time. Discussions suggest that miners may provide water to AGL for reuse rather than vice versa;

› Irrigation of urban parks and green areas – Council expressed no interest in using treated water within Gloucester for non-potable uses. Also at the present time, CSG infrastructure is prohibited within the 2km residential buffer area so such a scheme would be difficult to build and operate;

› Artificial Storage and Recovery (ASR) – data and desktop technical feasibility assessments suggest that reinjection would not be viable unless the treated water volumes were very small and a suitable high permeability and depleted storage location was identified. Groundwater recharge is prohibited under the current planning approval and NOW is not supportive of any ASR scheme.

5. AGL's Preferred Water Reuse and Discharge Strategy

AGL has re-evaluated the original beneficial reuse proposals presented in the EA in 2009 (AECOM, 2009 and 2010), reviewed the broad opportunities that were described in the Gloucester Shire Council report (RPS, 2014), and reviewed the results of the Tiedman (blended water) irrigation program (PB, 2015a).

Upon consideration of the options and following community feedback, AGL's preferred strategy for managing extracted water for the Stage 1 GFDA is:

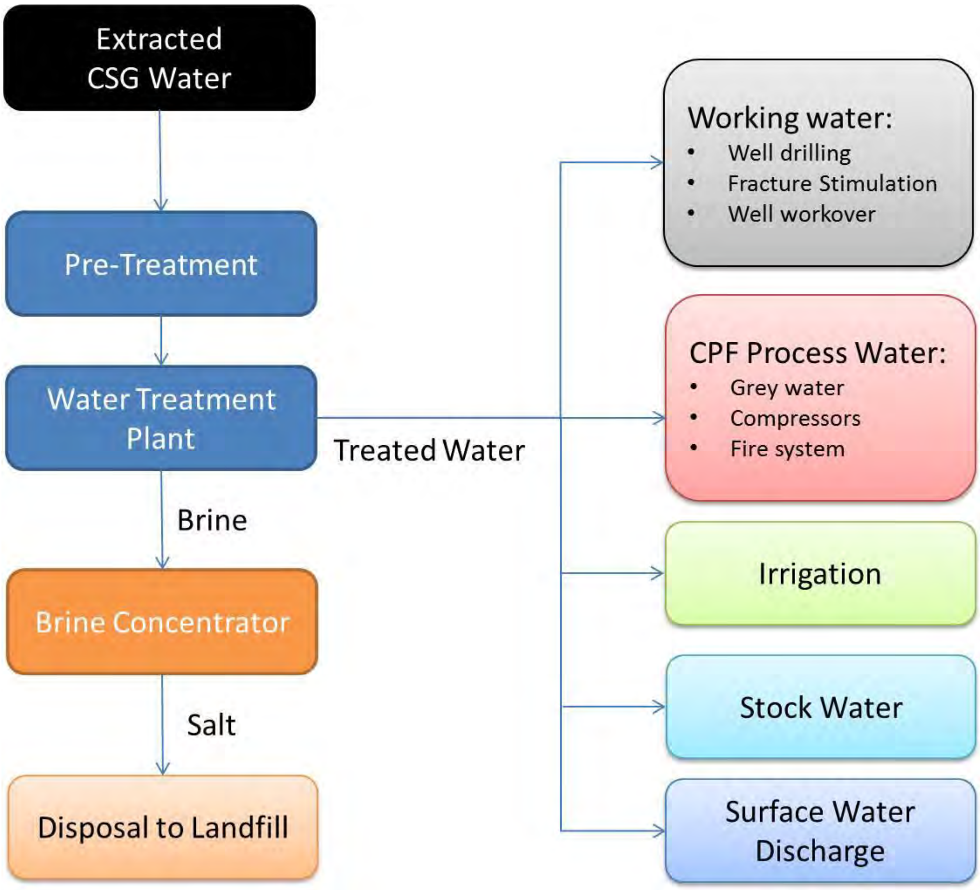
- Treatment and desalination of extracted water to produce treated water and brine;
- Reuse, when required, of treated water for CPF processes, and drilling, fracture stimulation and workovers (i.e. working water);
- Beneficial reuse of treated water for stock and irrigation purposes;
- Discharge of treated water to streams (when irrigation is not possible and high flows are occurring along the Avon River);
- Landfilling of the primary solids from the pre-treatment process to an appropriately licensed facility; and
- Landfilling of the mixed salt from the brine stream to an appropriately licensed facility.

A small but useful new source of low salinity water will be available for consumptive uses within the northern Avon River catchment. All new water for consumptive uses will be piped to the reuse areas. The Avon River will not be used as a distribution channel for treated water during low flow periods. The mixed salt removed from the extracted water via desalination and salt concentration and crystallisation processes will be trucked off-site and disposed to licensed facilities outside of the catchment as general solid waste (GSW).

Water balance modelling together with the current water production profile for 110 wells has been used to generate the volumetric estimates for treated water for reuse and brine water for disposal. A separate report for the water balance modelling is provided in **Appendix B**.

5.1. Extracted Water Management Components

The proposed extracted water management system is shown in **Figure 5.1**. This flowchart generally represents the proposed flow path options 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 the following sections.

5.1.1. Extracted Water Gathering System

The extracted water gathering system consists of a central spine line with a network of smaller pipelines from each of the wells. The flowback and produced water will be gathered and transferred to the receiving water pond (RWP) located at the CPF through the main water gathering lines. 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 watering purposes).

A third (bi-directional) water pipeline will be installed between the Tiedman storages and the CPF to allow water (mainly treated water) to be transferred between these two storage facilities. Installation of extracted water and working water lines will reduce the number of vehicle and truck movements over the life of the project.

5.1.2. Water Treatment Plant

The water treatment plant (WTP) comprises all the plant and equipment from the receiving water pond (RWP) to the discharge water pond (DWP). The primary components are:

Pre-treatment systems

The extracted water will be treated by several pre-treatment systems to remove particulate matter, compounds that could scale the RO membranes, and residual fracture stimulation additives to render this water acceptable as feed water to the reverse osmosis (RO) plant.

The pre-treatment systems prior to the RO plant include:

› Dissolved air flotation (DAF) unit.

› Disc filtration (DF) unit.

› Microfiltration and ultrafiltration (MF/UF).

› Ion exchange (IX) unit.

For the GGP start-up, it is expected that water from freshwater sources or residual produced water located in the Tiedman storage ponds from exploration programs will be used and processed through the pre-treatment systems and the RO plant. This water will gradually be recycled and replaced by flowback water and produced water from the fracture stimulation, dewatering and commissioning phases of the Stage 1 program.

Desalination plant

Water from the pre-treatment system will be desalinated by the RO unit. RO membrane separation technology is the preferred desalination option to treat the extracted water generated over the life of the project. RO is well proven, robust and is widely applied within the Australian CSG industry as the preferred desalination technology.

RO desalination potentially offers the lowest life cycle cost and the highest water recovery (i.e. potentially treated water recovery greater than 85%) 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 which is likely to use thermal brine concentration and crystallisation technology to produce salt.

Post Treatment systems

Any residual hydrocarbons in the treated water from the RO plant will be treated and removed by using granulated activated carbon (GAC) between the treated water tank (TWT) and the DWP.

5.1.3. Brine Management Plant

Based on the composition of produced water and the design of the WTP, a small brine stream 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 produces a mixed salt.

AGL's preferred approach is the production of a mixed salt (general solid waste (GSW)) suitable for transport to a licensed facility in accordance with regulatory requirements. This approach will remove all the salt from site (and the Avon River catchment) but will allow the salt to be potentially recovered from the licensed facility if suitable reuses are identified longer term.

At this stage, the variable composition of the salt, and the low and variable 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 and reuse applications can be 'bolted on' in the future if appropriate.

5.1.4. Water Reuse and Discharge

To maximise beneficial reuse of the treated water, AGL prefers irrigation and stock as the prime beneficial reuses with discharge to the Avon River at times when irrigation is not possible. The water volumes proposed for process water reuse are small by comparison with irrigation use. Working water volumes are higher for the first three years but are negligible thereafter. The treated water quality will be managed to ensure that:

› Only one treated water quality type will be generated and this quality will be the lowest salinity required for irrigation, stock, working water or stream discharge purposes;

› The water quality for irrigation will not exceed the water quality thresholds for irrigation and stock use (see Section 2.4.1); and

› The water quality for discharge to the Avon River will not exceed the ANZECC environmental thresholds and flow conditions (see Section 2.4.2).

In practice the water quality able to be achieved by the WTP for the treated water will be significantly lower than the proposed irrigation and river discharge thresholds.

5.1.5. Water Production Profile

The water production profile for Stage 1 has been revised based on the expected design and construction, fracture stimulation and commissioning schedules for the 110 gas wells that will comprise the Stage 1 development. Based on the latest available information on geology, flow rates and likely schedule for field development, extracted water volumes are expected to be much lower than the approved 2 ML/d.

These aggregated water production profiles are shown in **Figure 5.2** for the P10, P50 and P90 water production scenarios. The profiles are shown in cubic metres per day (m^3/day). Curves are also compared against the P50 water production profile for extracted water that was used in earlier water projections.

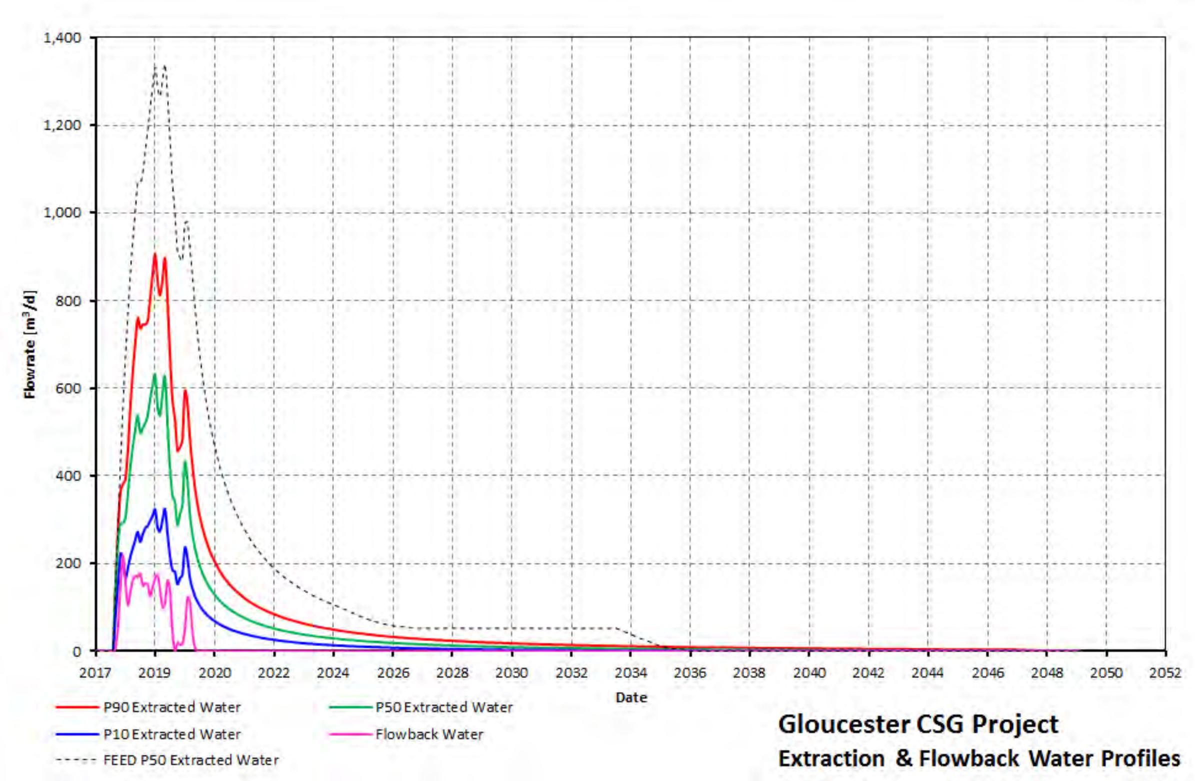


Figure 5.2 - Predicted extracted water flow profiles

The current water balance modelling (Worley Parsons, 2015) is presented in **Appendix B**. Modelling suggests that the maximum (P90) water production rates (for extracted water) will be peak at around 0.9 ML/d within the first 36 months. Flows will then diminish to less than 0.1 ML/d after five years.

5.2. Reuse for Working Water

Working water is water that has been treated at the WTP and is suitable for return to the field for drilling, fracture stimulation and well workover purposes when required. Water will be treated at the WTP to a high standard to meet all reuse and discharge requirements.

Drilling

It is estimated that approximately 0.5 ML of water will be required for drilling at each well. Initially, drilling water will be sourced from existing (produced water) holding ponds at Tiedmans or freshwater sources. When and if available, treated water will be used in preference to these water sources. However given the early timing for the drilling program, treated water is unlikely to be available for the first 50% of new gas wells.

Fracture Stimulation

The initial fracture stimulation water will be sourced from AGL's existing (produced water) holding ponds at Tiedmans or freshwater sources at the start of the fracture stimulation campaign. Once treated water from the WTP is available, this water will be used for fracture stimulation. AGL estimates between 0.5 and 1.5 ML of water will be required to fracture stimulate each well (and average around 1 ML per well). Water volumes will be dependent on the final well designs and the number of fracture stimulation intervals. It is estimated that the total demand for fracture stimulation water will be approximately 100 ML over the entire well development phase.

Workovers

Well workover operations will be conducted over the life of the project and are likely to be approximately 0.05 ML per well. Working water will be sourced from treated water from the WTP. It is expected that workover frequency and associated working water demands for each well will be highest in Years 2 to 5 with a large decrease beyond Year 5.

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 non-potable domestic needs);

› Process water for compressors and cooling systems; and

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

These demands for water at the CPF will be sourced from the treated water tank (TWT) or the discharge water pond (DWP) within the WTP. The quantity of water required to supply CPF operations is very small and is estimated to be approximately 2 ML per year.

Drinking water at the CPF will be trucked to the site from a potable water supply source.

5.4. Reuse for Agricultural Purposes

5.4.1. Reuse for Stock

There will 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 flow rates are dependent on seasonal conditions and contractual arrangements to supply stock water. These have not been determined at this time. The stock reuse component is part of the treated water volume identified for irrigation reuse. Water is expected to be delivered via the working water delivery lines and will be to a high standard defined by other beneficial reuses.

5.4.2. Reuse for Irrigation

Under this irrigation reuse option, treated water from the WTP would be transferred to storage ponds at the Tiedman property 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 in an average rainfall year. 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 rates are high (mostly spring and summer). Seasonally the irrigation application rates could vary between 2 ML/ha/year and 6 ML/ha/year.

5.4.3. Future Water Opportunities

Over the course of the project, new opportunities may arise for the beneficial use of untreated and treated extracted water. As part of the Consultation Draft dialogue, AGL made an initial call for 'Expressions of Interest' from third parties for use of both water (treated and untreated) and salt. Eight expressions of interest were received for the use of desalinated water for irrigation and stock purposes. AGL will continue to identify potential third party users for both water and salt.

There is the opportunity to supply farming properties with treated water close to the proposed reticulated water pipelines. Treated water will be suitable for both stock and irrigation uses so there is the potential for farmers to be supplied with additional water or replacement water during periods of drought. Stock water is a higher priority than irrigation water and hence it is expected that stock supplies would be maintained in preference to irrigation supplies.

The ongoing availability and quantity of this water for external consumptive uses will diminish with time and there are risks regarding new developments based on what could be a limited and declining water supply if subsequent stages are not developed.

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 (although it is again stressed that water availability is limited and start up opportunities would have to align with the early years of the GGP). 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 desalinated water (which is new water from the deep groundwater systems) is only expected to provide a small increase in available water supplies.

Even assuming high water production rates (P90 case), modelling suggests that the water for irrigation and stock use will peak at just over 200 ML/yr in the early years of production and average less than 60 ML/yr for the whole operational period (Worley Parsons, 2015). This new water represents less than a 10% increase on estimated current water use for these purposes across the catchment (RPS, 2014).

5.5. Surplus Water Discharge to Surface Water

The last (and least favourable) extracted water management option is to discharge treated water to surface waters. There will be no discharge of (untreated) extracted water to any surface water receptors. Discharge to the Avon River would occur when the preferred irrigation and stock options are not available due to climatic conditions, namely extensive wet weather periods, and there is insufficient detention storage capacity for treated water for an extended period.

AGL has completed an ecological and geomorphological assessment study to confirm a suitable discharge location along the Avon River (Cardno, 2015). Further details are provided in Section 9.2 and **Appendix C**.

No discharges of treated water are expected if average to dry seasons prevail as all water can be stored and beneficially reused though stock and irrigation use.

If high rainfall conditions prevail during the early years of the development, small discharges of treated water into the Avon River may be required as a 'pressure relief valve' on the system. Total volumes are expected to be less than 20 ML. These projections only occur for the worst case climate conditions and only for the peak of the extracted water production period in Year 3 of the project (Worley Parsons, 2015). 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.

Discharges (if required) would be managed in accordance with the relevant licences.

Taking into account community and regulatory feedback, it is expected that periods of moderate to high flow conditions would represent the most favourable conditions for discharge of treated water. During these periods (after the high flow/flood peak) the lowest salinity would be present in the streams and the treated water quality would be compatible with the receiving waters. 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 long term reuse for irrigation and stock.

6. Extracted Water Quantity and Quality Characteristics

The target coal seams will be fracture stimulated to increase gas flow. Initially, freshwater (or stored produced water that is treated) will be used for fracture stimulation operations. A large proportion of this fracture stimulation fluid is recovered during initial dewatering as 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 from individual wells when the extracted water volume is equivalent to 100% of the injected water volume and water quality (primarily salinity) matches the natural formation water (groundwater) quality. Subsequent extracted water is termed "produced water".

6.1. Flowback Water Volumes

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. The initial water for drilling programs will be from freshwater sources. The water for fracture stimulation programs is expected to be treated water from the WTP delivered by the working water delivery lines.

Flowback water will be recycled through the WTP. For each well it is expected that approximately 30% of flowback water will be recovered within seven days of commencing dewatering and that the remaining flowback would be recovered within approximately eight to 12 weeks of commencement.

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 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 was mostly adopted for the Waukivory Pilot program (AGL, 2014a).

The flowback water is expected to contain a mixture of the injected water, formation water, and the fracture stimulation additives. Typically the flowback water will contain very low concentrations of fracture stimulation additives such as Monoethanolamine Borate (MEAB), Tetrakis (hydroxymethyl) phosphonium sulphate (THPS), and BTEX compounds from the coal formations. Recent water quality data from the Waukivory pilot program has provided additional results to characterise flowback water. Typical flowback water and produced water quality is provided in the specification in **Appendix D**.

6.3. Produced Water Volumes

Typically, dewatering rates decrease over the life of each well.

Based on the results of flow testing programs across the basin, current well designs, and the development timetable, a likely water production profile has been developed for the 110 wells that comprise the GGP Stage 1. The median or most likely water production profile is referred to as P50. In addition the water balance modelling has considered P10 (low) and P90 (high) water production profiles (Worley Parsons, 2015). These water production profiles (which are for extracted water which includes flowback water as well as produced water) are provided in **Figure 5.2**.

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 water year. Latest water balance modelling suggests that the daily and annual (extracted) water production rates will be much less than these approved volumes (and produced water volumes will be less again).

This is because of the geology and likely schedule for field development, and the fact that the wells will be completed in low permeability strata and the shallowest coal seam targets are now likely to be greater than 250 mbgl (rather than the original 150 mbgl).

6.4. Produced Water Quality

The quality of the produced water varies according to the geology of the region. Summary information is provided in RPS Group, 2014.

The most recent water quality data is available from historical flow testing programs across the basin being the 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 current Waukivory flow testing program in the north of the Stage 1 GFDA is also providing additional information on water quality.

The CR06 well is located near the centre the Gloucester Basin but in the southern portion of the Stage 1 GFDA. Wells which are located more centrally within the basin (and completed across deeper coal seams) are expected to produce water with a higher salinity than wells which are located further east. This is due to groundwater recharge mostly occurring along the eastern coal seam outcrop area and shorter residence times.

The results from CR06 are therefore considered representative and are being used for the design of the WTP at the CPF. Additional water quality data from the Waukivory wells now on test has provided additional data on the spatial variability of flowback and produced water quality. Typical flowback water and produced water quality is provided in the specification in **Appendix D**.

6.5. Extracted Water Characteristics

Flowback water can vary between freshwater and slightly saline water depending on the raw water source that is used for fracture stimulation programs. Most produced waters from the Stage 1 development area are expected to be either brackish or slightly saline. At worst, the water quality will be moderately saline as deep groundwater quality in the Gloucester Basin is known to be brackish to moderately saline.

For extracted water:

- Heavy metal concentrations are either low or negligible;
- Iron and manganese concentrations can be high;
- Boron concentrations can be high in flowback water;
- Nutrient levels are low in produced water except for occasional high ammonia; and
- Hydrocarbon concentrations are low although may be slightly higher in flowback water than produced water.

The concentration of fracture stimulation additives in flowback water is low and negligible concentrations are expected in produced water. In practice at the WTP flowback water will be comingled with produced water (because wells will be commissioned at different times). The proposed water treatment plant will remove fracture stimulation additives and reduce salinity, resulting in treated water that is suitable for proposed reuse options (predominantly stock and irrigation use) and for discharge to surface waters.

The following is a summary of the expected longer term produced water characteristics based on the results of 12 months of water quality results from the Craven (CR) 06 well.

Salinity

The produced water is generally dominated by sodium, chloride and bicarbonate. The salinity at CR06 varied between 5500 and 7500 µS/cm.

pH

The pH of most natural waters ranges between 5.0 and 8.0. The pH of produced water at Gloucester is alkaline (generally pH 7.5 – 9.5) and at CR06 varied between pH 7.2 and 9.6.

Sodium and Chloride

Sodium (Na) and chloride (Cl) are two of the most common elements in produced water (ranging from 1,000 mg/L to 3,500mg/L for sodium with CR06 showing a concentration of around 1,750 mg/L and chloride levels ranging from 400 mg/L to 2,000 mg/L with CR06 showing a maximum concentration of 1,570 mg/L).

Potassium

The potassium (K) levels in the produced water at Gloucester are low with a predicted range of 5 mg/L to 30 mg/L, with CR06 showing a concentration of around 12 mg/L.

Calcium and Magnesium

The calcium (Ca) and magnesium (Mg) content is relatively low. Calcium is expected to range from 1 mg/L to 75 mg/L with CR06 showing a concentration of around 20 mg/L whereas magnesium is predicted to range from 1 mg/L to 10 mg/L with CR06 showing a concentration of around 5 mg/L.

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.

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 1,300 mg/L to 6,000 mg/L (expressed as $CaCO_3$) with CR06 indicating an alkalinity of around 2,000 mg/L.

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 up to 300 mg/L. Lower concentrations are expected when water is pumped to/from the RWP and enters the WTP. Although these are elevated TSS levels, it is not likely to be of concern since settlement within the RWP and suspended solid removal during pre-treatment will capture all particulate matter.

Silica

The silica (Si) levels in the produced water are expected to range from 10 mg/L to 40 mg/L (with CR06 showing a concentration of around 15 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 if appropriate anti-scalant is adopted.

Manganese

The manganese (Mn) levels in the produced water are expected to range from 0.1 mg/L to 1.0 mg/L with CR06 showing a concentration of around 0.4 mg/L.

Iron

The iron (Fe) levels in the produced water are expected to range from 1 mg/L to 70 mg/L, with CR06 showing a variable content of up to 35 mg/L. This is a high iron concentration but typical of natural groundwater.

Strontium

The strontium (Sr) concentrations in the produced water are expected to range from 1 mg/L to 10 mg/L, with CR06 showing a concentration of between 3 and 4 mg/L.

Fluoride

The fluoride (F) present in the produced water is predicted to range from 0.1 mg/L to 3.0 mg/L, with CR06 showing a concentration of around 1.5 mg/L.

Boron

The boron (B) present in the produced water is predicted to range from 0.1 mg/L to 0.5 mg/L with CR06 showing concentrations up to 0.35 mg/L. Flowback water can however have higher concentrations of dissolved boron due to the breakdown products of MEAB. Levels from the Waukivory pilot site have recorded concentrations up to 12 mg/L.

Other Trace Metals & Inorganics

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

The aluminium, barium, copper, and zinc content of CR06 were at low levels and do not present any issues in regard to WTP operation, and do not exceed the threshold values for irrigation and stock water or stream discharge.

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

BTEX and other hydrocarbons

The total benzene, toluene, ethyl benzene and xylenes (BTEX) concentration in produced water is predicted to range between 10 and 100 µg/L with CR06 showing concentrations up to 20 µg/L.

Concentrations are expected to be higher in flowback water from individual gas wells immediately after fracture stimulation where concentrations of total BTEX could be up to 1000 µg/L at individual well sites.

The concentrations of other hydrocarbon compounds such as phenolic compounds and polycyclic aromatic hydrocarbons (PAH) are expected to be negligible to low. Concentrations at CR06 were negligible and were less than 5 µg/L for a couple of individual phenolic compounds. No PAHs were detected in the produced water from CR06.

These hydrocarbon concentrations are typical of formation waters that occur in deep coal seams.

7. Stakeholder Consultation

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

- Office of Coal Seam Gas (OCSG);
- NSW Office of Water (NOW);
- Hunter Local Land Services (HLLS);
- Environment Protection Authority (EPA); and
- Relevant Councils.

Relevant councils are deemed to be Gloucester Shire Council (the whole of the Stage 1 development is located within their local government area) and MidCoast Water (who are responsible for water supply and sewerage matters across Gloucester Shire, Taree City, and Great Lakes Shire areas).

The development of the EWMS must be to the satisfaction of the Secretary of the DPE. In recent times agency roles and responsibilities have changed in relation to regulating CSG exploration and production activities so the discussion below reflects on both the consultation process in 2014 and the current regulatory arrangements in 2015.

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

A one day workshop was held in Gloucester on 13 August 2014 prior to the formal release of the EWMS to discuss the strategy and content of the Consultation Draft with the relevant agencies. OCSG, NOW, EPA, DPE, Gloucester Council (GSC), and MidCoast Water (MCW) staff attended. A number of changes were made to the Consultation Draft prior to its formal release on the 21 August 2014.

Although not required under the Part 3A approval, AGL also placed the EWMS on exhibition for four weeks to obtain community responses to the extracted water management proposals. The exhibition period for the Consultation Draft was 21 August to 19 September 2014. **Appendix A** summarises both the agency and community submissions.

The final EWMS will be submitted to the Department of Planning and Environment (DPE) to address Condition 3.12 and to ensure that the EWMS is to the satisfaction of the Secretary. Under Condition 21 of the EPBC Approval, the Commonwealth Minister will also be provided a copy of the EWMS.

7.1. Consultation Process

The consultation process for the EWMS included:

- Distribution of the Consultation Draft EWMS and inviting all the nominated agencies (Office of Coal Seam Gas (OCSG), NSW Office of Water (NOW), Environment Protection Authority (EPA), Department of Planning and Environment (DPE), Hunter Local Land Service (HLLS), Gloucester Shire Council (GSC) plus MidCoast Water (MCW)) specified in Condition 3.12 to a workshop in August 2014.
- Sending copies of the EWMS to other government agencies not directly involved in the development of the EWMS.
- Advertising the release of the EWMS and community information sessions.

- Holding a workshop with Council, MidCoast Water, regulators and other government agencies (13 August 2014).
- Launching the EWMS at the Gloucester Community Consultative Committee (GCCC) on the 21 August 2014.
- Publishing and exhibiting the Consultation Draft of the EWMS on AGL's website (21 August to 19 September 2014).
- Presenting to the Advance Gloucester meeting on 20 August 2014.
- Organising and attending two community information sessions in August 2014.
- Being available (via mail, phone or drop in to the local office) to answer any queries during the exhibition of the EWMS, and ongoing as water treatment queries arise.
- Preparing this final draft of the EWMS for agency review incorporating comments and feedback from consultation.

AGL also proactively informed the community through various media about the strategy for produced and flowback water in order to address concerns regarding:

- Salinity/salt loads from produced water;
- Heavy metals and contaminants in extracted water and treated water;
- Potential impacts from our operations e.g. water affecting local river systems;
- Differentiating exploration activities from proposed production activities;
- The irrigation of untreated produced water that was not diluted or treated;
- Completion of the Tiedman irrigation program, and not continuing with the blended water irrigation program; and
- The sustainability of the preferred strategy and associated practices.

The proposal for this Final Draft version of the EWMS and 2015 timetable is to:

- Circulate the Final Draft version of the EWMS for agency comment (in September 2015).
- Workshop with key agencies in mid-September 2015.
- Inform community representatives that the draft is available on AGL's Gloucester website (September 2015).
- Finalise EWMS (in October 2015).
- Submit EWMS to DPE for their assessment (in November 2015).
- Submit to Commonwealth Minister for Environment for their information/assessment (in November 2015).
- Publish the EMWS on AGL's website (after State and Commonwealth assessments).

7.2. Division of Resources and Energy (DRE)

NSW Department of Industry, Skills and Regional Development (DoI) is the lead economic development agency in New South Wales responsible for driving sustainable economic growth across the state. DoI replaced the Department of Trade and Investment (DoTI) and the Department of Industry and Investments (DII) in recent years.

The Division of Resources and Energy (DRE) delivers policy, programs and compliance services across the mineral resources and energy sectors. The Division consists of the following business units and program areas: Mineral Resources, Energy, National Policy and Sustainability, Mine Safety, Industry Investment, Office of Coal Seam Gas and Coal Innovation NSW. Its functional responsibilities relate to:

Minerals and mining

- Deliver quality geological and geophysical maps and data about NSW
- Authorise mining exploration and production
- Keep the environment safe during exploration and mining activities
- Regulate health and safety for the mining and petroleum industries
- Attract local and offshore investment into the NSW resources sector

Energy

- Distribute safe reliable and cost-competitive energy to consumers
- Provide financial assistance through customer programs to energy consumers
- Support growing investment in renewable energy in NSW
- Monitor electricity and gas networks and licensed pipelines

In regard to CSG activities, DRE is responsible for geological mapping, exploration activities, titles, health and safety, and is the repository of all the geological data collected across NSW (including well completion reports and data). The Office of Coal Seam Gas (OCSG) is now part of DRE.

DRE were invited to the first workshop but did not attend, although representatives from OCSG were present. A copy of the Consultation Draft EWMS was sent to the DRE for information. No comments were received.

7.2.1. Office of Coal Seam Gas (OCSG)

In 2014, the OCSG was operating independently to DRE. It has been subsumed back into DRE as part of the changed regulatory environment for managing CSG projects by the NSW Government. From 1 July 2015, OCSG still reviews and approves exploration and some production activities associated with CSG projects. The compliance and enforcement requirements associated with PELs and PPLs are now administered by the Environment Protection Authority (EPA).

Ongoing, the OCSG group within DRE 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 rehabilitation and security deposits; and
- the application of workplace health and safety requirements under the Petroleum (Onshore) Act 1991 and the Work Health and Safety Act 2011 (NSW) to petroleum operations.

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. This plan has been completed and approved (AGL, 2014b and AGL, 2015a) and is published on AGL's and DRE's websites for our PEL 285 exploration activities. OCSG advised in their 2014 submission that it is unlikely that a PWMP will be formally required under the PPL conditions, however a similar document may now be required under other approvals (such as the EPL) given the changed regulatory responsibilities.

OCSG provided a brief submission on relevant Codes of Practice and advised that the PPLs are more likely to focus on rehabilitation standards and security matters than produced water management matters.

7.3. 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 the Consultation Draft EWMS was sent to the Land and Water Commissioner for information. No comments were received.

7.4. 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 (July 2013), a final report (September 2014) and a number of background papers have been prepared by the Office of the CSE and its independent experts. Several of these relate to produced water and produced water management.

A copy of the Consultation Draft EWMS was sent to the CSE for information. No comments were received.

7.5. 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. From 1 July 2015 the EPA is the primary regulator for CSG across NSW and is responsible for the compliance and enforcement of all licence and consent conditions for gas exploration and production activities.

Also since late 2013, the proponents of all CSG projects, from exploration, assessment to production are now required to hold an environment protection licence (EPL) issued by the EPA for their premises.

When the EWMS is approved and a financial investment decision is made on the project, AGL will seek a variation to modify the EPL for the GGP. The variation will cover the reuse of treated water, the discharge of treated water to streams, and the disposal of all waste streams generated at the CPF. The expected focus will be on soil/water monitoring aspects of the EWMS.

EPA provided a detailed submission on the basis that there would only be an EWMS and not a more detailed and focused PWMP prepared prior to construction of the Stage 1 development. EPA were wanting a more detailed assessment of the WTP design but many of the requested details are beyond what has to be submitted to comply with Condition 3.12 of the Part 3a approval and will only be available after the awarding of the WTP contract. The EPA submission focused on:

- WTP infrastructure system details (Section 11 – detail not required to be included in the EWMS);
- waste streams associated with the WTP (Section 13 – detail not required to be included in the EWMS);
- trigger values for water reuse and discharge (Exec Summary, Section 2.4 and Section 12);
- assessment of the current irrigation program (Section 3.1);
- river flow objectives (Section 11.6.2 and Section 12) and low flow discharges (now deleted from the EWMS based on earlier consultation and feedback);
- brine tank system details (detail not required to be included in the EWMS);
- salt and disposal options (detail not required to be included in the EWMS);
- nominated receiving facilities (detail not required to be included in the EWMS); and
- other waste streams (Section 13 - detail not required to be included in the EWMS).

Further detail is provided in **Appendix A** while AGL's responses to the issues raised by EPA are also provided in the nominated sections.

7.6. DPI Water

The NSW Office of Water (NOW) was replaced by DPI Water in July 2015. DPI Water remains part of the Department of Primary Industry (DPI) and reports to the Minister for Primary Industries, Lands and Water. DPI Water 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). They are responsible for the allocation and use of all water resources, and the protection of riverine environments and groundwater systems.

Under the Aquifer Interference Policy, DPI Water 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).

NOW provided a detailed submission on the Consultation Draft in September 2014 with queries on:

- water to third parties (Section 5.4.3);
- additional studies to support the discharge of treated water to Dog Trap Creek/Avon River (Section 11.6.2 and Appendix C);
- additional monitoring bores at Tiedmans (Section 14 and Appendix E);
- monitoring frequencies (Appendix E);
- definition of flowback water (definitions and Section 1.1);
- additional water balance modelling (Section 5 and Appendix B);
- surface water discharges (Section 11.6.2, Appendix B and Appendix C); and
- ASR feasibility (Section 11.7).

Further detail is provided in **Appendix A** while AGL's responses to the issues raised by NOW are also provided in the nominated sections.

7.7. 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. Local Land Services 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. The HLLS covers the Hunter, Karuah and Manning River catchments.

HLLS was invited to the August workshop but did not attend. The exhibited EWMS was also sent to HLLS with a reminder for comments by mid-September. The HLLS did not provide a submission on the EWMS.

7.8. Gloucester Shire Council (GSC)

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

Gloucester Council employed a Water Scientist to undertake a Water Study Project which includes managing a number of specialist studies under a cooperation agreement with AGL that commenced in October 2013 and concludes in September 2015. The components of the Water Study are:

- Baseline water surveys of the whole Gloucester Basin;
- Flood study (Avon and Gloucester River catchments);
- Produced water study; and
- Technical 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 produced water study (RPS, 2014) is the basis of the produced water management options that are described in Section 4.1 and could provide an economic stimulus to local development.

Council was concerned that the EWMS was too general in some places and if a PWMP was not going to be prepared then more detail regarding water treatment, wastes, water quality criteria and monitoring was required. Council provided a detailed submission on:

- Preferences for salt management (Section 13.4);
- Development of a PWMP (Executive Summary, Section 1.1, Section 1.6);
- Site specific water quality criteria (Section 2.4.2)
- Water quality targets (Section 12);
- Surface water discharge location and rates (Section 9.3 and Appendix C); and
- Approvals (Section 2).

Further detail is provided in **Appendix A** while AGL's responses to the issues raised by Council are also provided in the nominated sections.

7.9. MidCoast Water (MCW)

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

MCW provided a detailed submission on:

- Reliance on river discharge (Section 11.6.2, Appendix B and Appendix C);
- Continued consultation with MCW (noted);
- River discharges under low flows (now deleted from the EWMS based on earlier consultation and feedback);
- Operational risks (to be included in the PWMP);
- Surface water discharge location and rates (section 9.3 and Appendix C); and
- Monitoring plan deficiencies (Section 14 and Appendix E).

Further detail is provided in **Appendix A** while AGL's responses to the issues raised by MCW are also provided in the nominated sections.

7.10. NSW Health

NSW Health is responsible for the public health system across NSW, and provides advice on the suitability of water sources for drinking water supplies.

A copy of the Consultation Draft of the EWMS was sent to the appropriate Environmental Health Officer in the Hunter New England Health Service and to the Water Quality unit of NSW Health for comment after advice from MCW. NSW Health did not provide any comments on the EWMS.

7.11. Broader Community

The broader community was also invited to comment on the Consultation Draft of the EWMS. The document was publicly released on the 21 August 2014 at the Gloucester Community Consultative Committee (GCCC), drop in community information sessions were held same day (an afternoon and evening session), the EWMS was exhibited for a period of 28 days, and was placed on AGL's Gloucester Gas Project website with a call for submissions. AGL advertised extensively that the document could be downloaded from this site:

www.agl.com.au/gloucester

The following community organisations were advised that the document was available for comment:

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

Submissions on the Consultation Draft of the EWMS were received up until the 19 September 2014. Only two public submissions were received. The individual submissions provided comment on:

- Likely discharge of CSG (produced) water into the Manning River catchment

- Size and cost of a desalination plant
- Desalination is a public relations exercise, not a serious proposal from AGL
- CSG water contains contaminated salts while seawater contains non-toxic sea salt
- Flowback water should be separate to produced water
- The RO plant and the desalination proposal requires a full EIS
- Treated water should be sold to new ventures at below market rates
- Water generated but not used during winter and wet periods should be stored in the Stratford mine 'clean water' dam

Further details and responses regarding these submissions are provided in **Appendix A**.

AGL also sought early "Expressions of Interests" for the reuse of desalinated water and mixed salt. Eight expressions of interest were received for the use of desalinated water for irrigation and stock purposes. In entering into further discussions, AGL will emphasise that supplies are not guaranteed and that there are risks regarding new developments based on what could be a limited and declining water supply if subsequent stages of the gas project are not developed.

8. Irrigation and Stock Reuse

The application of treated water to irrigate crops and pasture, and to provide supplementary stock water has been identified as the preferred extracted water management option. Irrigation and stock use is a preferred option for the following reasons:

› Provides a new (small) source of water which is valued by the community and which will have tangible benefits to the primary producers of the district;

› Offers sustainable, beneficial reuse of extracted water;

› Stock use would occur during drier seasons when supplementary water is required for livestock;

› Irrigation use can be scaled to respond to changing volumes and seasonal conditions;

› Irrigation is a proven technology; and

› Cost effective (for a CSG project of this size).

At this stage, irrigation will be undertaken on hillside locations (away from water courses) at AGL's Rombo, Tiedman and Pontilands properties. Opportunities to supply landowners adjacent to the Stage 1 development area with both irrigation and stock water are being investigated.

8.1. Benefits and Constraints of Irrigation

Benefits

The potential benefits associated with irrigation are:

› Beneficial reuse of a new water source for the area (after the essential requirements of working water, process water and stock water);

› Economic benefits to landholders in the vicinity of the GGP;

› Reduced pressure on existing water resources; and

› Low cost of transportation of water given that:

  » the pipework is part of the gas gathering and working water pipeline network; and

  » the proposed irrigation areas are 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;

› Irregular and unpredictable volumes and availability of treated water; and

› Irrigation application rates and usage is lower in winter when crop and pasture requirements are less.

8.2. Benefits and Constraints of Stock

Benefits

The potential benefits associated with stock use are:

- Supplementary water to graziers during dry periods;
- Economic benefits to landholders in the vicinity of the GGP;
- Reduced pressure on existing water resources; and
- Low cost of transportation of water given that:
  - the pipework is part of the gas gathering and working water pipeline network; and
  - the proposed stock use areas are on AGL and private property at the end of the water gathering lines.

Constraints

The constraints associated with stock use are:

- Little additional water is required during average and wet seasons.

8.3. Site Characteristics

Location

To manage the development of the Stage 1 GFDA, an expanded irrigation area 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 **Figure 11.4**.

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.

No additional area is required for stock watering.

Crop selection

Crops such as lucerne, triticale and forage sorghum and pasture that includes kikuyu, ryegrass, clover and chickory have been proven as part of the Tiedman Irrigation Program. These crops together with improved pasture are suitable for the prevailing soil and water 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 balance between cropping and pasture is still to be decided but most of the new irrigation areas are expected to be improved pasture.

8.4. 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 Tiedman irrigation area. A mixture of 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 and freshwater (TSD and TND), and produced water (TED) (if in-field capacity is required).

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 freshwater for fracture stimulation or other industrial uses then this may also be stored in either of these ponds (although water is most likely to be taken from the WTP and piped direct to the required site through the working water lines).

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 will be used to store treated or freshwater from time to time.

8.5. Irrigation Demand

Based on the irrigation program results, approximately 4 ML/ha/year of irrigation water is required in an average season to grow summer and winter crops, and improved pasture. Actual application rates for fodder and improved pasture were between 4 and 5 ML/ha/year in recent years. Higher application rates (up to 7 to 8 ML/ha/year) could have been achieved during 2012/13 and 2013/14 if sufficient water was available. These seasons were drought seasons so 4 ML/ha/year is considered a reasonable expectation during an average season.

Typical monthly irrigation application rates for an average season are presented in **Table 8.1**.

Table 8.1: 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.

8.6. Stock Demand

Stock demand for treated water is uncertain. Less than 1 ML per property per year is expected to be required in all but the driest years. Water is most likely going to be required when farm dams are low and poor quality water is available from the river. Treated water piped through the working water delivery lines could substitute for tankered water and allow stocking rates to be maintained. Water for stock watering will take precedence over water for irrigation. The total volume of treated water available will remain the same.

9. Discharge to Surface Waters

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 limited capacity in the system to store any additional water at either the CPF or Tiedmans. Surface water discharges are only expected to occur during Year 3, if higher than expected water production rates occur and these rates coincide with unusually wet years. Volumes are expected to be less than 20 ML in total.

It is proposed to only discharge treated water from the discharge water pond at the CPF (or from the Tiedman storage ponds) that has been conditioned to meet the water quality target identified in Section 12.

It is proposed to discharge to surface water in combination with a high flow event in the catchment when the Avon River is flowing. Discharge during higher flows is the preferred option but given that all treated water storages would be filled first, the main flow peak may have passed in the Avon River. The most likely discharge scenario is that water would be discharged on the recession curve of a major flow event rather than at the peak of such an event.

Discharge rates are likely to be small and unlikely to ever exceed 2 ML per day. Based on the available data on the NOW website for the Waukivory stream gauge, this volume represents around 0.001% of the flow during a typical Avon River flood event. Discharges would be managed such that the creek geomorphology and the local ecology in the Avon River at the discharge location and immediately downstream are preserved.

Water quality will be tested at the DWP prior to discharge (see Section 14 and **Appendix E**).

9.1. Benefits and Constraints of Discharge to Surface Water

Benefits

The benefits associated with the managed discharge of treated water to surface waters during high flow events are:

› Ability to maintain gas production across the Stage 1 area without shutting down wells; and

› Additional freshwater for the environment.

Constraints

None identified (after the geomorphological and ecological study discussed in Section 9.2 below).

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 because the volume of natural flow would be large compared to the discharge volumes (Cardno, 2015).

9.2. Discharge Site Characteristics

Taking into account regulator and community comments, a geomorphological and ecological study has been completed to determine the best location for the few occasions when stream discharges are likely to be required for treated water (Cardno, 2015). A location on the Avon River upstream of the confluence of Dog Trap Creek has been recommended. The proposed discharge location in relation to the proposed water pipeline from the CPF to the Tiedmans storage ponds in shown on **Figure 9.1**. Full details are provided in **Appendix C**.

Figure 9.1: Proposed Avon River Discharge Location

The managed discharge outfall would be a very small structure designed to 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.

9.3. Proposed Flow Regime

Stream discharge would only occur when there was at least a 5-fold mixing factor at the point of discharge. 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 2 ML/d and would average less than 0.5 ML/d.

Substantially more dilution would occur once Avon River flows are joined by inflows from the downstream tributaries Dog Trap Creek and Waukivory Creek. Further downstream the Gloucester River and the Barrington Rivers provide even more dilution prior to these catchments joining the Manning River.

AGL is proposing stream gauge location TSW01 (on its Tiedman property) to determine when discharges of treated water can occur. Visible flow in the river would be required and flows in excess of 2.5 ML/d are proposed before any treated water could be discharged (but typically would be higher and in association with a high-flow event). Additional gauging is proposed to generate a calibrated rating curve for this stream gauge site.

For comparison purposes at this time, the flow data from the NOW Waukivory Gauging Station 208028 located downstream of the confluence with Waukivory Creek (about 3 km downstream of the Tiedman property) is presented in this EMWS to indicate when stream flow discharges may typically occur.

The flow hydrograph for NOW Gauging Station 208028 is provided in **Figure 9.2**.

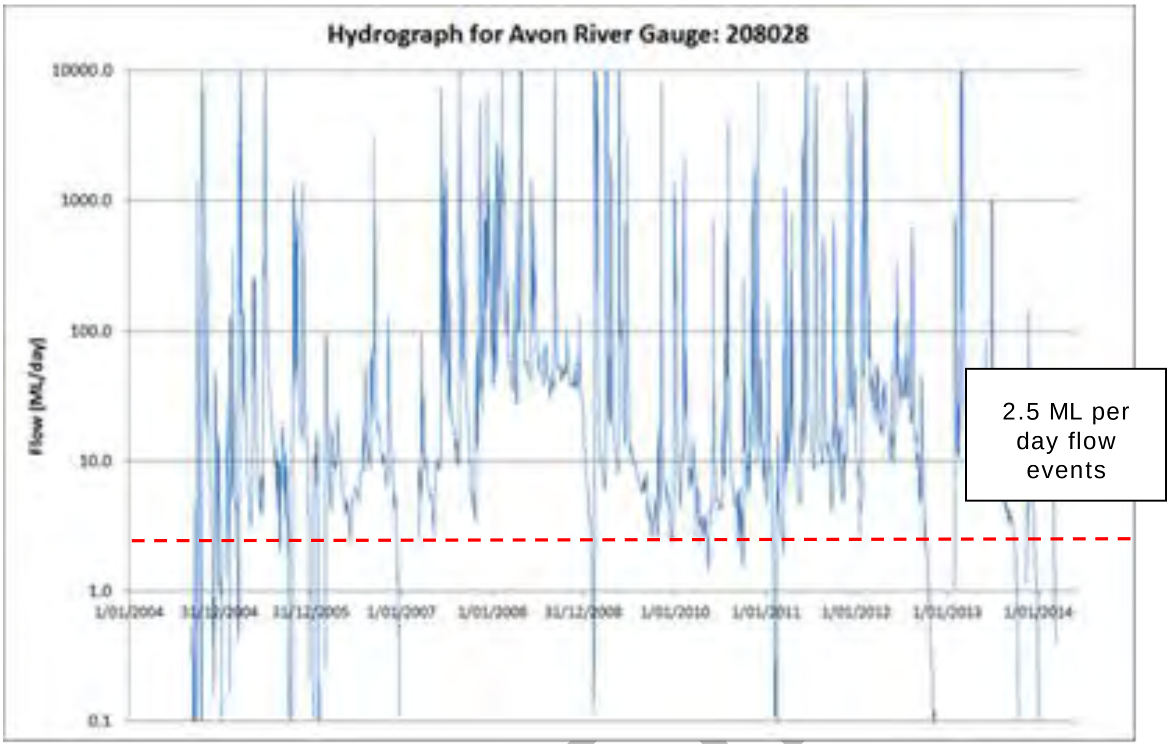


Figure 9.2: Streamflow Data for the Avon River (Gauge 208028)

The treated water will be discharged to the Avon River in a controlled manner, taking into consideration the sensitivity of the receiving watercourse. In-stream water quality monitoring will be undertaken to ensure that the released water does not cause adverse effects on the receiving environment.

10. Existing Water Management Infrastructure

AGL has some existing infrastructure to gather, store and treat freshwater 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 Stratford and Waukivory 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 these ponds and the irrigators;
- A pipeline to transfer river water to the ponds; and
- Irrigation infrastructure.

10.1. Water Supply Pumps, Dams 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 licence (refer **Figure 10.1**).

Figure 10.1: 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 off-river dam on an unnamed gully that drains to the Avon River. AGL holds a combined works approval for the dam and two pump sites and to use this water for industrial, irrigation and stock purposes.

Water Gathering Network

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

This local water gathering network will be replaced by the gathering network for the Stage 1 development.

Water Storage Ponds

Two 'turkey nest' ponds at the Tiedman property were constructed about 10 years ago to store freshwater and extracted water (TSD and TND). An additional storage (Tiedman East Dam – TED) was constructed by the NSW Soil Conservation Service in 2013 and is a double lined storage with seepage control for storing extracted water. These storages are approved under various REFs and ongoing approvals issued by DRE for PEL 285. These ponds will continue to store either extracted water, blended water or freshwater until the commissioning of the CPF.

The storages are not licensable under the *Water Management Act*, however all the water that is pumped into the storages is either licensed under existing WALs and works approvals, or existing bore licences under the *Water Act*.

Each pond is an above ground rectangular storage located on high ground beyond the Avon River floodplain. 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 10.1**. The two older ponds at the Tiedman property (TSD and TND) will be utilised in the proposed water management strategy for the irrigation and discharge of treated water from the WTP. The newer pond (TED) will be an in-field storage for extracted water (or longer term) a treated water storage pond.

Table 10.1: Summary of Existing Water Storage Ponds at the Tiedman Property

Name	Volume (ML)	Current Function	Proposed Function under EWMS	Lining
Tiedman North Dam (TND) *	20	Storage of catch dam water, residual blended water and produced 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 freshwater	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 flowback water and produced water from Waukivory Pilot	Storage of extracted water from pilot wells	Double lined with a HDPE membrane, mesh layer and inspection sump

Key: *: these two ponds are maintained with a freeboard of 500mm should there be an extreme rainfall event
**: TED is maintained with a freeboard of 600mm should there be an extreme rainfall event.

The ponds are located off the floodplain beyond the 1:100 and PMF flood levels (BMT WBM, 2015) and are only filled by reticulation and direct rainfall within their embankments. Therefore the ponds have minimal impact on surface runoff and do not reduce or impede catchment flows. There is a water monitoring system dedicated to the integrity of the existing water storage ponds.

10.2. Irrigation areas

AGL recently completed its blended water irrigation program for the historical produced water that was retained in storage since the late 2000s. Blended water (produced water mixed with freshwater) was irrigated across the Tiedman property on two small areas known as Stage 1A (12 ha) and Stage 1B (4 ha). Details are provided in Section 3.1 with the summary status of these two areas described in **Table 10.2**. No further blended water irrigation is planned in advance of the commencement of the Stage 1 development.

Under the broader irrigation scheme for the Stage 1 GFDA both the Stage 1A and 1B areas will be expanded. Treated (freshwater) water would be used for irrigation rather than blended water.

Table 10.2: Likely irrigation expansion areas on AGL's the Tiedman Property

Name	Active Irrigation Area (ha)	Likely to be Expanded as part of Stage 1 GFDA	Viable Irrigation Area (ha)	Current/Future Irrigation Method
Stage 1A	12	Yes	~20	Linear-move irrigator
Stage 1B	4	Yes	~20	Travelling irrigator

An aerial view of the Tiedman property is shown in **Figure 10.2**.

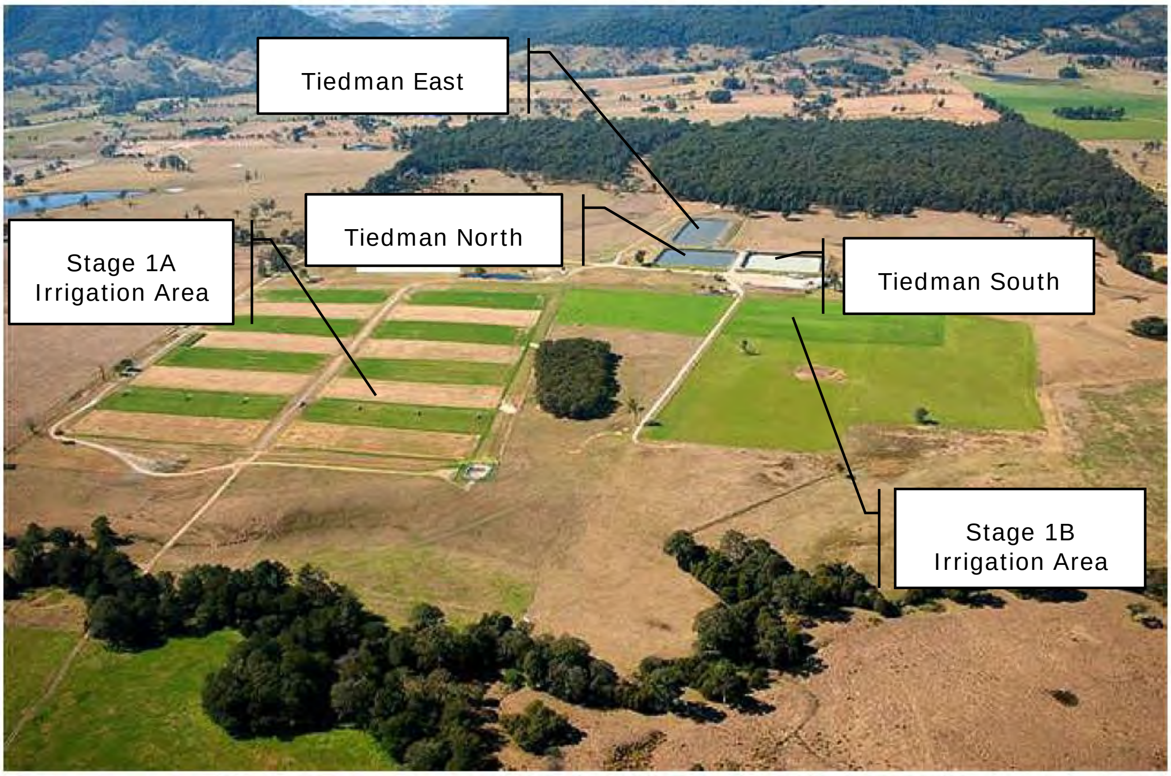


Figure 10.2: Aerial View of the Tiedman Property showing Pond Locations and Irrigation Areas Stage 1A & 1B (Fodder King, 2013)

11. Proposed Water Management Infrastructure

The preferred strategy detailed in Section 5 requires new infrastructure to gather, store and treat extracted water, and to reuse and dispose of treated water. There are also additional infrastructure requirements associated with the many beneficial reuse options and opportunities. Key additional infrastructure requirements (that were all identified in the EA and the Part 3A approval) include:

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

Final engineering design details for the gathering lines, water treatment systems and holding ponds are not yet available. These will be developed under an EPC contract that will be tendered and awarded as one of the first early works packages for the GGP Stage 1 development. Tendering and contract negotiations will be 'Commercial-in-Confidence'.

Under Condition 3.12 and the submittal of the EWMS, engineering designs for the water infrastructure and detailed descriptions of the adopted desalination and treatment technologies are not required. Hence general descriptions of the proposed water management infrastructure are provided in this EWMS.

Several of the agency submissions (from EPA, GSC, MCW and broader community) called for additional information on the design elements of the WTP. These issues are not addressed in this EWMS but instead are more appropriate for inclusion in the PWMP and any supplementary plans that may be prepared for the project.

The location of the proposed CPF site relative to the Tiedman property is shown in **Figure 11.1.** Both the CPF site and the Tiedman property where most of the above ground water infrastructure is sited, are located off the Avon River floodplain and beyond the 1:100 and PMF flood limits (BMT WBM, 2015). The location of each of these areas compared to the modelled extent of flooding is shown in **Figure 11.2**.

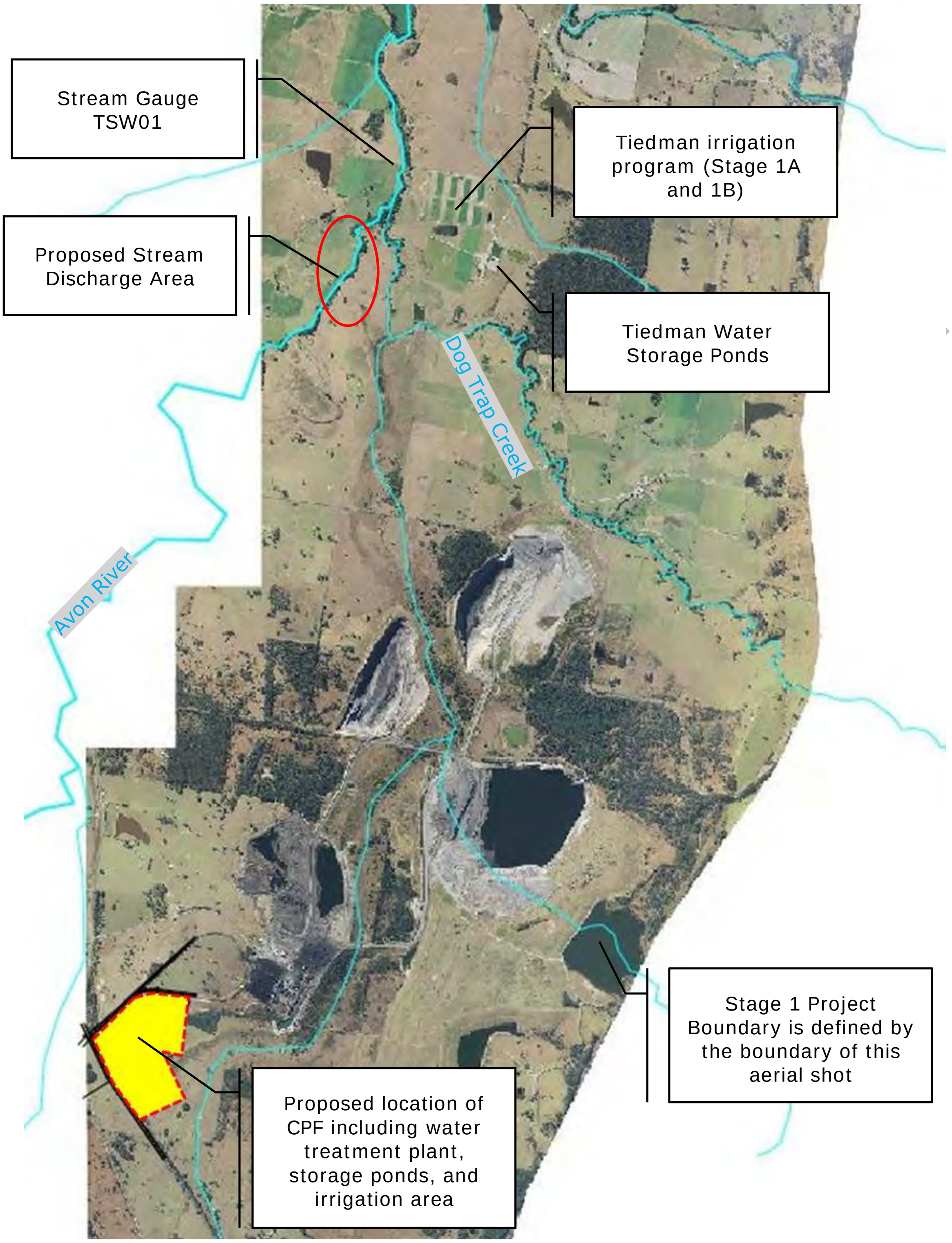


Figure 11.1: Proposed CPF Location Relative to the Tiedman Property within the Stage 1 GFDA

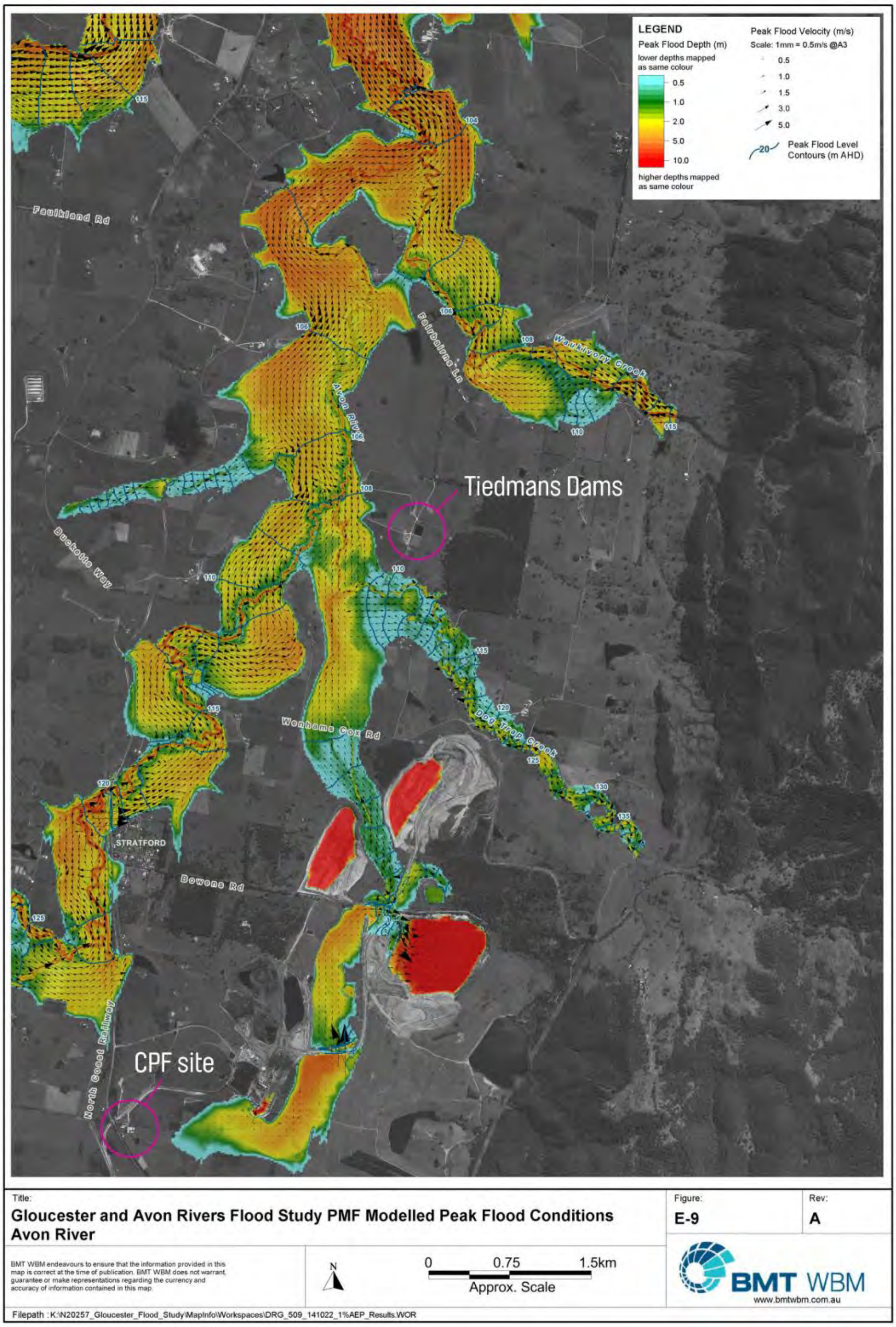


Figure 11.2: Proposed above-ground water infrastructure in relation to predicted flood levels

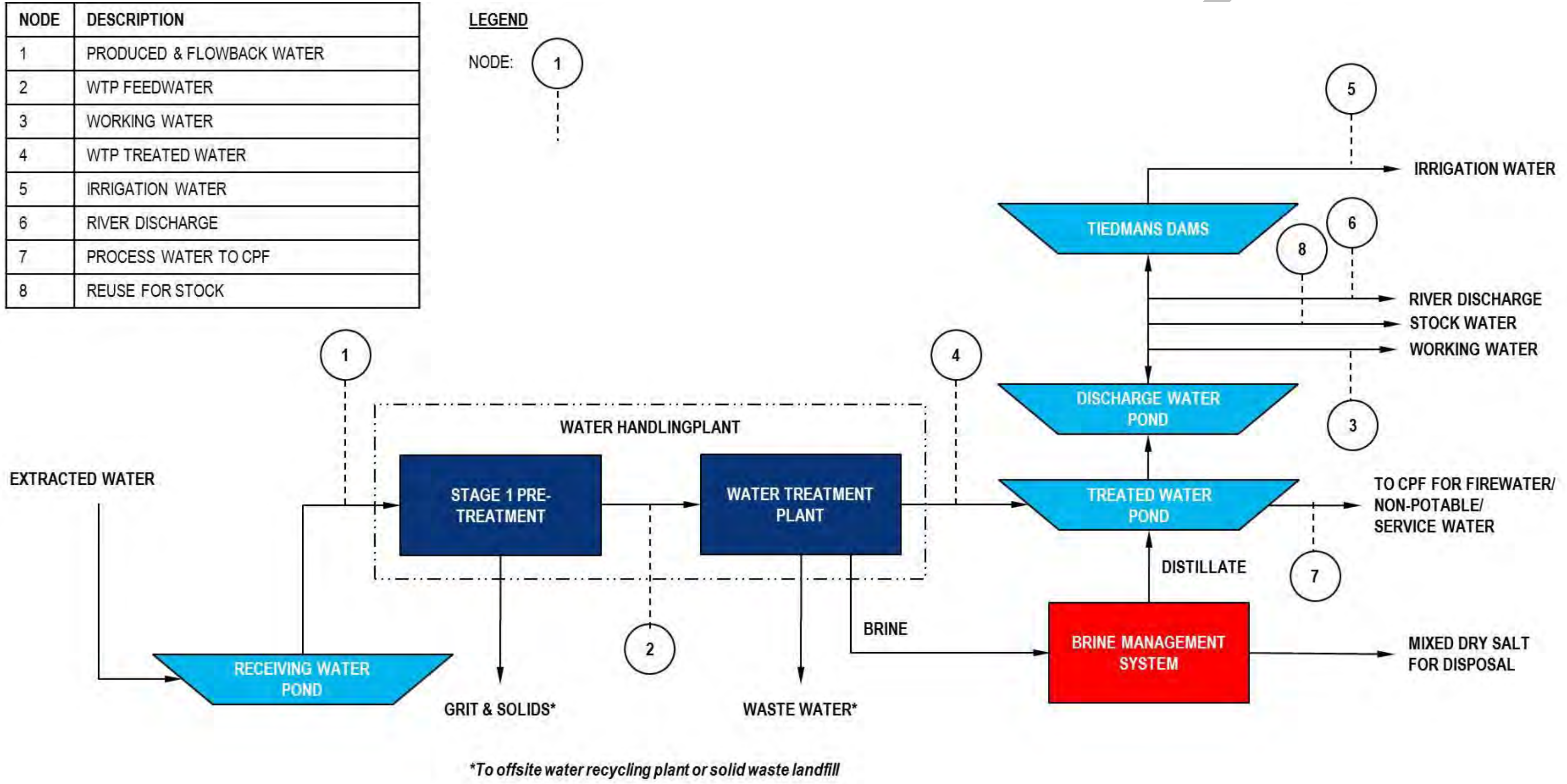
11.1. Water Infrastructure Flow Schematic

A simplified block flow diagram is provided in **Figure 11.3**, which gives an overview of all the water management infrastructure. Further detail is also presented in **Appendix B**.

For the purposes of this EWMS, the probable size of the water treatment plant and associated assets is described. Final dimensions and the exact location of all the assets won't be known until the awarding of the early works EPC contracts and the engineering design is completed.

The water infrastructure components of the Stage 1 project are unchanged from the assets identified in the Consultation Draft of the EWMS. Ponds and tanks have been reduced in size in accordance with the lower water production profile, expected water throughput, and expected plant redundancy. With the current lower than anticipated water production profile, each of the ponds at the CPF will be less than 25ML in capacity and the treated water pond will be replaced by an enclosed above ground (and bunded) tank/s.

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



Note – * the treated water pond is now replaced with two smaller tanks

Figure 11.3: Water Infrastructure Flow Schematic

11.2. Storage Ponds and Tanks

Water storage ponds and tanks will be required as part of the extracted water management strategy. The proposed 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 and conditioned water); and
- Brine water.

AGL has approval to construct up to three new ponds (each up to 25 ML capacity) at the proposed CPF site, however with the expected lower water production rates only two smaller ponds and two smaller treated water tanks are proposed.

The proposed ponds and tanks are:

- Receiving Water Pond (approximately 12 ML);
- Treated Water Tanks (2 x 1 ML);
- Discharge Water Pond (maximum 20 ML); and
- Brine Storage Tank (2 ML).

The three existing ponds and irrigation infrastructure at the Tiedman property will be retained.

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 ponds, together with seepage control, inspection sump and pump out capability. They will be holding ponds with a relatively small footprint and are not constructed as evaporation ponds.

Ponds developed as part of the GGP will be lined and have level detection systems and will be designed to retain a 1-in-100 year rainfall event and meet flood design standard.

11.2.1. Receiving Water Pond (12 ML capacity)

The Receiving Water Pond (RWP) will receive extracted water delivered from a water gathering network. The RWP will also receive return water from the DAF plant and process water that is treated by an oily water separator located in other parts of the CPF. Process water inflows are expected to be relatively minor (less than 0.01 ML/d).

The proposed RWP design is based on an interconnected two compartment system, consisting of a feed compartment and a buffer compartment. Each compartment will be capable of receiving all of the flowback water flow, produced water, any process or recycle streams. The RWP will be designed to enable maintenance without disrupting WTP operation and receiving various flows. This grit and sediment that accumulates in the RWP would be periodically removed by a floating suction.

The RWP would always be operated at reduced storage levels so as to maximise capacity to store inflows if the water treatment plant capacity was restricted in any way. The maximum daily inflow to the RWP is expected to be approximately 1 ML/d initially reducing to 0.5 ML/d longer term (well below the approved produced water volume of 2 ML/d). The RWP will therefore have a capacity to detain extracted water inflows for up to 12 days during the peak water production period (and for much longer periods during low water production periods) should there be any disruption to WTP operations.

11.2.2. Treated Water Tanks (2 x 1 ML capacity)

The Treated Water Tanks (TWT) will receive treated water from the WTP after the Reverse Osmosis (RO) process. The TWT is expected to receive a peak inflow of around 0.9 ML/d and provide a couple of day's storage at peak production rates.

11.2.3. Discharge Water Pond (maximum 20 ML capacity)

The Discharge Water Pond (DWP) will receive treated water from the TWT and distillate from the brine management system prior to transfer and reuse. The DWP is expected to receive a peak inflow of around 0.97 ML/d (assuming 90% recovery through the RO plant and 80% recovery through the BTP).

If there is any final adjustment of water quality required for irrigation, stock or stream discharge (e.g. to adjust pH or correct the residual SAR) then it would occur within either the TWT or the transfer lines from the TWT to the DWP. The target water quality will be in accordance with the most sensitive water quality required (see Section 12) and will be well below the adopted thresholds for each reuse (see Sections 2.4.1 and 2.4.2).

A floating pontoon pump station/s will be installed in the DWP to pump water to the Tiedman storage ponds, Rombo irrigation area and to the surface water discharge location as required.

11.2.4. Brine Storage Tank (2 ML capacity)

The brine storage tank (BST) will receive RO brine concentrate from the WTP. The RO brine 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 flow received by brine storage tank is expected to be approximately 0.1 ML/d. This maximum flow rate will occur towards the end of the initial development phase, as more wells come online. Longer term the volumes of brine will be very small.

The BST is expected to be enclosed and located indoors in a secure and bunded area to provide secondary containment.

The BST has been sized at 2ML for a 20 day detention time at maximum production rates (and for much longer periods during low water production periods).

11.3. Extracted Water Treatment System

The WTP will operate 24 hours a day seven days a week and will be modular so that it can be upsized/downsized as required.

11.3.1. Pre-treatment Systems

Pre-treatment systems are required in combination with desalination plants to condition the extracted water ahead of the RO plant and to minimise the fouling of membranes. This is especially the case where there is particulate matter in the extracted water and variable water quality from wells in different parts of the basin taking produced water from different coal seams.

A pre-treatment system with a 1 ML/d maximum design flow rate will be provided to treat extracted water. This will remove physical and biological contaminants to provide appropriate quality water suitable as feed water to the RO plant. Subject to the final WTP design, the three major components of the pre-treatment system are:

Dissolved Air Flotation (DAF)

DAF uses micro-bubbles of dissolved air that attach to solids, causing them to float to the surface where they are removed by a mechanical skimmer. It is assumed that algae solids will have a propensity to float and that DAF will be the most suitable technology for the removal of these solids. DAF is preferred as the clarification technology for the purposes of the WTP design.

The DAF will remove suspended solids, algae, and potential iron and manganese oxides. These are the primary solids that will be removed via dewatering. The grit and sediment will be spadeable and suitable for disposal at a licensed facility in accordance with regulatory requirements. It is expected that at the peak inflow rate of 0.9 ML/d that the peak volume of dry solids would be around 1 m^3/d (maximum two trucks per month).

Disc Filtration (DF)

A DF system (a solids screening process) may be required to protect the UF membrane operation. The DF system nominally removes solids greater than 200 µm that are not captured and removed by the DAF plant.

A small volume of watery fine sediment will be generated that will be returned to the DAF plant for further treatment and removal.

Microfiltration/Ultrafiltration (MF/UF)

The MF/UF system provides sufficient net usable filtrate to maintain design flow to the downstream RO membranes of the desalination plant. The MF/UF filtrate tank receives and balances MF/UF filtrate from the MF/UF train/s prior to delivery to the ion exchange system.

The MF/UF train/s will produce a filtrate with turbidity less than 0.1 NTU and a Silt Density Index (SDI) of less than 3. Backwash waste from the MF/UF is sent to the spent backwash balancing tank and ultimately back to DAF plant for further treatment.

Ion Exchange (IX)

MF/UF filtrate is transferred to the ion exchange (IX) system. The function of the IX system is to soften RO feed water to minimise scaling potential of the membranes (primarily hardness such as calcium, magnesium and other trace metal salts) that could potentially cause membrane scaling and therefore shortening the life of the RO membranes.

IX product water will be delivered to the RO feed tank with IX regeneration waste passing directly to a brine storage tank for brine treatment plant processing.

11.3.2. Desalination

The primary component of the WTP to desalinate extracted water is RO. The WTP would be designed with a modular configuration to accept a maximum flow rate of 1.2 ML/d (i.e. two treatment trains each with a capacity of 0.6 ML/d). For the majority of the production phase period, the WTP would operate at less than 50% of its design capacity. The proposed WTP modular design allows the facility to be flexible, and easily reconfigured, so it can be adapted to meet the changing water production needs over time.

The WTP would treat extracted water that has been through the pre-treatment system to a raw water quality suitable for all beneficial reuses and river discharge options, namely:

- General consumption (for the CPF);
- Working water;

- Stock water;
- Irrigation water; and
- Treated water for managed discharge to the Avon River.

Some final water conditioning will be required after desalination to ensure that the water quality is suitable for its intended use/stream discharge (Section 12). This will include stripping any residual hydrocarbons from the treated water using granulated activated carbon (GAC).

11.3.3. Post treatment systems

Treated water from the RO plant will be stored in the TWT and then conditioned and transferred to the DWP. Any residual hydrocarbons in the water will also be treated and removed at this time by passing the water through granulated activated carbon (GAC).

11.4. Brine Treatment

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 treatment plant (with a nominal design capacity of 0.2 ML/d) will comprise a brine concentrator and brine crystalliser, and be capable of treating the entire brine stream. This capacity is double the expected RO brine feed flow rate. A centrifuge will be required to turn the final salt paste into a dry mixed salt.

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 less than one truck per month for the longer term.

11.5. Gathering and Distribution Systems

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

11.5.1. Water Gathering Lines

A low pressure water gathering system will connect each well to the CPF. Small volumes of extracted water may be stored at low water-producing well sites in bunded above-ground (enclosed) tanks so that water can be pumped efficiently in batches to the CPF. Extracted water will discharge directly into the RWP. During the field development period, all collected flowback water/produced water will be discharged to the RWP prior to treatment.

These water gathering lines will be co-located with the gas gathering network. All water gathering lines will be inspected and integrity (pressure) tested prior to being commissioned.

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

A separate line will also be installed to deliver working water to wells for fracture stimulation and workovers. This working water line will be co-located with the water and gas gathering lines. The working water lines may also deliver stock water to landowners who have expressed an interest in receiving treated water for on-farm use.

Treated water will be transferred from the DWP for the following uses:

› Stock water: To individual tanks and troughs on properties via the working water delivery lines.

› Irrigation Water: Either directly to the Rombo irrigation area or to the water storage ponds on Tiedmans via a separate distribution spine line.

› Discharge to Avon River: An offtake from the distribution spine pipeline (delivering treated water to Tiedman property for irrigation) will deliver treated water for discharge to the preferred discharge location. Alternatively the conceptual design also allows for stream discharge from the Tiedman holding ponds.

These lines will be co-located with the gas and water gathering lines where possible. All return water lines will be inspected and integrity (pressure) tested prior to being commissioned.

11.5.3. Miscellaneous Distribution Pipelines

It is envisaged that the following 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 new pumps and pipelines to supply treated water to the irrigation areas at Rombo, Tiedmans, Pontilands and possibly Avondale.

› 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.

Within CPF area there will be transfer pipelines, including associated pumps and controls to connect ponds and tanks. All water and transfer systems required within the CPF (or generated by the CPF design such as sewage and stormwater) will be dealt with onsite as part of the detailed design for the WTP and CPF.

11.6. Reuse and Discharge Infrastructure

11.6.1. Irrigation

Some 60 ha of irrigation area has been identified at the start of the project for the irrigation of treated water. This area is based on a maximum requirement to irrigate a maximum of 200 ML of treated water per annum. The recent blended water irrigation program at Tiedmans achieved application rates of between 4 and 5 ML/ha/yr on both fodder crops and irrigated pasture during dry to average seasons. 60 ha of irrigation aligns with this maximum water volume (and doesn't allow for the other proposed reuses) therefore AGL expects that the actual irrigation area required longer term will be much less.

A number of potential irrigation areas on AGL-owned properties have been identified as being suitable. 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 Rombo, Tiedmans, Pontilands and possibly Avondale. There may be some rotation between irrigation areas. The irrigation areas in likely priority area are:

- Rombo (10ha)
- Tiedman (several areas totalling 40ha),
- Pontilands (10ha) (if required), and
- Avondale (if required).

The final agricultural layout, crop types and irrigation strategy will be described in a farm master plan that focuses on the probable irrigation areas, irrigation infrastructure, irrigation methods and crop types. Other properties in the vicinity of the CPF and Stage 1 area will also be considered for supplementary irrigation. The delivery of water to private properties and the reduction in AGL irrigated areas will be the subject of further negotiation with individual landowners as part of the required access and compensation agreements.

The possible irrigation areas on AGL-owned properties are shown on **Figure 11.4**.

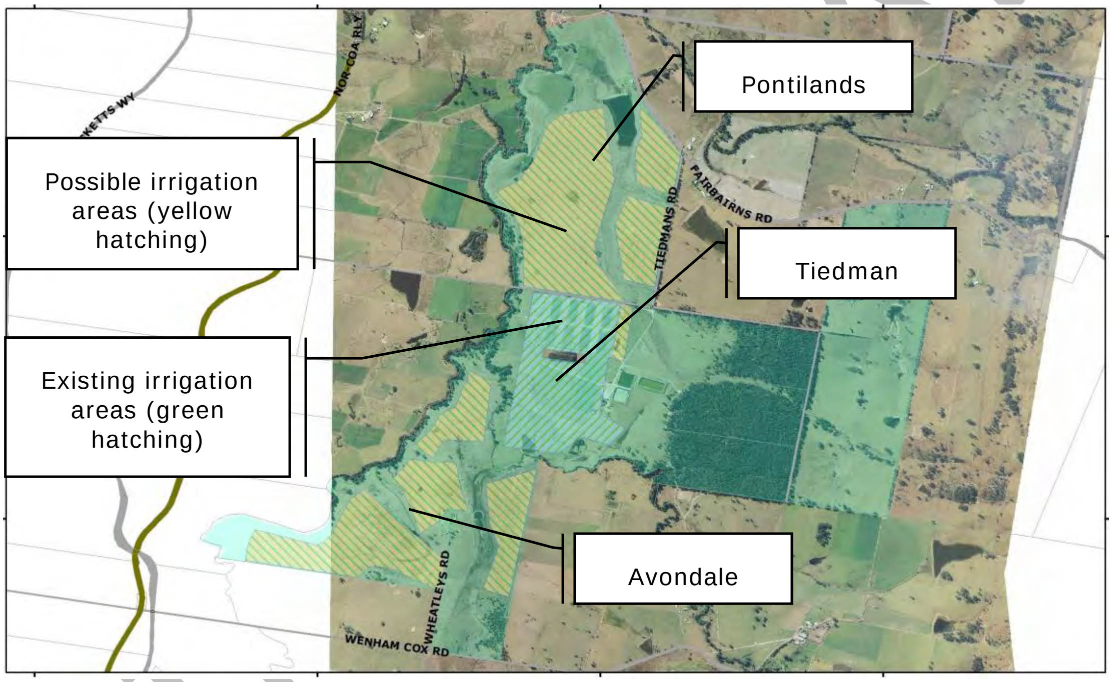


Figure 11.4: Existing and Proposed AGL Irrigation Areas for Treated Water (except Rombo south of the CPF)

11.6.2. Stream Discharge

Discharges will be to the Avon River upstream of the confluence of Dog Trap Creek and the Avon River (the indicative area is shown on **Figure 11.1**). The final preferred site is location AV2 outlined in the ecological and geomorphic impact assessment study (Cardno, 2015). This location is shown in **Figure 9.1** and described in **Appendix C**. The preferred area is near the proposed return water pipeline transporting treated water to the Tiedman holding ponds.

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 on the Consultation Draft.

Importantly, water quality for any stream discharges will be freshwater quality (the final criteria are subject to proposed negotiations with EPA and approvals under AGL's EPL).

The water balance modelling study (**Appendix B**) suggests that no treated water will require discharging to the Avon River during dry and average seasons. The discharge of treated water to the Avon River is only expected for the P90 water production profile and only if P90 rainfall events occur. Discharge volumes are expected to be less than 20 ML in total (Worley Parsons, 2015). After the first three years of operations, 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.

AGL will maximise the storage of treated water prior to any requirement to stream discharge. This stream discharge option is a last resort if irrigation and stock watering are not possible and all water storages at the CPF and at Tiedmans are close to full (there is expected to be at least 90 to 100 ML of storage capacity within the system). Development or the availability of additional irrigation area is not a solution during extended wet seasons when no irrigation is possible for long periods (Worley Parsons, 2015).

11.7. 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. The EPBC approval requires this assessment even though reinjection to groundwater is specifically banned under the Part 3A approval.

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 moderately or highly 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 potential for additional groundwater system storage is low;
- All of the rock permeabilities are low;
- The groundwater systems are full (there are no depleted storage areas at this time);
- The water quality is poor in all aquifers and water bearing zones;

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

› If untreated produced water/brine water was injected under pressure into deeper groundwater systems, the formations would not accept much water because of the required high pressures, limited 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 would 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 small to moderate volumes of untreated produced water, brine or treated water to any of the groundwater systems within the Gloucester Basin. If produced water volumes reduced to very low volumes (say less than 0.01 ML/d) then ASR could be re-evaluated (together with other low volume options) to assess 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.

NOW endorsed AGL's conclusion that aquifer recharge (storage and recovery) is not a feasible water and brine management strategy for this project.

11.8. Management of Excess Extracted Water

Extracted water may occasionally be generated at rates greater than 1 ML/d for very short periods of time if a large number of wells are fracture stimulated in a single program and brought on line quickly. However based on the most recent water production profiling, it is unlikely that the actual produced water rates (once the flowback water is recovered) would exceed 1 ML/d. AGL's dewatering is capped at a maximum 2 ML/d of produced water extraction (Condition 3.11 of the Part 3A approval).

Exceedances of this rate (irrespective of whether it is flowback water or produced water) for a few days or weeks as new wells are commissioned is not considered to be an issue from an operational perspective as there is sufficient storage capacity at Tiedmans and at the CPF for higher extracted water flows. In the unlikely event of a higher rate of produced water extraction occurring for an extended time the following issues arise:

› Lack of water treatment capacity at the CPF;

› Lack of storage capacity with the wellfield; and

› Insufficient irrigation area.

Each of these issues has been assessed and mitigation/management measures are proposed.

WTP Capacity

The WTP at the CPF will be sized to treat an extracted water flow rate of 1.2 ML/d. Two RO treatment trains (each of 0.6 ML/d capacity) are proposed to cater for breakdowns, maintenance and occasional flow peaks. Some day to day variability is expected and some excess capacity is being built into the design to ensure that the water treatment system is fully functional at all times.

To cater for extracted water flows greater than 1.2 ML/d that may occur for longer periods (highly unlikely), the WTP can be expanded by adding additional RO modules to increase capacity. There is also a large RWP (12 ML) with multiple compartments to cater for occasional higher inflows. At least 10 days of storage is considered reasonable to address this unlikely scenario. Buffer storage for extracted water is also available in-field at Tiedmans (TED storage) to be used in the event of higher water production volumes.

In the extremely unlikely scenario where extracted water volumes were exceeding 2ML/d for extended periods (thereby potentially breaching the cap of 730 ML per year), 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 into production until water production rates diminished at existing sites.

The WTP will be of a packaged modular flexible system that would be designed with adequate redundancy (e.g. using several 0.6 ML/d capacity RO treatment modules) primarily to provide redundancy and operational flexibility to manage variable flow rates.

Storage Capacity

The total storage capacity of holding ponds and tanks at the CPF and at Tiedmans will be at least 90 to 100 ML. This equates to around 100 days of storage if the maximum flow rate of 0.9 ML/d is generated from the wellfield for any length of time.

Irrigation Area

A shortage of available irrigation area is also an unlikely scenario as more than 60 ha of irrigable area will be available on AGL properties alone (although it is unlikely that more than 60 ha will be utilised at any one time).

Stream Discharge

If there was insufficient irrigation area, all treated water storages were full, and the flow conditions in the Avon River were suitable, then treated water would be discharged to the river to relieve the pressure on having to build additional storage for treated water for an extended period. Stream flow discharges for extended periods is an extremely unlikely scenario (Worley Parsons, 2015).

11.9. 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 proposed ponds:

› 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 alternative 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. In any event, birds have not been an issue at the three similarly sized ponds at Tiedmans to date. Netting of the ponds will be considered as a contingency response if birds are wanting to colonise the ponds.

12. Treated Water Quality Target

The treated water salinity from the WTP will most likely be less than 250 mg/L TDS. The proposed water treatment technologies (particularly the RO plant) will remove the larger dissolved cations, anions and any heavy metals to achieve this low salinity water quality. The proposed water quality target is based on the expected output of the RO plant and other proven water treatment technologies that are proposed to be used.

The desalination process will produce extremely pure water that can be corrosive and be dominated by ions such as sodium (Na) and chloride (Cl). To soften and rebalance the ionic ratios, some additional conditioning is required for the treated water from the RO plant. The salts to be added include calcium and magnesium salts that will rebalance the SAR. These chemical adjustments generally add calcium, magnesium and chloride ions back into the treated water to make it more suitable for the proposed uses. Minor pH adjustment to adjust the acidity/alkalinity to be close to neutral is also anticipated.

AGL is proposing water for the following beneficial reuses:

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

› CPF process water;

› Stock water;

› Irrigation water; and

› Supplementary environmental flows (discharge water).

In the Consultation Draft of the EWMS, AGL was proposing different water quality for different reuses. This would be difficult to manage and control at the WTP (and would require batching rather than a generating a constant stream of treated water). Consequently in this Final Draft EWMS, AGL has adopted a simplified approach.

AGL is proposing to produce one water quality stream. Water from the RO plant will be conditioned after the RO plant and before the TWT to be suitable for all proposed uses. Stream discharges have the most stringent water quality criteria and therefore the treated water will be conditioned to meet this target criteria (final criteria are subject to negotiations with EPA and approvals under AGL's EPL). Stream discharge salinity and temperature will closely match the Avon River water quality at the time of discharge. Salinity will be compatible with the receiving waters. Discharge water volumes will be very small and only be released during natural high flow periods.

Process water for reuse within the CPF will be chlorinated.

For the purpose of this EWMS, a salinity level of 250 mg/L TDS has been assessed as the most likely treated water salinity after RO desalination. This salinity could increase to a maximum 500 mg/L TDS after chemical conditioning. For comparison, water with a salinity less than 800 µS/cm (about 500 mg/L) is freshwater and drinking water quality. A summary of the target water quality criteria for proposed water reuses and discharge water is provided in **Table 12.1**. This criteria has been developed from the basis of design for the WTP infrastructure and the known water quality that can be achieved with the proposed water treatment technologies.

Table 12.1: Target Water Quality Criteria for Treated Water (after conditioning)

Primary Parameter	Unit	Range or Upper Limit	Remarks
pH	pH units	6.5 to 8.0	
Suspended solids	mg/L	<10	
Turbidity	NTU	<15	
Salinity	µS/cm	350 to 800	
TDS	mg/L	250* <500	250 mg/L is the expected output from the RO plant but the actual target water quality at the DWP will be slightly higher depending on the chemical conditioning required
Sodium	mg/L	<80	
Calcium	mg/L	<10	
Magnesium	mg/L	<2	
Total alkalinity (as $CaCO_3$)	mg/L	<60	
Iron	mg/L	<1	
Manganese	mg/L	< 0.5	
Aluminium	mg/L	<0.2	
Chloride	mg/L	<100	Limit is for river discharge water quality
Sulphate	mg/L	<40	Limit is for river discharge water quality
Phosphorus	mg/L	<5	
Fluoride	mg/L	<1	
Boron	mg/L	< 0.5	
Residual disinfectant (monochloramine)	mg/L	<0.05	
Ammonia	mg/L	<0.05	
SAR		<15 (preferably <9)	Limit is for irrigation water quality
Dissolved oxygen	% saturation	>25% saturation	

13. Brine and Waste Management

Several waste streams will result from operations associated with managing extracted water. This waste is expected to be generated and controlled at the following locations:

- Receiving water pond (RWP) receiving extracted water from the field;
- Pre-treatment processes (primarily the DAF plant); and
- WTP (IX and RO plants) processes.

The RO plant within the WTP and the Brine Treatment Plant (BTP) will also generate brine (and salt) as the main by-product of the desalination process.

Primary solids from the pre-treatment system and salt will be collected and disposed at an offsite waste facility in accordance with regulatory requirements. Liquid wastes will be recycled within the each of the component processes of the WTP and then included in the brine waste stream for ultimate salt disposal.

13.1. Receiving water pond

Extracted water as received from the gathering systems may contain small volumes of grit and sediment. This is expected to collect in the first of the cells in the RWP. Occasional cycling of cells will be required to remove the sediment. Waste volumes will be highly variable with most sediment generated during the gas well commissioning period. Volumes are expected to decrease as wells mature and produced water volumes decrease. Solid waste volumes cannot be quantified at this time but will be small.

Once removed from the RWP these sediments will be dried and stockpiled in an appropriate contained and bunded facility with the small volume of solid wastes from the pre-treatment processes. These will be periodically disposed at an offsite waste facility in accordance with regulatory requirements.

13.2. Pre-treatment waste management

The pre-treatment facility will collect finer grit and sediment that does not settle in the RWP.

Backwash waste streams from the DF and MF/UF systems will be sent to the spent backwash balancing tank and then recycled through the DAF plant. Minor quantities of solid waste (fine grit and sediment) will be generated as an output of the DAF process. Sediment volumes are expected in an appropriate contained and bunded facility to be less than 1m^3/d (as 25% dry solids at maximum flow rates). These will be dried and stockpiled with the RWP solid wastes and periodically disposed at an offsite waste facility in accordance with regulatory requirements.

13.3. WTP waste management

Several of the WTP processes generate minor chemical waste streams typical of all desalination plants. Chemical wastes will be directed to the Brine Storage Tank (BST) for BTP processing. The chemical waste streams are:

- IX acid regeneration waste;
- UF membrane CIP waste, and

› RO membrane CIP waste.

These waste streams are generated periodically and their volume is negligible compared to the RO brine stream. Any acid or alkaline wastes will be neutralised prior to being diverted to the Brine Storage Tank.

13.4. Brine management

RO membrane desalination will generate a brine concentrate stream that will contain the salts present in the extracted water, but at significantly elevated concentration levels.

Salt recovery and reuse of brine and salt streams is AGL's preferred management strategy, however given the variability in the produced water salinity within the Gloucester Basin and the salt being a mixed sodium-chloride-bicarbonate salt, the reuse opportunities appear limited.

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 salty paste. A centrifuge is then used to create a mixed (dry) salt suitable for disposal off site as a solid waste.

This approach by removing the salt from site and exporting it from the catchment would avoid the legacy of land at the CPF being rendered unusable in the future if there was solid waste encapsulated at the site.

The mixed salt content of the produced water and the small and decreasing volumes 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 if proven to be economically viable.

The maximum volume of salt that would be generated at the maximum P90 water production rate of 0.9 ML/d if the water salinity was 5000 mg/L TDS would be 4.5 tonnes per day (t/d). The peak P50 water production profile rate of 0.6 ML/d would produce 3 t/d of salt. Once the produced water volumes dropped to 0.1 ML/d (after five years) the salt tonneage would reduce to a very small 0.5 t/d.

13.5. Final Salt Disposal

The mixed dry salt will be predominantly sodium-chloride-bicarbonate (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).

There are no assays available for the crystallised salt derived from produced water from Gloucester gas wells at this time, although initial testing is proposed as part of the current Waukivory pilot program. These solid waste results will inform the final waste classification and landfill options. Further testing will be completed once the BTP becomes operational and salt is being generated for offsite disposal at a licensed facility. Based on the known water quality, it is expected that the salt will be classified as a general solid waste (GSW) (non-putrescible).

The total identified capacity to receive GSW in the Newcastle/Sydney Basin is approximately 2.3 Mt per annum. The expected peak salt production in the initial years is expected to be less than 1000 tonnes per annum (t/a) with the long term average salt production expected to be less than 200 t/a. This equates to about two trucks per week initially and then one truckload of salt per month for disposal at a licensed facility outside of the catchment. This average compared to the regional capacity to receive such waste represents around 0.009% of the general solid waste stream. The relative percentages are shown in **Figure 13.1**.

The crystallised salt by-product would most likely be classified as General Solid Waste (GSW) (non-putrescible) under the NSW *Waste Classification Guidelines* (EPA, 2014). AGL has identified multiple landfills operated by major waste disposal companies in the Newcastle/Sydney Basin region that are licensed to receive crystallised salt as General Solid Waste (non-putrescible). No approaches to landfill operators have been made at this time to accept this solid waste.

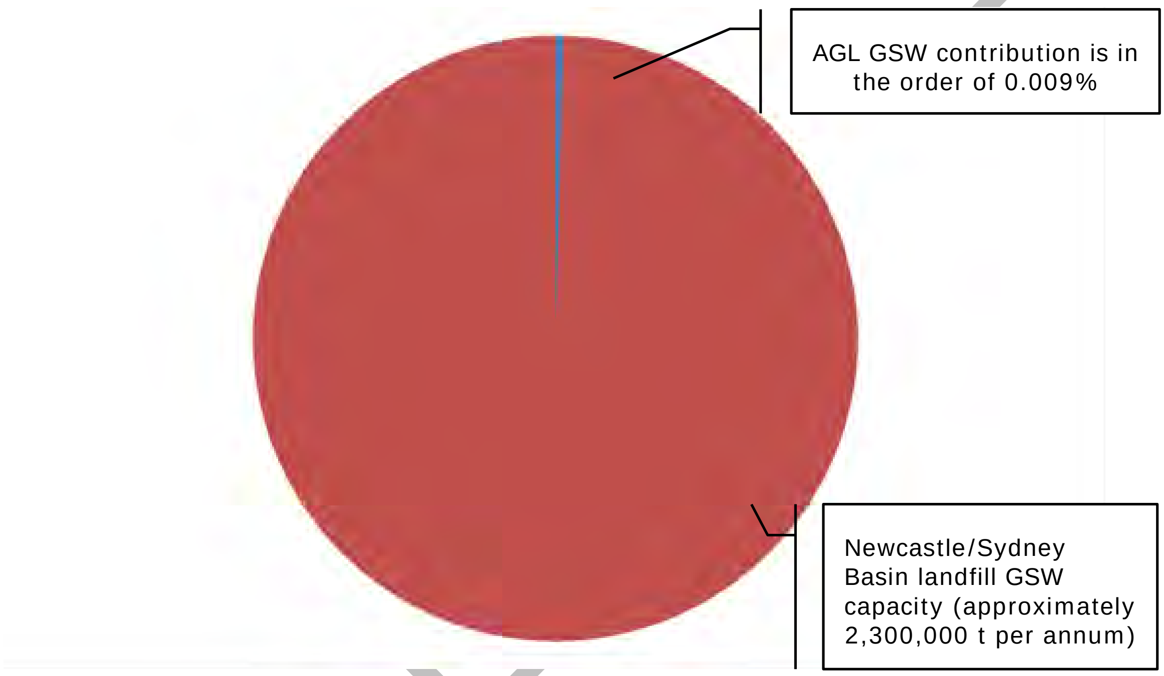


Figure 13.1: AGL's Estimated Contribution to GSW (non-putrescible) received in Newcastle/Sydney Basin Region

14. Monitoring Plan Principles

This section outlines the monitoring principles and the likely monitoring requirements for the management of extracted water and treated water. Detailed monitoring requirements will be included in a Produced Water Management Plan (PWMP) and any supplementary plans required prior to commissioning of the CPF. An outline of the probable water monitoring program for the proposed water infrastructure and reuses is provided in **Appendix E**.

The water monitoring objectives and principles for managing extracted water and protecting human health and environmental receptors are:

› To effectively monitor the water infrastructure (gathering lines, holding ponds and tanks, reticulation pipelines and storage ponds) to ensure there are no leaks or overflows;

› For extracted water, to protect human health by minimising exposure pathways and to undertake monitoring at locations where there is storage or detention of extracted water prior to treatment;

› For extracted water, to protect the environment by ensuring there is an adequate surface water and groundwater monitoring network in place to capture baseline data and then transient data at appropriate frequencies for the life of the Stage 1 GFDA;

› For treated water, to ensure that the treated water quality meets the proposed water quality targets and never exceeds the thresholds proposed in this EWMS; and

› For treated water, to protect the environment by ensuring that the natural water levels and quality in natural systems (both surface water and groundwater) are not impacted by the proposed reuses by having an adequate surface water and groundwater monitoring network in place.

The PWMP will:

› Detail inspection procedures for assessing and maintaining the integrity of the gathering systems, reticulation pipelines, storage ponds and tanks, and pond liners;

› Identify the water monitoring network for extracted water, the water treatment plant and reuse water applications;

› Identify the upstream and downstream monitoring requirements for the proposed stream discharge location;

› Detail the locations of monitoring points, parameters to be measured, frequency of monitoring, and monitoring/sampling methodology;

› Identify trigger values for key measured parameters;

› Describe investigations to assess the level of impact caused in the event of leakage to underlying groundwater or adjacent surface water from water gathering and water storage infrastructure; and

› Detail additional hydrogeological investigations to assess the extent and significance of any water level or water quality impact that occurs as a result of reuse or discharge.

Some of the likely content for a PWMP is outlined in **Appendix E**.

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 and more consultation with the regulators and the community, AGL's preferred strategy for extracted water and associated salt is:

- Pre-treatment and desalination of extracted water to produce treated water and brine;
- Reuse of treated water for CPF processes, and 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 high flows are occurring along the Avon River);
- Landfilling of the primary solids from the pre-treatment process; 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 stream discharge;
- Minor post-treatment to condition the treated water for all reuses and stream discharge;
- Brine concentration; and
- Crystallisation of brine water to produce salt.

The 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.

Further investigation of new market opportunities for water and mixed salt will continue with a local focus on 'Expressions of Interest' received for the available water and salt.

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