Produced Water Management Plan for PEL 285 - Gloucester

Date: 06 May 2015

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Document Revision History

Date	Version	Author	Comment
WMP for Tiedman Irrigation Program			
6 January 2012	V1-1	John Ross	Draft for Internal Review
20 January 2012	V1-2	John Ross	Final for submittal to NOW, DTIRIS and EPA for REF approval
14 May 2012	V1-3	John Ross	**PUBLISHED** - Final for public release with REF approval
PWMP for PEL 285			
22 September 2014	V1-1	John Ross	Draft for Internal Review
24 September 2014	V1-2	John Ross/Jenny MacMahon	Final Draft for Internal Review
26 September 2014	V1-3	John Ross/Jenny MacMahon	Final for submittal to Office of Coal Seam Gas (OCSG)
14 October 2014	V1-4	John Ross	Revised Final for submittal to Office of Coal Seam Gas (OCSG) after NOW review
22 October 2014	V1-5	James Duggleby	**PUBLISHED** - Revised Final following Ministers approval
1 May 2015	V2-1	John Ross	Draft for Internal Review after variations lodged to change the management of flowback water, and after the expiry of the Tiedman Irrigation Program approval
5 May 2015	V2-2	John Ross	Revised Final for submittal to Office of Coal Seam Gas (OCSG) for approval with April 2015 REF variation application
6 May 2015	V2-3	John Ross	**PUBLISHED** - Revised Final (after DRE feedback) for submittal to Office of Coal Seam Gas (OCSG) for approval with April 2015 REF variation application

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.
Aquifer properties	The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction.
Aquifer, confined	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Aquifer, semi-confined	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the confining layer – also known as a leaky artesian or leaky confined aquifer.
Aquifer, unconfined	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
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.
Dewatering	The process of removing formation water from a targeted coal seam. Dewatering is required to reduce pressure in the coal so gas can desorb and produce.
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	Extracted water is the collective term for both flowback water and produced water.
Fracture stimulation	A technique that increases the productivity of a gas well by creating a pathway into the targeted 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.
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.
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.
Limit of Reporting (LOR)	This is the detection level for a particular analyte when a sample is submitted for analysis at a NATA laboratory. If the result is less than the LOR the analyte is "non detect".
micro Siemens 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	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 classification	***Fresh water quality –*** water with a salinity <800 µS/cm. ***Marginal water quality –*** water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. ***Brackish quality –*** water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. ***Slightly saline quality –*** water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. ***Moderately saline quality*** – water that is more saline than 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.
Source Water	Water used to carry the sand and minor chemical additives used for fracture stimulation programs.
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.
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.

1. Introduction

1.1. Overview

AGL Upstream Investments Pty Ltd (AGL) is the holder of Petroleum Exploration Licence (PEL) 285 for the Gloucester Basin (which includes the Waukivory Pilot Project Approval) issued for the Gloucester Gas Project (GGP) coal seam gas exploration activities. PEL 285 expired on 15 April 2012 and was renewed on 6 August 2014.

AGL has prepared this Produced Water Management Plan (PWMP) to meet the requirements of PEL 285 Conditions 16, 17 and 18. The PWMP has been prepared in consultation with the NSW Office of Water (NOW) and is submitted to the NSW Office of Coal Seam Gas (OCSG) for approval by the Minister administering the *Petroleum (Onshore) Act 1991*.

1.2. Definition

Produced water is the 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 (PEL, 6 August 2014).

1.3. Purpose

The purpose of the PWMP is to describe the management of produced water that will be brought to the surface in the course of PEL 285 exploration activities.

The plan will be updated annually or whenever new exploration activities are approved that involve the capture, transport, reuse or disposal of produced water.

1.4. Scope

This PWMP is applicable to water that is taken (brought to the surface) in the course of PEL 285 prospecting operations such as:

- pilot testing of new gas wells for appraisal purposes (including hydraulic fracturing); and
- workover activities on (exploration) gas wells.

The PWMP focuses on the management of produced water; however the PWMP also addresses the management of:

- flowback water; and
- natural shallow groundwater (from air drilling, development and purging of test and monitoring bores).

The PWMP relates to exploration activities and is separate to the Extracted Water Management Strategy (EWMS) (AGL, 2014c) required under the Part 3A project approval for the Stage 1 Gloucester Field Development Area (GFDA).

In addition to the PWMP, there are a number of other water management plans required by different agencies for different exploration program activities within PEL 285 (refer **Figure 1.1**).

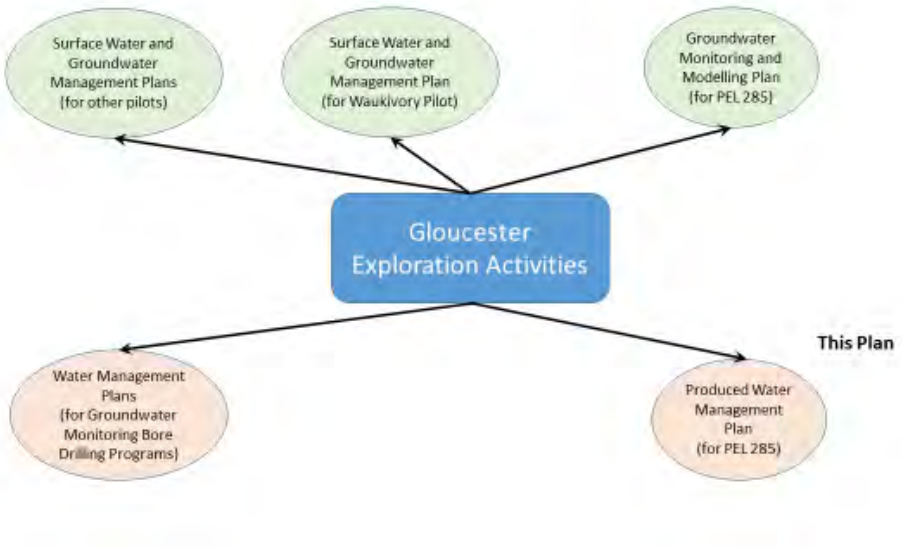

Figure 1.1: Water Management Plans for Exploration Activities

The PWMP does not include:

- water monitoring and management activities associated with water resource protection (covered under the Groundwater Monitoring and Modelling Plan (GMMP); and the respective Surface Water and Groundwater Management Plans (SGMPs) for individual exploration pilot activities – which is limited to the Waukivory Pilot at present (AGL, 2015a).

This PWMP covers the produced water management process from when it reaches surface at individual gas wells to where it is reused, stored or disposed from the Tiedman storage dams. This version of the PWMP does not include the Tiedman Irrigation Program (TIP) approval for blended water irrigation of produced water as this Part 5 approval expired on the 30 April 2015.

1.5. Location

The PEL 285 area and the Gloucester Basin area are shown in **Figure 1.2**.

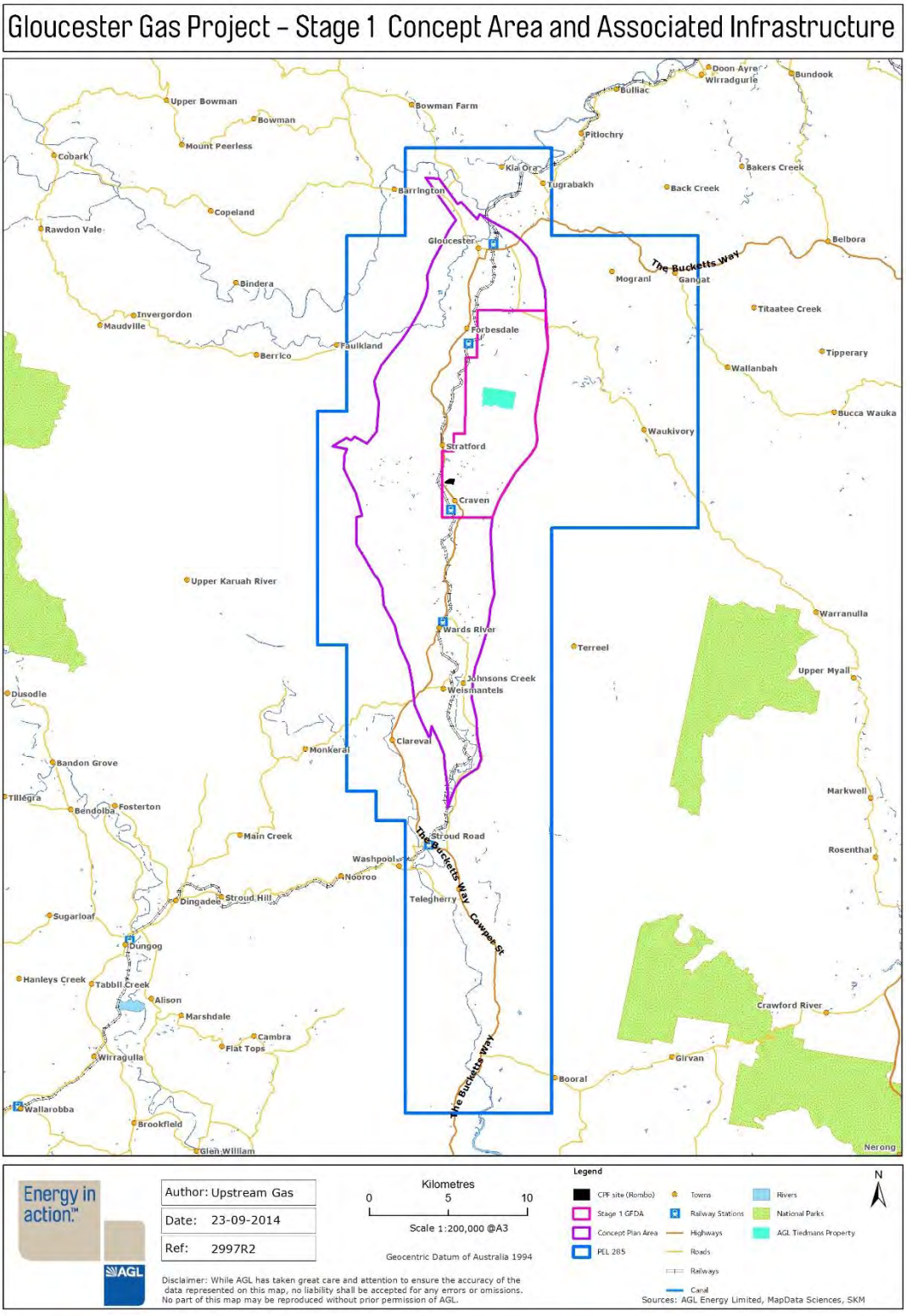

Figure 1.2: PEL 285 Area and Gloucester Basin Area

1.6. Approvals

The following approvals are relevant to the PWMP:

- PEL 285 renewed on 6 August 2014 and variations to the approved Waukivory Pilot activity;
- Environment Protection Licence (EPL) 20358 issued on 6 August 2014 and as varied in October and December 2014, and February 2015;
- various bore licence approvals for groundwater abstraction and use; and
- various surface water approvals for surface water abstraction and use.

1.6.1. PEL 285

PEL 285 includes the following conditions for a PWMP:

16. Prior to conducting prospecting operations with the potential to generate more than three (3) megalitres per year of produced water (as a result of cumulative prospecting operations within the exploration licence area), the licence holder must obtain the Minister's approval for a Produced Water Management Plan prepared in accordance with the requirements set out in conditions 17 and 18.

17. The Produced Water Management Plan must be prepared in consultation with the NSW Office of Water.

18. The Produced Water Management Plan must address the following matters:

a) the expected sources and estimated quantity of the produced water;
b) the proposed containment and treatment measures for the produced water;
c) the proposed beneficial reuse or disposal methods for the produced water;
d) the controls to be implemented to prevent and/or minimise pollution;
e) how records of all relevant parameters for the quality, quantity, transport and disposal of all water will be maintained;
f) the staging process for implementation of the plan; and
g) any additional requirements prescribed by the Secretary.

The requirements of Conditions 16, 17 and 18 and where they are addressed in this PWMP are provided in **Table 1-1**.

Table 1-1: PEL Conditions 16, 17 and 18

PEL 285 Condition	PWMP Reference
Condition 16	Ministers Approval granted: 21 October 2014 Version 1-5 published as the final on 22 October 2014.
Condition 17	Consultation summary: • Consultation with NSW Office of Water (NOW) on the PWMP commenced in September 2014 and consisted of review of the final draft PWMP (V1-3) and provision of comments.
Condition 18	
Part a) relates to the sources and estimated quantities of produced water	Section 4.1 and 4.2 (produced water) Section 5.1 (flowback water) Section 6.1 (natural groundwater)

PEL 285 Condition	PWMP Reference
Part b) relates to the proposed containment and treatment measures for produced water	Section 4.4 (produced water) Section 5.2 (flowback water) Section 6.2 (natural groundwater)
Part c) relates to the proposed beneficial reuse or disposal methods for produced water	Section 4.5 (produced water) Section 5.3 (flowback water) Section 6.3 (natural groundwater)
Part d) relates to the controls to be implemented to prevent and/or minimise pollution	Section 4.6 (produced water) Section 5.4 (flowback water) Section 6.4 (natural groundwater)
Part e) relates to how records of all relevant parameters for the quality, quantity, transport and disposal of all water will be maintained	Section 4.7 (produced water) Section 5.5 (flowback water) Section 6.5 (natural groundwater)
Part f) relates to the staging process for implementation of the plan	Section 3.6
Part g) any additional requirements prescribed by the Secretary.	Part g) is not dealt with at this time because there are no additional requirements prescribed by the Secretary.

1.6.2. EPL 20358

Monitoring of water quality and water pollution is regulated by the NSW Environment Protection Authority (EPA) under the *Protection of the Environment Operations Act 1997* (NSW). Environment Protection Licence (EPL) 20358 has been issued for approved exploration activities within PEL 285 including the TIP.

For the Waukivory Pilot, there are substantial monitoring requirements for surface water and groundwater levels and quality. Baseline monitoring programs commenced in 2013 (PB, 2014c) and continued into 2014. The required locations, analytical suites, and monitoring frequencies are described in the EPL and reflected in the Waukivory Surface Water and Groundwater Management Plan (SGMP) (AGL, 2014b and AGL, 2015a).

The management controls imposed by the EPA under the EPL water conditions are focused on protection of the environment and particularly identifying water level and water quality trends, and protecting adjacent and underlying water resources.

1.6.3. Water licences

The access, taking and use of groundwater in NSW is managed and implemented by the NSW Office of Water (NOW) under two primary legal instruments — the *Water Management Act 2000* (WMAct) and the *Water Act 1912* (WAct).

The main focus of the production bore licences for pilot testing is to regulate and monitor the water volumes extracted from this sedimentary rock groundwater system.

Information regarding the surface water and groundwater licences that are current for the exploration activities within PEL 285 are provided in **Appendix 1**.

2. Environmental Context

2.1. General

Gas wells can be located at many different sites in the landscape from the valley floor to ridgeline areas. The Waukivory Pilot area is located at the confluence of the Avon River and Waukivory Creek (Forbesdale). The Avon River and Waukivory Creek are normally permanent streams, although they can be reduced to water holes and these streams do not flow for long periods of time during extended dry periods.

Similarly the Avon River at the Tiedman property is normally a permanent stream, although it can be reduced to water holes and does not flow for long periods of time during extended dry periods. Water levels are highly variable and water quality becomes increasingly brackish during dry periods. Salinities (pre-irrigation) up to 1300 µS/cm have been observed in the Avon River adjacent to the Stage 1A irrigation area (PB, 2013b).

2.2. Hydrogeology

In the Gloucester Basin the produced water yield from the deep groundwater systems (predominantly the coal seam water bearing zones) is low (i.e. the production rates and volumes extracted from individual gas wells are low) and the water quality is brackish to slightly salty.

Substantial exploration and water investigation studies have been completed across PEL 285, including several pilot testing programs. AGL has a reasonable database on both water volumes and water quality characteristics of produced water within the Gloucester Basin, however new pilots provide additional results that are important in improving the management of produced water.

Gas wells are constructed to maximise the recovery of gas and to minimise the volume of produced water. However as depressurising (and dewatering) coal seams is necessary to flow gas, the pumping of deep groundwater from coal seams to surface is a necessary process. In order to minimise produced water volumes, coal seams below 200m are targeted and for the Waukivory Pilot the shallowest seams that were targeted were below 350m.

Based on the water level, water quality and isotope data from extensive water studies (e.g. PB, 2013b and PB, 2014c), there is a good appreciation of groundwater recharge, discharge and flow processes through the different groundwater systems of the Gloucester Basin. These hydrogeological units (based on PB, 2013a) are:

- alluvial aquifers - minor sand and gravel aquifers;
- shallow fractured rock aquifers – minor aquifers in various fractured rock units;
- deep coal seam water bearing zones - very poor aquifers/aquitards; and
- deep coal measure interburden confining units (claystone, siltstone, indurated sandstone) - aquitards/aquicludes.

The **alluvium** is only shallow (maximum 12m thickness) and in some areas contains an unconfined (sand and gravel) aquifer. Water levels are usually less than 5 metres (m) bgl. Groundwater flow processes are relatively simple with rainfall being the predominant recharge source on the floodplain. Flooding occasionally adds additional recharge water to the alluvial water table. Groundwater discharge from the alluvium is to the rivers as baseflow and shallow groundwater is also expected to be transpired by riparian vegetation.

The **fractured bedrock** contains mostly tight siltstone and indurated sandstone rock types with occasional thin semi-confined sedimentary/fractured aquifers (typically to around 75m depth). Water tables are generally deeper than 10mbgl with deepest levels at elevated sites and in areas of active coal mining. Rainfall is the only recharge source to the bedrock aquifers and recharge does not occur everywhere in the landscape. Recharge mostly occurs in areas of rock outcrop. In areas where there is a weathered (clayey) profile, brackish to saline water quality suggests there is negligible (vertical) rainfall recharge. Groundwater flow in bedrock aquifers is lateral, either within local fracture zones or individual strata if there are no interconnecting and open fracture zones. Groundwater discharge is via seepage to springs and to the alluvium (and indirectly to creeks and rivers) along the floor of the valley.

The groundwater in the **deeper bedrock** units is moving very slowly with lateral movement within each rock unit predominating. Confining rock permeabilities are very low, coal seam permeabilities are slightly higher (but are still not high enough to be considered useful aquifers).

There are no known groundwater dependent ecosystems (GDEs) (apart from stream baseflow accessions) although there may be some uptake of shallow groundwater (from the alluvium) by native terrestrial vegetation on the floodplain. Diffuse discharge of saline groundwater from bedrock seeps is thought to occur into the alluvium as stream salinity increases during dry periods. Groundwater discharge is diffuse and discharge does not occur at any one point in the landscape.

3. Produced Water Management Options

3.1. Options for Produced Water Reuse and Disposal

The following options have been considered in recent years for managing produced water within PEL 285:

- Temporary storage in lined holding dams at the Tiedman property and beside two of the Stratford wells;
- Off-site disposal;
- Reuse with no or limited treatment:
    - Industrial use
    - Blended water irrigation use
    - Stock use; and
- Reuse with treatment (desalination or other water treatment technology):
    - Industrial use
    - Irrigation use
    - Stock use
    - Stream disposal.

It has never been AGL's intention to store produced water for long periods of time in dams and allow it to evaporate. Along the lower north coast rainfall exceeds evaporation for all months of the year so stored water (with the addition of rainfall) will actually accumulate in surface storages rather than passively evaporate. Consequently the temporary holding ponds have been designed to occupy a relatively small area (all are less than 1ha in size) and are typically 4 to 5 metre deep.

3.2. Adopted Options for Produced Water

For the relatively small volumes of produced water derived from exploration activities within PEL 285, a combination of local reuse with limited treatment technologies and storage with no off-site disposal (except for flowback water) has been adopted.

Most of the water from historical drilling and pilot exploration programs (about 55 megalitres (ML) in total) has been stored in Tiedman North Dam (TND) and Tiedman South Dam (TSD) (40 ML total capacity). TND will continue to be the main storage for any new produced water. There was some additional offsite storage in the two smaller Stratford dams (total 16 ML capacity). Fifty four megalitres of this water was blended and used for irrigation in accordance with the Tiedman Irrigation Program (TIP) REF approval between 2012 and 2015.

The Stratford dams have been decommissioned and the sites rehabilitated. Most of the produced water (about 50 to 52ML) was derived from Stratford drilling and pilot testing programs. Additional volumes from flow testing programs (Stratford 04, Craven 06 and Waukivory 03) and several groundwater drilling programs added an additional 3 to 5ML in recent years.

As at the 30 April 2015 (the date of the expiry of the TIP approval), all the stored produced water had been blended and there was only 13 ML of water remaining in all of the Tiedman holding dams.

The primary reuse for (exploration) produced water was the TIP. The only 'treatment' was the blending of produced water with freshwater sources to achieve a blended water with a salinity of less than 2000 µS/cm.

The adopted options for produced water, flowback water and natural groundwater from monitoring bore locations, associated with the current exploration program activities are:

- Industrial use (drilling and work over source water, and potentially dust suppression and fire fighting) – using produced and/or blended waters stored within the three Tiedman Dams (very occasional use).
- Industrial use (fracture stimulation source water) – using produced and/or blended waters stored within the three Tiedman Dams (not implemented yet).
- Irrigation use – blended water taken from TSD (which is mostly produced water blended with fresh source waters to achieve a salinity of less than 2000 µS/cm) (primary reuse which is now completed).
- Stock use – natural groundwater from monitoring bore drilling programs and from produced and/or blended waters stored within the three Tiedman Dams (not implemented yet).
- Off-site disposal – temporary storage of flowback water from the Waukivory Pilot (an expected 3 to 3.5 ML) has been approved. Temporary storage in the double lined dam TED is proposed for 2015 until contractual arrangements are in place to lawfully dispose of this water at an offsite facility.
- Off-site disposal – produced water with greater than 15,000 µS/cm (if ever encountered and unable to store) (not implemented yet because water of that salinity has not been encountered).

AGL is committed to the beneficial reuse of all produced water from exploration activities across PEL 285 where possible. Blended water irrigation under the TIP has been AGL's preference for reuse, with occasional industrial use.

At the conclusion of the current TIP approval period (30 April 2015) there was approximately 54ML of produced water beneficially reused. There is approximately 6ML of blended water remaining in TSD. There is also 2 ML of freshwater stored in TED (mostly rainfall) and 5 ML of freshwater stored in TND (rainfall and catch dam return water). Small volumes of water are being transferred from TED to TND (to reduce the stored water in TED to less than 1 ML) in advance of the Waukivory flowback water being temporarily stored in TED.

In the unlikely event that no development proceeds beyond the current exploration activities then AGL will ensure that all produced water in storage is treated (if required) to an appropriate standard and beneficially reused for irrigation and stock purposes subject to the appropriate regulatory approvals being in place and the water quality meeting the commitments in the respective plans.

3.3. Waukivory pilot activities

The Waukivory Pilot involves the fracture stimulation and pilot testing of four gas wells concurrently (WK11, WK12, WK13, and WK14). The full impact assessment is provided in the REF documentation being:

- Waukivory Pilot REF (EMGA/Mitchell McLennan, 2013a);

- Addendum to the REF – Preferred Activity Report (PAR) (EMGA/Mitchell McLennan, 2013b);
- Further Addendum to the REF – Preferred Activity (EMGA/Mitchell McLennan, 2014);
- Waukivory Fracture Stimulation Management Plan (AGL, 2014); and
- Waukivory Pilot Project – Request to vary the approved activity (EMGA/Mitchell McLennan, 2015)

The Waukivory Pilot REF and associated documents (including the Surface Water and Groundwater Management Plan (SGMP)) undertook a detailed impact assessment of the Waukivory Pilot, including produced water, on:

- water quality;
- hydrogeology and the water table;
- aquatic ecology;
- aquifers;
- soil;
- socio-economic impacts;
- human health and environment risk assessment; and
- agricultural impact statement – assessment on agricultural resources.

The Waukivory REF and associated documents are available on AGL's website, and should be referred to for detailed impact assessment information.

3.4. Waukivory water infrastructure

The major infrastructure associated with transporting and containing water associated with the Waukivory flowback and produced water management process includes:

- dams;
- above ground storage tanks (AST); and
- pipelines.

A description of the dams used as source water and in the management of Waukivory flowback water and produced water (after fracture stimulation) is included in **Table 3.1**. The three 'turkeys nest' dams on Tiedmans are constructed as temporary holding ponds for waters generated from PEL 285 exploration projects. All dams are located beyond the floodplain. They have small footprints and are relatively deep.

TSD and TND were constructed for pilot testing programs associated with the Stratford exploration program while TED was constructed under the TIP REF approval to cater for the temporary storage of produced water from the Waukivory pilot. The dimensions of the TED are as follows:

- Size – approximately 0.9ha being 150m long by 60m wide by 4.4 to 5.7m deep
- Storage capacity – 20.4 ML
- Additional freeboard/capacity – 600mm which equates to an additional 4.3ML of storage

A description of the ASTs used in the management of Waukivory flowback water and produced water (after fracture stimulation) is included in **Table 3.2**.

A description of the pipelines used for source water and in the management of Waukivory flowback water and produced water (after fracture stimulation) is included in **Table 3.3**.

Table 3.1: Dams used for Waukivory flowback water and produced water management

Name	Location	Approved Use	Details	Approved Function	Reference
Pontilands Farm dam	Located on Lot 2 DP 1040412	Irrigation, Industrial and Stock Purposes (freshwater source)	• Large farm dam on unnamed gully leading to the Avon River • Excavated and unlined • 50 ML capacity • 20 ML Water Access Licence • Not in a flood prone area	Natural water source dam for fracture stimulation, workover activities and other industrial uses. Used primarily as source water for the fracture stimulation program but can be used for workover water and other miscellaneous industrial uses at Waukivory if required	Works approval 20CA212873
Tiedmans North Dam	Located on Lot 85 DP979859	Produced water	• Turkeys Nest dam • Single lined - HDPE • 15 year dam and liner life expectancy • 20 ML capacity • 500 mm freeboard before it spills • Not in a flood prone area	Produced water storage dam for PEL 285 exploration activities	REF approval No works approval required because the water that is pumped into this dam is taken from other licenced works
Tiedmans South Dam	Located on Lot 85 DP979859	Freshwater dam for irrigation – water sourced from works approvals 20CA212873 and 20CA204347	• Turkeys Nest dam • Single lined – HDPE • 15 year dam and liner life expectancy • 20 ML capacity • 500 mm freeboard before it spills • Not in a flood prone area	Historically produced water storage dam for PEL 285 exploration activities but mostly the blended water irrigation dam for the Tiedman Irrigation Program. Ongoing will be a freshwater dam	Freshwater dam
Tiedmans East Dam	Located on Lot 85 DP979859	Flowback and/or produced water	• Turkeys Nest dam • Double lined – HDPE – with seepage control and inspection sump • 15+ year dam and liner life expectancy • 20.4 ML capacity • 600 mm freeboard before it spills (extra 4.3 ML capacity) • Not in a flood prone area • Not an evaporation pond	Flowback water and produced water storage dam for PEL 285 exploration activities	REF approval No works approval required because the water that is pumped into this dam is taken from other licenced works

Table 3.2: Above ground storage tanks used for Waukivory flowback water and produced water management

Name	Location	Approved Use	Details	Function	Reference
AST 1	Waukivory 13 (refer Figure 3)	Source water and produced water	• 1.5 ML above ground storage tank (AST) total capacity; however actual capacity is reduced to 1.1 ML taking into account 500 mm freeboard • open topped • leak detection system • 500mm freeboard • located in a flood prone area	• AST 1 was used for the storage of freshwater (Pontilands source) during fracture stimulation. • Produced water from Waukivory 11, 12, 13 and 14 is pumped to AST 1. • Produced water in AST 1 is pumped to the Tiedman East Dam (TED) initially then Tiedman North dam (TND). • AST 1 will remain on site after fracture stimulation as a 'balance' tank for produced water or until such time that the produced water rate is low enough for either an alternate (smaller) tank to be located on site.	REF Approval
AST 2	Waukivory 13 (refer Figure 3)	Flowback water	• 1.5 ML AST total capacity; however actual capacity is reduced to 1.1 ML taking into account 500 mm freeboard • open topped • leak detection system • 500mm freeboard • located in flood prone area	• Flowback water from Waukivory 11, 12, 13 and 14 is pumped to AST 2 • Flowback water in AST 2 is pumped to TED in the produced water pipeline. • AST 2 will remain on site for the temporary storage of flowback water for approximately 3 to 6 months after the pilot re-commences after suspension • Some produced water may also be pumped through this tank as the flowback criteria is 100% of volume injected at each well plus an EC of 5000 µS/cm	REF Approval
Batch tank (BT) 1	Tiedmans	Flowback water and/or produced water prior to off site treatment	• Nominal 50,000 L AST total capacity • closed topped • located in bund with 110% containment • not in flood prone area	• Flowback / produced water is decanted from TED into BT1 • Sampling, analysis and assessment of water quality in BT 1 is undertaken prior to loading into a tanker for lawful off site treatment and disposal. • BT 1 will remain on site until lawful off site disposal of flowback is complete	REF Approval (April variation)
BT 2	Tiedmans	Flowback water and/or produced water prior to off site treatment	• Nominal 50,000 L AST total capacity • closed topped • located in bund with 110% containment • not in a flood prone area	• Flowback / produced water is decanted from TED into BT2 • Sampling, analysis and assessment of water quality in BT 2 is undertaken prior to loading into a tanker for lawful off site treatment and disposal. • BT 2 will remain on site until lawful off site disposal of flowback is complete • BT1 and BT2 are used alternatively	REF Approval (April variation)

Table 3.3: Water pipelines used for Waukivory flowback water and produced water management

Name	Location	Approved Use	Details	Function	Reference
Source water pipeline	Pontilands dam to AST 1	Source water for the fracture stimulation program and workover water	• poly pipe • underground • hydraulically pressure tested • located in both flood prone and non-flood prone lands.	• Water pipeline used for transferring water from Pontilands Dam (freshwater) to the WK13 staging area • This connection to the main transfer pipeline was isolated after the completion of the fracture stimulation program so that flowback water or produced water could not impact the freshwater in Pontilands Dam.	REF approval
Waukivory to Tiedmans flowback and produced water pipeline	AST 1 and AST 2 to TED (flowback water) and TND (produced water)	Main transfer pipeline for transferring flowback water and produced water	• poly pipe • underground • hydraulically pressure tested • located in both flood prone and non-flood prone lands.	• Water pipeline used for transferring water from the Waukivory (WK) 13 staging area (either AST 1 or AST 2) to TED (flowback water) or TND (produced water)	REF approval (April variation)
Waukivory site flowback and produced water pipelines	Waukivory 11, 12, 13 and 14 to AST1 and AST 2 at WK13 staging area	Spur pipelines for transferring flowback water and produced water to the WK13 staging area	• poly pipe • underground • hydraulically pressure tested • located in both flood prone and non-flood prone lands.	• Water pipelines from individual wells to the WK 13 staging area	REF approval
TED loading bay	From TED to BT 1 and BT 2	Lawful disposal of flowback water	• poly pipe • above ground • located on non-flood prone lands	• Water pipeline to transfer water from TED to BT 1 and BT 2 • This pipeline will remain on site until lawful off site disposal of flowback is complete	REF approval (April variation)

3.5. Waukivory water management

The original proposal in the Waukivory REF (September 2013) and the Preferred Activity Report (December 2013) was for flowback water to be disposed offsite from the WK13 staging area and the produced water to be piped to Tiedmans for storage and blended water irrigation.

The current proposal (under the 'Request to vary the approved activity' dated 15 April 2015) is to pipe the remaining flowback water to Tiedmans, temporarily store this water in TED, then dispose it offsite from this location. The produced water would be stored separately in TND while the flowback water is stored in the TED.

3.5.1. Flowback water

Flowback water is captured in temporary above-ground water storage at each well site and then collectively in a 1.5 ML above ground storage tank (AST) (AST 2) at the WK13 water staging point before being pumped to TED for temporary storage. Flowback water will be stored in the TED until a third-party contractor is engaged, or the Stage 1 Gloucester Gas Project commences, at which time the water will be treated via the desalination process outlined in the Extracted Water Management Strategy (EWMS).

If Stage 1 of the GGP has not commenced by 22 February 2016, and lawful offsite disposal of flowback water is still required and not available (or commercially viable) for AGL despite all reasonable and practicable efforts, AGL will seek approval for a mobile containerised water treatment unit to be located at Tiedmans.

Currently 0.42ML of workover and flowback water has been disposed offsite and there is some 3 to 3.5ML of flowback water still to be recovered and pumped to TED. There is about 2ML of freshwater currently stored in TED but this volume will be reduced to less than 1ML.

3.5.2. Produced water

Produced water transitions from flowback water once 100% of the fracture stimulation volume is recovered from each well and the produced water quality exceeds 5000 µS/cm. Produced water is then pumped into a 1.5 ML above ground storage tank (AST) (AST 1) at the WK13 water staging point before being pumped to TND for temporary storage. The maximum produced water volumes are expected to be 15 ML, and most likely (depending on length of test etc) to be less than 10 ML.

This water was originally to be blended and irrigated under the TIP approval, however with the expiry of this approval on the 30 April 2015, the new produced water is to be temporarily stored in TND while flowback water is stored in TED.

3.5.3. Water balance

The water balance for the Waukivory Pilot/TIP (as at 30 April 2015) and the expected volume of produced water to be stored is shown in **Table 3.4**. This simple water balance assumes that the pilot continues for 6 months, all of the flowback water is lawfully disposed from Tiedmans and all of the produced water is stored at Tiedmans.

The water balance indicates that there is more input water than output water, hence the water volumes in storage will increase over time. Evaporation volumes from TED and TND

are low compared to rainfall accessions. For TED in an average rainfall year, if the flowback water was stored for 6 months then:

- rainfall accessions would be approximately 5 ML; and
- evaporation would be approximately 3.7 ML.

The current storage volumes in all dams are low and there is ample storage capacity for the expected water inputs. The TND will store the bulk of the produced water until the commencement of the Stage 1 GFDA.

Table 3-4: Simple Water Balance Reconciliation for Waukivory Pilot

Storage Inputs/Outputs	Maximum Capacity (ML)	Current Storage (ML)	End of Waukivory Pilot Approval (ML)
Storage			
TED	20	2	<1
TSD	20	6	1
TND	20	5	20 (2)

Inputs	Maximum Volume (ML)	Likely Volume (ML)	Final Volume (ML)
Flowback Water	3.5	3.5	0 (7)
Produced Water	15 (1)	5-10 (say 8)	8
Rain (3)		8.9	17.8 (4)
Catch Dams (5)		0	0
Sub-Total		*20.4*	*25.8*
Outputs	Maximum Volume (ML)	Likely Volume (ML)	Final Volume (ML)
Offsite Disposal	3.5	3.5	0 (7)
Irrigation	0	0	0
Industrial		0	0
Stock		0	0
Evaporation (6)		6.7	13.4 (4)
Sub Total		*10.2*	*13.4*

Key: (1) - maximum expected volumes; actual volume is expected to be less (assumed 8)
(2) – assumes 8ML of produced water is stored
(3) - based on average rainfall of 1000 mm per annum (but pro-rataed over 6 months to end November 2015) and TSD/TND area of 7850m^2 and TED area of 9970 m^2
(4) – per annum estimates
(5) - catch dams assumed not to be operational
(6) - based on average evapotranspiration rate of 750 mm per year (but pro-rataed over 6 months to end November 2015)
(7) – assumes all flowback water is disposed offsite

3.5.4. Ongoing Strategy

The current produced water strategy allows:

- temporary storage of flowback water in TED;
- storage of produced water from AGL's offsite operations in TND and TED;
- reuse for stock use, subject to the water quality meeting the relevant ANZECC criteria;

- reuse for miscellaneous industrial uses such as workovers, dust suppression and firefighting, subject to water quality meeting the relevant ANZECC criteria; and
- storage for future drilling and hydraulic fracture stimulation purposes.

The current proposed reuses are for stock use, workovers, dust suppression and firefighting. These reuses will only occur directly if the produced water salinity is less than 6,000 µS/cm, and the water quality meets the relevant ANZECC criteria (6,000 µS/cm will be the criteria for stock use while 2,000 µS/cm will be the criteria for dust suppression and firefighting).

The onsite water management strategy (after the fracture stimulation program) involves:

- water gathering lines from each pilot well to the water staging point at WK13;
- temporarily storing flowback water in a large above ground storage tank (AST) at WK13 and monitoring storage levels;
- monitoring the volume and salinity of the flowback water at individual wells and assessing the transition to produced water (EC criteria of 5,000 µS/cm);
- pumping and temporary storage of flowback water in TED at Tiedmans;
- transportation of flowback water for disposal at a licensed facility from Tiedmans;
- the transition from flowback water to produced water is 100% recovery of the injected water volume plus a salinity of 5000 µS/cm;
- monitoring the salinity of the produced water at the wells and AST#1– water quality is unlikely to exceed 15,000 µS/cm and more likely to be around 7,000 µS/cm;
- temporarily storing produced water in AST#1 at WK13 and monitoring storage levels; and
- pumping of produced water to TED/TND on the Tiedmans property for storage; and
- monitoring as per Waukivory approvals and licences.

The raw produced water quality will vary slightly from each of the pilot wells (with the deeper zones in each well expected to have the highest salinities).

The water infrastructure (wells and water pipeline between the Waukivory Pilot and the Tiedmans property) is illustrated in **Figure 3.1**. This figure shows the:

- source water options (Pontilands Dam and the TND) and the water transfer pipeline;
- four pilot wells fracture stimulated and to be flow tested;
- water gathering lines internal to the pilot that connect each of the gas wells to the tankage at WK13; and
- water transfer pipeline that will transfer flowback and produced water from the ASTs at WK13 to TED.

The water management infrastructure (source water tanks, flowback tanks, and the large above ground tanks) located on the pad at WK13 is shown in **Figure 3.2**.

Further details regarding the water monitoring programs, triggers and responses are provided in the SGMP (AGL, 2015a).

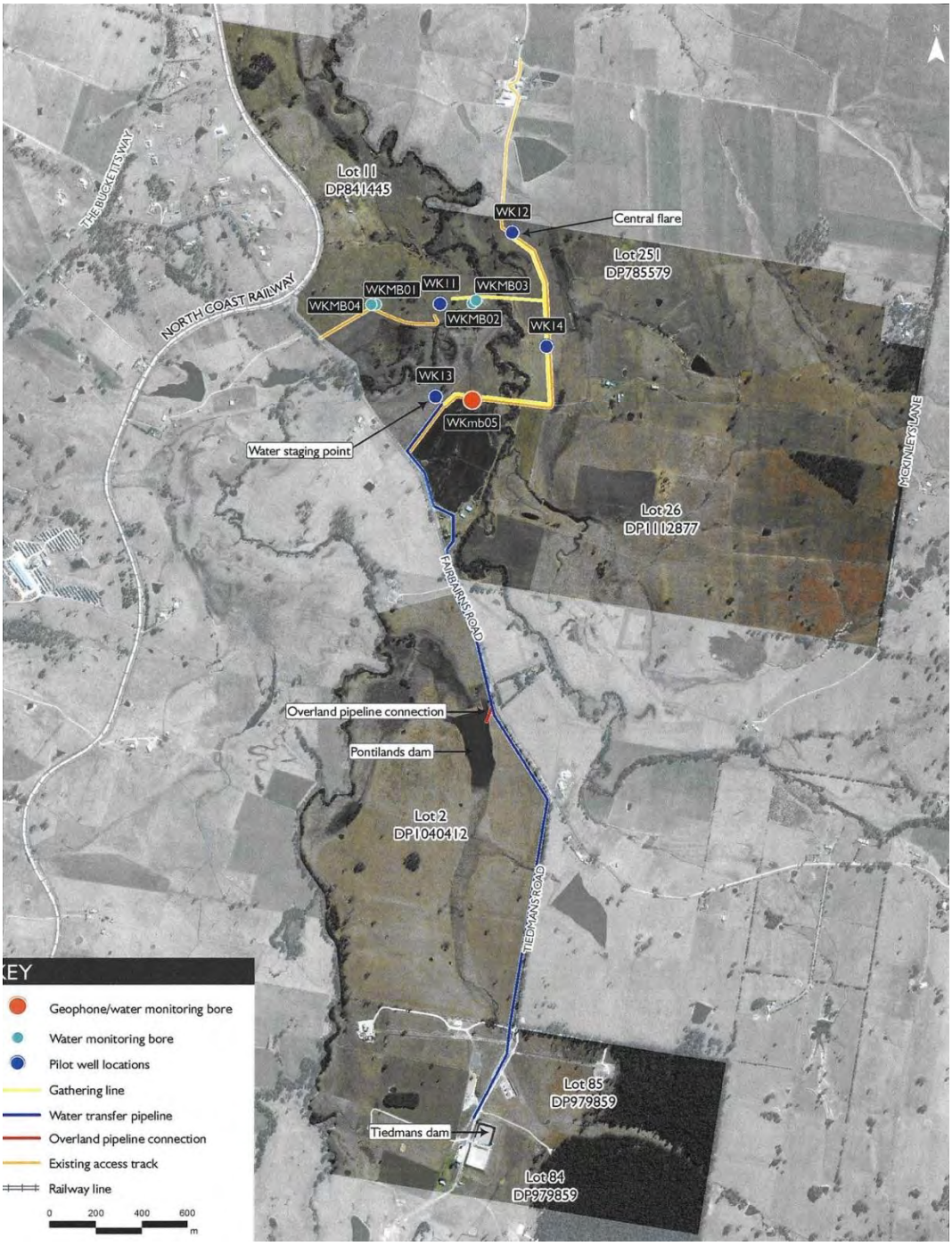

Figure 3.1: Waukivory wells and water gathering and transfer lines

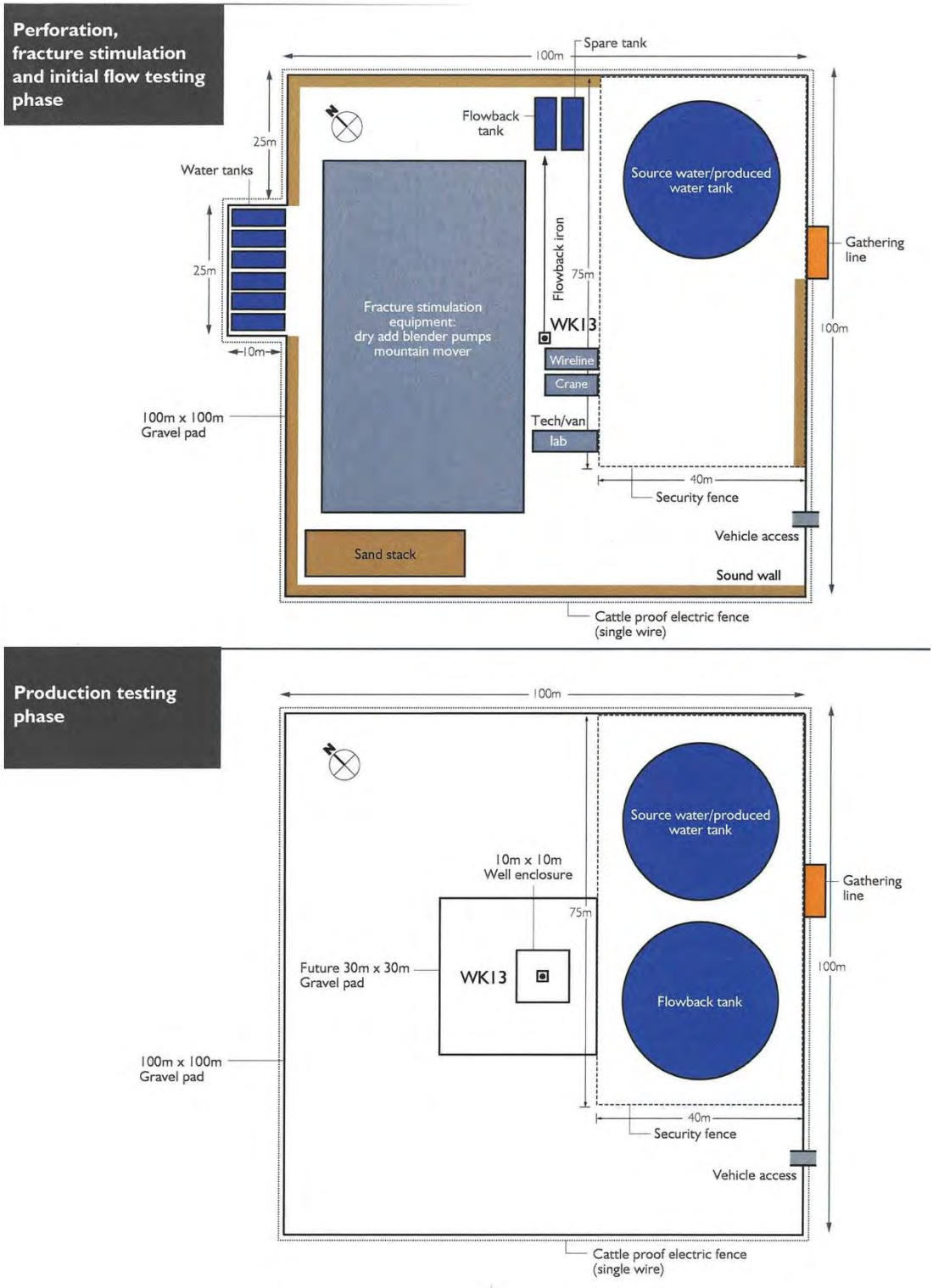

Figure 3.2: WK13 proposed site layout – Water infrastructure

3.5.5. Flooding

A quantitative assessment of floodplain obstruction and contingency management of the Waukivory Pilot activities is provided in the Preferred Activity Report (PAR) for the Waukivory REF (EMGA MM, 2013b).

The installation of water and gas gathering lines by HDD under Waukivory Creek effectively removes the interaction between the gathering lines and flood water at the Avon River and Waukivory Creek. Therefore, flood impacts are expected to be negligible.

Well surface infrastructure at WK12, WK13 and WK14 is within the 1 in 100 year AEP flood level. Well surface infrastructure including the temporary above-ground water tanks at WK13 and the three 20 foot flares at WK12 are relatively small and were considered by the flood assessment to be insignificant from a flood impact point of view.

All the Tiedman dams are located well above the 1 in 100 (and PMF) flood levels as shown in **Figure 3.3** (adopted from BMT WBM, 2014). Even with the maximum flowback water volume (3.5ML) plus current water volumes (2ML), the TED will have approximately 15ML capacity for the temporary storage of flowback water and direct rainfall. There is a further 600 mm or 4.3ML of capacity before water in TED would overflow the spillway.

The risk of a significant flood event resulting in the mixing of flowback water or produced water with flood waters is also very small. The well heads are fully enclosed and water gathering lines buried. The above-ground water tanks at WK13 will be constructed to have 500 mm freeboard above the 1 in 100 year AEP flood level and an operating freeboard of 500 mm will be maintained in the water tanks at all times to allow for heavy rainfall. The maintenance of an operating freeboard will be monitored through the AGL 'daily environmental checklist' procedure and remotely monitored and alarmed continuously through telemetry.

The implementation of the mitigation strategy outlined in the REF and the PAR are considered appropriate to manage flood impacts and minimise the impacts of floodplain obstruction arising from the Preferred Activity.

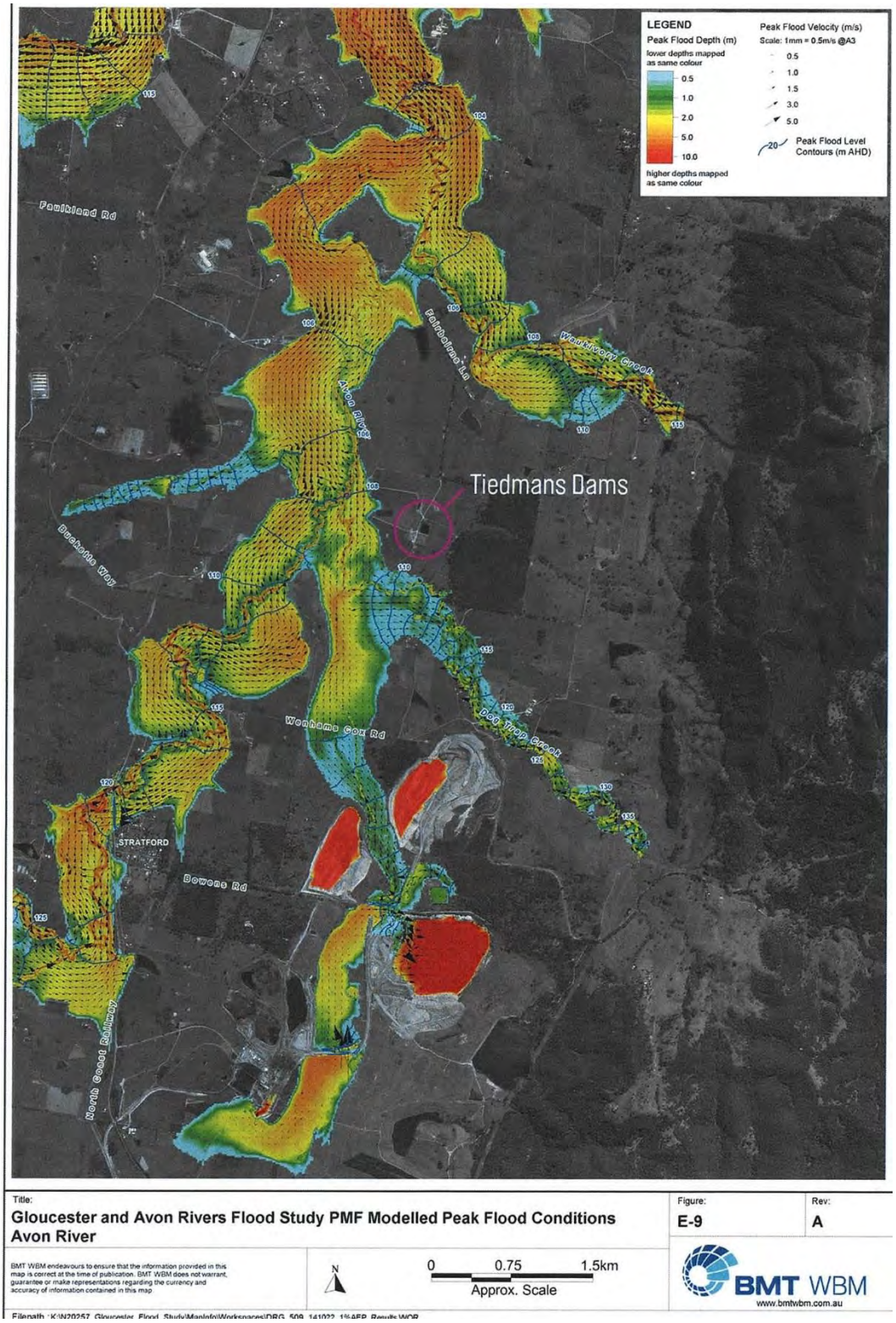

Figure 3.3: Modelled PMF Flood Conditions – Avon River Catchment

Measures to protect the floodplain, as stated in the REF and PAR, include:

- the 1.5ML above-ground water tanks at the water staging point will be designed to have 500 mm freeboard above the 1 in 100 year AEP flood level to prevent overtopping during a flood event. This will prevent the mixing of flowback water and produced water with flood waters;
- the operating procedure for the 1.5ML above-ground water tanks at the water staging point will include maintaining 500 mm freeboard in the tanks at all times. The level of freeboard in the tanks will be monitored through AGL's 'daily environment checklist' procedure; and
- weather will be monitored, and in the event of a likely flood, AGL will maximise the flowback water and produced water volumes pumped to the Tiedman dams (and minimise the volumes held in the ASTs).

3.5.6. Contingency planning and emergency management

AGL has prepared a detailed Environmental Management Plan (EMP) for all our exploration activities associated with PEL 285 (AGL, 2014d). This EMP details environmental management requirements around our exploration (flow testing) programs. In regard to flow testing and associated produced water management there are also separate sub-plans for:

- flood management; and
- soil and water management.

In addition, AGL has prepared an Emergency Response Plan (ERP) and Pollution Incident Response Management Plan (PIRMP) for all PEL 285 activities (AGL, 2014e). These plans deal with responses to:

- flooding;
- oil and chemical spills which include produced water management; and
- notification and reporting to regulatory agencies, including regulatory agency contact details.

These documents would be available for inspection if required by the relevant agencies. The PIRMP is available on AGL's website.

Specifically in regard to the Waukivory Pilot, there are:

- extra frac tanks on each well pad to deal with any surcharges of flowback water and produced water, or should temporary storage be required prior to pumping to the large above-ground tanks or further pumping to TED/TND;
- alarmed systems on the 1.5ML above-ground storages that alert operators regarding leaks and storage levels; and
- an on-site vac truck to capture any spills within the 'duck pond' and water transfer areas.

3.6. Exploration program water management

Most water is generated from pilot testing activities (i.e. the flowback water and the produced water). However, to describe all waters that are stored and/or disposed as part of the PEL 285 exploration activities, AGL has included in this PWMP:

- water generated from groundwater drilling activities where natural groundwater is produced from shallow aquifers during the construction and development of monitoring bores; and
- residual water from previous drilling and pilot testing programs (there is total of 13ML of water remaining as at 30 April 2015).

Exploration program water management activities are shown schematically in **Figure 3.4**.

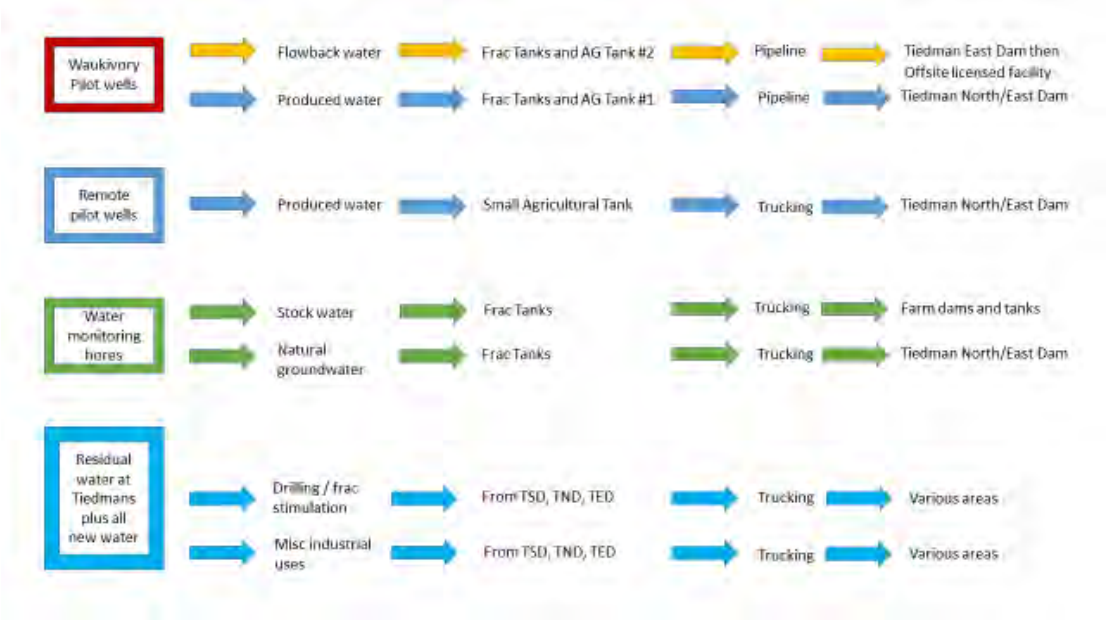

Figure 3.4: Extracted water types and adopted reuse/disposal options

3.7. Staging of the implementation of the PWMP

As the (produced water) exploration work program activities relates only to the Waukivory Pilot program at this time, there is limited staging information included for the implementation of this plan. Different Water Management Plans (WMPs) for the different exploration activities will describe the detailed water management and monitoring requirements.

As at the date of this version of the PWMP, there is one approved pilot testing program (Waukivory), and several minor approvals relating to pumping/flow tests and water monitoring bore drilling and sampling programs. The following WMPs apply to these activities:

- this PWMP; and
- the Waukivory surface water and groundwater management plan (SGMP) (AGL, 2015a).

4. Produced Water

Produced water in this section is defined as water taken in the course of a prospecting operation that is part of, or incidental to, prospecting operations but excludes flowback water and natural (shallow) groundwater.

4.1. Sources

Expected sources of produced water across the PEL 285 area are:

- pilot testing of new gas wells for appraisal purposes (including hydraulic fracturing); and
- workover activities on (exploration) gas wells.

4.2. Estimated Quantity

Produced water volumes from pilot testing depend on the length of the pilot testing programs; however volumes typically diminish over time. Typical water production curves are shown in **Figure 4.1**.

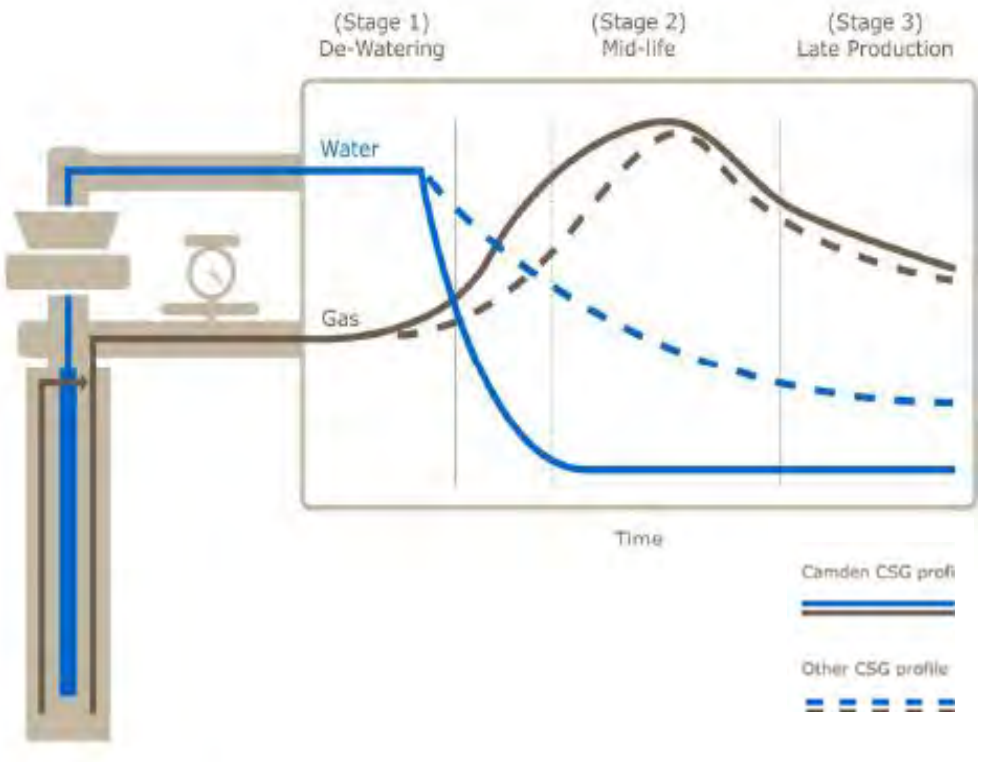

Figure 4.1: Typical gas and water production profiles

At Gloucester, produced water rates from pilot testing generally peak around 0.5 litres per second (L/s) per well at the commencement of pilot testing programs but quickly diminish to much lesser volumes (typically an order of magnitude lower). A recent example is the flow testing of the Craven 06 well (PB, 2014d and PB, 2015b) that produced a peak 0.7 L/s at the commencement of the program but quickly diminished to less than 0.05 L/s.

Maximum expected volumes for wells on test would be around 5 ML per year (ML/year) if the wells were continually operating. Pilot tests are rarely longer than 3 to 9 months.

At Gloucester, the peak production rate of any new gas well (especially after fracture stimulation) would be in the first 2 months of operation. It is not possible to provide an accurate water production rate or volume for any particular gas well or any particular pilot without completing a pilot testing program. The pilot testing is akin to a long term pumping test on a new water supply bore to determine the optimum pumping rate, pump setting and likely extraction volume.

For the Waukivory Pilot, there are four wells that will be pilot tested concurrently (WK11, WK12, WK13, and WK14). Each of these wells is licensed for 5 ML/year (this is the combined flowback and the produced water volume). This volume is based on historical pilot testing programs, the most recent of which produced about 2ML for a 6 to 9 month period of operation (for each of CR06 in 2013/2014 and WK03 in 2013). An estimate of the quantity for the expected sources of produced water is included in **Table 4-1**.

Table 4-1: Estimated produced water volumes for a typical pilot well - Gloucester

Source	Maximum estimated produced water (ML/year)
Pilot testing (per well)	5
Workover (per well)	<0.1

4.3. Water Quality

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

Typical groundwater quality characteristics of produced water are described below.

- Salinity

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

  Based on the available water quality data and existing groundwater salinity classifications, deep groundwater in the Gloucester Basin may be classified as brackish to moderately saline. Most produced waters are expected to be either brackish or slightly saline. The produced water is generally dominated by sodium, chloride and bicarbonate. Salinities can range from 3000 to 12000 µS/cm with CR06 having a salinity of around 7000 µS/cm.

  Produced water from the Waukivory pilot program (for the purpose of transition from flowback to produced water) is natural groundwater extracted after recovery

of 100% of the volume injected plus the water quality reaching a salinity of 5000 µS/cm.

- pH

  The pH of most natural waters ranges between 5.0 and 8.0. The pH of produced water at Gloucester is slightly alkaline (7.5 – 9.5).

- Alkalinity

  Alkalinity is the measure of water's ability to neutralise acids. Carbonate ions (CO3-) from dissolved salts such as calcium carbonate (CaCO3), bicarbonate ions (HCO3-) from dissolved salts such as calcium bicarbonate (Ca[HCO3]2), sodium bicarbonate (NaHCO3), and magnesium bicarbonate (Mg[HCO3]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 CaCO3.

  The bicarbonate levels in the produced water are predicted to range from 1,400 mg/L to 4,000 mg/L (expressed as CaCO3) with CR06 showing a concentration of 2,020 mg/L indicating a high alkalinity.

- Sodium and Chloride

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

- Potassium

  The potassium levels in the produced water at Gloucester are low with a predicted range of 8 mg/L to 18 mg/L, with CR06 showing a concentration of 12 mg/L.

- Calcium and Magnesium

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

- Manganese

  The manganese levels in the produced water are predicted to range from 0.3 mg/L to 1.0 mg/L with CR06 showing a concentration of 0.475 mg/L.

- Iron

  The iron levels in the produced water are predicted to range from 30 mg/L to 70 mg/L, with CR06 showing a content of 37.8 mg/L. This is a high iron concentration but is typical of natural groundwater.

- Strontium

  The strontium levels in the produced water are predicted to range from 2 mg/L to 6 mg/L, with CR06 showing a content of 3.06 mg/L.

- Other Trace Metals & Inorganics

  The arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, mercury, molybdenum, nickel, selenium, uranium and vanadium content of CR06 produced water were below the limit of reporting (i.e. results are 'non detect') for the particular metal, and do not present any issues with regard to storage or disposal.

The aluminium, barium, copper, and zinc content of CR06 were at low levels and do not present any issues with regard to storage or disposal.

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

- Fluoride

  Fluoride is found in most natural waters at low concentrations 0.01 mg/L to 0.5 mg/L. The fluoride present in the produced water is predicted to range from 1.0 mg/L to 3.0 mg/L, with CR06 showing a content of 1.4 mg/L.

- Boron

  The boron present in the produced water is predicted to range from 0.2 mg/L to 0.5 mg/L with CR06 showing a content of 0.27 mg/L.

- BTEX

  The total benzene, toluene, ethyl benzene and xylenes (BTEX) at CR06 was low with ranges of 16 to 20 µg/L. The maximum benzene concentration was 5 µg/L. Produced water from Waukivory was expected to be similar but concentrations in flowback water at individual wells are significantly higher than at CR06 (with total BTEX up to 795 µg/L).

The water quality at a particular gas well is unlikely to change over the period of a 6-9 month pilot testing program, as all coal seams are likely to be contributing to the produced water volume. However as water volumes diminish and some coal seams produce less water, the water quality may change. Again this water quality profile cannot be predicted without first completing the pilot testing program.

4.4. Containment and Treatment Measures

4.4.1. Waukivory Pilot

The Waukivory pilot will use the following infrastructure and containment facilities for produced water:

- Containment:
  - A 1.5 ML, purpose built, double lined above ground tank (originally used for source water) (AST#1) will remain on site at WK13 as a balance tank for the temporary storage of produced water, or until such time that produced water volumes are low enough for either an alternate (smaller) tank to be installed or water is transferred directly via buried pipeline to the Tiedman East Dam (TED);
  - 'Duck pond' secondary containment for several above ground storage tanks with tank capacity up to 75,000 L (excluding the 1.5 ML above ground tank) will be used at each well site to capture 110% of potential stored volume of ancillary tanks;
  - Tiedman East Dam (TED) will contain some produced water as the flowback water does not transition to produced water at the same time at each of the gas wells. Until all water from all wells transitions to produced water, all extracted water will be stored in TED; and
  - Tiedman North Dam (TND) will be the main storage for produced water once water transitions from flowback water. If TND is nearing capacity, excess produced water will be stored in TED.

- Infrastructure:
    - Four gas wells (WK11, WK12, WK13 and WK14) will pump produced water. Produced water will be tested prior to storage in the 1.5 ML AST#1 at WK 13;
    - Water pipelines (buried) to and from each gas well (WK11, WK12 and WK14) to and from the WK13 above ground storage tank; and
    - A flowback/produced water pipeline (buried) to discharge produced water from AST#1 at WK13 to the TED.

Each of the Tiedmans dams is of a 'turkey's nest' style construction, HDPE lined, 20ML in capacity, and located on high ground (beyond the floodplain) and are designed to prevent ingress from surface run off.

The two older dams (TND and TSD) are single lined ponds that have contained produced water from historical pilot testing programs and drilling programs. TSD will be the freshwater irrigation dam (previously blended water for the TIP), and TND will contain residual water and the produced water from new programs.

The newer dam (TED) is a double lined dam purpose built for the flowback water/produced water for the Waukivory Pilot and any future exploration pilots that maybe approved and commissioned.

4.4.2. Workover Activities

Workovers will use the following produced water infrastructure:

- Containment:
    - several above ground tanks (75,000L capacity each) for the temporary storage of produced water prior to transfer via either the buried pipeline or road tanker to the TED.
- Infrastructure:
    - individual gas wells that require a workover will generate produced water during the workover.

4.5. Beneficial Reuse or Disposal

Apart from small industrial reuses, there will be no other beneficial reuse or disposal of (exploration) produced water in the immediate future. All water (apart for small volumes that may be used for workovers and other miscellaneous uses) will be stored in TED or TND until the commencement of either the Stage 1 GFDA or other exploration pilot testing programs. It is anticipated that on commencement of Stage 1 of the GGP, the produced water (after treatment) will be used for drilling and fracture stimulation purposes and will be managed in accordance with the approved EWMS. These uses are not discussed further in this PWMP because they are associated with production activities rather than exploration activities.

4.6. Controls

4.6.1. Infrastructure and Containment - Pilots

The control measures that are in place to prevent and/or minimise pollution from infrastructure and containment of produced water at the Waukivory Pilot area and the TED/TND are listed in **Table 4-2**. AGL's standard operating procedures (SOP) (where available) and inspection/record forms are also quoted in this table.

Table 4-2: Produced Water Infrastructure and Containment Control Measures

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
1.5 ML above ground storage tank (AST#1) (at WK13) and associated infrastructure.	• Double HDPE lining	N/A		
	• Alarmed and activated sump that recirculates water to the tank	Continuous – check weekly	Operations Manager	Weekly Environmental Inspection Form
	• Visual inspection of the collection sump that drains between the double liners.	Weekly	Operations Manager	Weekly Environmental Inspection Form
	• Visual inspection to assess the integrity of the liner; condition of secondary containment; fill level; signs of seepage around the tank base; alarms, and potential impact from flood.	Daily and following rainfall events	Operations Manager	Weekly Environmental Inspection Form
	• Water quality monitoring at WK11, WK12, WK13 and WK14 (comprehensive suite)	Once water transitions from flowback water - every 2 months	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality monitoring at AST#1 (comprehensive suite)	Once water transitions from flowback water - every 2 months	Senior Hydrogeologist	Field sheets and CoCs
TED ** #	• Double HDPE lining.	N/A		

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
	• Visual inspection of the collection sump that drains the mesh between the double liners. (flowback water measure)	Weekly	Operations Manager	Weekly Environmental Inspection Form
	• Water quality sampling and analysis of TED water and water from the TED inspection sump (basic plus BTEX). (flowback water measure)	Monthly	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality sampling and analysis of TED water and water from the TED inspection sump (comprehensive).	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality sampling and analysis of seepage water in nearby monitoring bores (TMB04 and TMB05) (comprehensive).	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
	• Water level and quality sampling (field parameters) of water in the inspection sump at TED	Weekly	Environmental Manager	Water Quality Field Summary sheet
	• Visual inspection to assess the integrity of the liner; fill level; signs of seepage around the pond base and downgradient of TED.	Weekly	Operations Manager	Weekly Environmental Inspection Form

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
TND **	• Visual inspection to assess the integrity of the liner of each dam, fill level; signs of seepage around the base and downgradient of TND.	Weekly	Operations Manager	Weekly Environmental Inspection Form
	• Water quality sampling and analysis of TND waters (comprehensive)	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality sampling and analysis of seepage water in nearby monitoring bores (TMB04 and TMB05) (comprehensive).	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
	• Water level monitoring of the two seepage monitoring bores around TND and TSD.	Continuous	Senior Hydrogeologist	Excel data file
	• Calibration of water level loggers in two seepage monitoring bores	Quarterly	Senior Hydrogeologist	Check against manual WL records on field sheet
	• Water quality sampling and analysis of seepage water in nearby monitoring bores (TMB04 and TMB05) (comprehensive).	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
Water gathering lines	• Pressure testing of water gathering lines.	Prior to commissioning	Operations Manager	Construction Records
	• Inspection of water gathering lines within the immediate pilot area	Daily	Operations Manager	Daily Environmental Inspection Form

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
	• Inspection of water gathering lines from WK13 to TED	Weekly	Operations Manager	Weekly Environmental Inspection Form
	• Comparison of volumes discharged from the WK13 above ground storage tank meter to the volumes received at the TED meter.	Pumping event based	Operations Manager	Field Sheet TBA
	• Calibration records for in-line water meters	As per manufacturers recommendations	Operations Manager	Field Sheet TBA, Notifications via CMO
Above ground storage tanks with capacity up to 75,000 L	• Inspection of 'duck pond' secondary containment	Daily	Operations Manager	Daily Environmental Inspection Form
	• Visual inspection to assess the integrity of the tanks; condition of secondary containment; fill level; signs of leakage around the tanks; and potential impact from flood.	Daily	Operations Manager	Daily Environmental Inspection Form

Notes: * if the WK13 site is inundated by flooding and access is not possible to inspect the tanks then the inspection will occur on the first day after floods recede and the site is accessible
** additional monitoring bores are proposed around TSD, TND and TED as part of the EWMS and the water management strategy for the Stage 1 GFDA
# the same as for flowback water control measures (as most water in TED will be flowback water)

4.6.2. Leak detection at TND and TED

TND is a single lined water storage dam that is approved to store produced water at Tiedmans. There are two seepage monitoring bores in close proximity to TND – locations TMB04 and TMB05. For the produced water monitoring program, AGL will undertake:

- quarterly (comprehensive) sampling from the TND;
- quarterly (comprehensive) sampling of the two seepage monitoring bores (TMB04 and TMB05); and
- continuous (ongoing) water level monitoring of the two seepage monitoring bores (TMB04 and TMB05).

TED is a double lined dam with a leak detection inspection sump to assess any leaks to this liner. It is proposed that there will be a visual check of the liner weekly and the inspection sump be monitored weekly (both water level and field water quality parameters).

After the flowback water pumping is complete and the water transitions to produced water, AGL will undertake:

- quarterly (comprehensive) sampling from the TED and the inspection sump; and
- quarterly (comprehensive) sampling of the two seepage monitoring bores (TMB04 and TMB05).

The analytical suite for these two storage dams and leak detection locations (TED inspection sump, and TMB04 and TMB05) are described in Section 6.8 of the SGMP (AGL, 2015a).

There is no requirement for additional monitoring bores upgradient and downgradient of the new double lined storage dam (TED) at this time. Maximum produced water volumes from Waukivory are expected to be 15 ML, and most likely (depending on length of test etc) to be less than 10 ML. Additional monitoring bores are proposed as part of the EWMS to be implemented in 2016/17.

4.6.3. Water quality monitoring

For the Waukivory pilot testing program, produced water quality monitoring will occur at the following locations:

- individual wells (WK11, WK12, WK13 and WK14);
- AST#1;
- TED and TND storages;
- the seepage monitoring bores (TMB04 and TMB05); and
- the inspection sump that monitors seepage between double liners at TED.

For produced water from the Waukivory Pilot, full details of water monitoring (including parameters monitored, sampling procedures, sampling frequency for each parameter, sampling locations, reporting and availability of monitoring results and monitoring data, and proposed response triggers) are provided in Section 6.8 of the SGMP (AGL, 2015a).

4.6.4. Water volume monitoring

There is substantial monitoring of water volumes around pilot testing programs. Metering (or monitoring) of water volumes occurs at the following locations for the Waukivory Pilot:

- at individual wells (WK11, WK12, WK13 and WK14) during flowback and produced water extraction; and
- at the 1.5 ML above ground tank (AST#1) at WK13 receiving the produced water from individual wells and at the TND/TED storage dams.

4.7. Records

Records of control measures that prevent and/or minimise pollution from infrastructure and containment are listed in **Table 4-2.**

Data from the Waukivory Pilot will be collated and analysed and the results interpreted and written up into detailed technical reports that include:

- For the water monitoring program under the PEL approval, AGL will produce:
    - baseline data reports (to February 2014) (PB, 2014c);
    - quarterly technical reports during the pilot testing program. The first report has been completed and released (PB, 2015a); and
    - final technical report of all the water data collected through the fracture stimulation and flow testing program.
- Trend analysis and reporting occurs in respect of:
    - water level data;
    - water quality data and several key analytes; and
    - water volume data.
- Several graphical methods are used to assess the water quality data and apparent trends including:
    - Piper tri-linear diagrams; and
    - time series plots.
- Under the EPL, AGL will publish monthly water monitoring reports and compile information into an annual report regarding the:
    - water level and water quality trend data.

5. Flowback Water

5.1. Source and Estimated Quantity

For the purposes of pilot programs at Gloucester, flowback water is defined as the return to surface of fracture stimulation fluids before transition to natural formation water (deep groundwater), after which fluid flowing from the well is termed produced water. The criteria for flowback water is 100% of the volume injected at each well plus achieving a salinity (EC) of 5000 µS/cm.

This is the current criteria adopted for the Waukivory pilot program; however the water quality criteria may change from pilot to pilot. The quantity of flowback water aligns with the volumes used for the fracture stimulation program. This is generally between 0.5 and 1.5 ML per well. For the Waukivory pilot program, the following volumes were used for the fracture stimulation program:

- Waukivory (WK) 11 – 783,156 L (0.78 ML);
- Waukivory (WK) 12 – 479,210 L (0.48 ML);
- Waukivory (WK) 13 – 1,512,396 L (1.51 ML); and
- Waukivory (WK) 14 – 465,128 L (0.47 ML).

5.2. Containment and Treatment Measures

The Waukivory pilot will use the following water infrastructure and containment facilities for flowback water:

- Containment:
    - one 40,000 L open-top, purpose built steel flowback tank with internal diffuser located at each well site for immediate storage of flowback water during fracture stimulation and well completion. Once the surface production skid is installed, flowback water will be piped back to the WK13 staging area;
    - one purpose built, double lined, 1.5 ML above ground tank (AST #2) at the WK13 staging area for the temporary storage of flowback water prior to the off-site disposal of this water to a licensed water recycling facility;
    - 'Duck pond' secondary containment for several above ground storage tanks with tank capacity up to 75,000 L (excluding the 1.5 ML above ground tank) at each well site to capture 110% of potential storage volume of ancillary tanks;
    - Tiedman East Dam (TED) will contain all the flowback water from each of the gas wells. This storage is a double lined dam with inspection sump and associated controls; and
    - two enclosed and bunded tanks (each with a capacity of around 50,000 L) located beside TED (Batch tank #1 and Batch tank #2) to allow the water from TED to be batched and sampled prior to offsite disposal.
- Infrastructure:
    - four gas wells (WK11, WK12, WK13 and WK14) will produce flowback water. Flowback water will be tested prior to storage in the 1.5 ML above ground storage tank(s) at WK 13;

- water pipelines (buried) to and from each gas well (WK11, WK12 and WK14) to and from the WK13 above ground storage tank(s); and
- a flowback/produced water pipeline (buried) to discharge flowback water from the above ground storage tank (AST#2) at WK13 to the TED.

There may be temporary storage of flowback water in the open-top flowback tank associated with each well during workover operations (if required). There will be temporary storage of flowback water at the centralised AST#2 at WK13 until such time that the water is tested and pumped to TED for storage pending lawful offsite disposal. Three of the four gas wells and the infrastructure at WK13 are all located on the Avon River floodplain. To minimise the risk of overflowing to floodwater during a high rainfall event, flowback water is being transferred to the more secure TED storage located off the floodplain. It is proposed that 3 to 3.5 ML of flowback water will be stored in TED pending AGL engaging a third party contractor to lawfully dispose of the flowback water offsite from this location.

The 1.5 ML AST#2 will be used for approximately three months while flowback of the fracture stimulation water occurs. The flowback water tank will be dismantled and taken away after use.

Flowback water disposal will occur from Batch tank #1 and Batch tank #2 located at TED once a licensed facility is contracted.

Water quality from individual wells, AST#2, TED and the Batch Tanks (#1 and #2) will be monitored in accordance with the methodology in the SGMP (AGL, 2015a) and the water monitoring conditions of EPL 20358. No water treatment is proposed for flowback water.

Similar containment and offsite disposal is planned if any future pilots are planned and approved across PEL 285.

5.3. Beneficial Reuse or Disposal

No beneficial uses for flowback water generated from exploration activities are proposed at this time (even though the water quality would be suitable for irrigation reuse). All flowback water after temporary detention in TED and a suitable contractor is engaged is to be trucked to an approved and licenced facility.

5.4. Controls

The control measures that are in place to prevent and/or minimise pollution from infrastructure and containment of flowback water at the Waukivory Pilot area are listed in **Table 5-1**. AGL's standard operating procedures (SOP) (where available), trigger action response plan (TARP), and inspection/ record forms are also quoted in this table.

The TARP (AGL, 2015b) details the trigger levels and actions during the trial flowback period for:

- Hydrogen Sulphide (H_2S) concentrations in water and gas samples;
- Benzene, Toluene, Ethyl Benzene and Xylenes (BTEX) concentrations in water samples;
- odour from the above ground storage tank (AST) AST 2; and
- freeboard on AST 2.

Table 5-1: Flowback Water Infrastructure and Containment Control Measures

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
1.5 ML above ground storage tank AST#2 (at WK13) and associated infrastructure.	• Double HDPE lining	N/A		
	• Alarmed and activated sump that recirculates water to the tank	Continuous – check weekly	Operations Manager	Weekly Environmental Inspection Form
	• Visual inspection of the collection sump that drains between the double liners.	Weekly	Operations Manager	Weekly Environmental Inspection Form
	• Visual inspection of AST2 tank to check level water level below 500mm freeboard marker	Daily	Operations Manager	In accordance with Trigger Action Response Plan (TARP)
	• Visual inspection to assess the integrity of the liner; fill level; signs of seepage around the tank base; alarms, and potential impact from flood.	Daily and after rainfall events >25mm	Operations Manager	Daily Environmental Inspection Form
	• Water quality monitoring at WK11, WK12, WK13 and WK14 (comprehensive suite)	Every fortnight for first 8 weeks BTEX daily for the initial 4 weeks.	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality monitoring at AST#2 (comprehensive suite)	Every fortnight for first 8 weeks BTEX daily for the initial 4 weeks.	Senior Hydrogeologist	Field sheets and CoCs
TED ** #	• Double HDPE lining.	N/A		
	• Visual inspection of the collection sump that drains the mesh between the double liners.	Weekly	Operations Manager	Weekly Environmental Inspection Form

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
	• Water quality sampling and analysis of TED water and water from the TED inspection sump (basic plus BTEX).	Monthly	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality sampling and analysis of TED water and water from the TED inspection sump (comprehensive).	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
	• Water quality sampling and analysis of seepage water in nearby monitoring bores (TMB04 and TMB05) (comprehensive).	Quarterly	Senior Hydrogeologist	Field sheets and CoCs
	• Water level and quality sampling (field parameters) of water in the inspection sump at TED	Weekly	Environmental Manager	Weekly Environmental Inspection Form and Water Quality Field Summary Sheet
	• Visual inspection to assess the integrity of the liner; fill level; signs of seepage around the pond base and downgradient of TED.	Weekly	Operations Manager	Weekly Environmental Inspection Form
Water gathering lines	• Pressure testing of water gathering lines.	Prior to commissioning	Operations Manager	Construction Records
	• Inspection of water gathering lines within the immediate pilot area	Daily	Operations Manager	Daily Environmental Inspection Form
	• Inspection of water gathering lines from WK13 to TED	Weekly	Operations Manager	Weekly Environmental Inspection Form

Containment	Control Measures	Frequency	Responsibility	Procedure and Required Records
	• Comparison of volumes discharged from the WK13 above ground storage tank meter to the volumes received at the TED meter.	Pumping event based	Operations Manager	TBA
	• Calibration records for in-line water meters	As per manufacturers recommendations	Operations Manager	Field Sheet TBA, Notifications via CMO
Water tankers removing flowback water from Batch #1 and Batch #2 enclosed tanks	• Inspection of 'duck pond' secondary containment	Daily	Operations Manager	Daily Environmental Inspection Form
	• Inspection to assess the integrity of the tanks; fill levels; signs of leakage around the tanks; and bunds around load areas	Daily	Operations Manager	Daily Environmental Inspection Form
	• Tracking volumes delivered offsite to a licenced facility	Campaign based	Environmental manager	Water & Waste Material Tracking Form, Licenced facility dockets
	• Water quality sampling and analysis of batch tank water (basic to align with trade waste guidelines).	Per batch (will require fast turnaround)	Environmental manager in consultation with Senior Hydrogeologist	Field sheets and CoCs
	• Confirmation that the licenced facility is certified for disposal of flowback water.	6 Monthly	Environmental manager	CMO and Disposal facility licence

Notes: * if the WK13 site is inundated by flooding and access is not possible to inspect the tanks then the inspection will occur on the first day after floods recede and the site is accessible
** additional monitoring bores are proposed around TSD, TND and TED as part of the EWMS and the water management strategy for the Stage 1 GFDA
# the same as for produced water control measures

5.4.1. Leak detection at TED

TED is a double lined dam with a leak detection inspection sump to assess any leaks to this liner. The details regarding the installation and the specifications of the inspection sump are provided in **Appendix 2**. It is proposed that there will be a visual check of the liner weekly and the inspection sump be monitored weekly (both water level and field water quality parameters).

During the flowback period, monthly laboratory testing (basic suite) of the TED dam and sump waters is proposed to ensure that the primary liner is not leaking. Monthly BTEX samples will also be taken from each of these locations during the flowback water pumping period.

After the flowback water pumping is complete and the water transitions to produced water (see Section 4.6.2), AGL will undertake:

- quarterly (comprehensive) sampling from the TED and the inspection sump; and
- quarterly (comprehensive) sampling of the two seepage monitoring bores (TMB04 and TMB05).

The analytical suite for this storage dam and leak detection location (TED inspection sump) are described in Section 6.7 of the SGMP (AGL, 2015a).

5.4.2. Water quality monitoring

For the Waukivory pilot testing program, flowback water quality monitoring will occur at the following locations:

- individual wells (WK11, WK12, WK13 and WK14);
- AST#2;
- TED storage;
- the inspection sump that monitors seepage between double liners at TED; and
- the two batch tanks at TED (Batch#1 and Batch#2)

For the Waukivory Pilot, full details of water monitoring (including parameters monitored, sampling procedures, sampling frequency for each parameter, sampling locations, reporting and availability of monitoring results and monitoring data, and proposed response triggers for reporting to agencies) are provided in Section 6.7 of the SGMP (AGL, 2015a).

5.4.3. Water volume monitoring

There is substantial monitoring of water volumes around pilot testing programs. Metering (or monitoring) of water volumes occurs at the following locations for the Waukivory Pilot:

- at individual wells (WK11, WK12, WK13 and WK14) during flowback and produced water extraction; and
- at the 1.5 ML above ground tank (AST#2) at WK13 receiving the flowback water from individual wells and at the TED storage.

5.5. Records

Records of control measures that prevent and/or minimise pollution from infrastructure and containment are listed in **Table 5-1.**

Further details regarding the flowback water monitoring network are provided in the Surface and Groundwater Management Plan (SGMP) for the Waukivory Pilot (AGL, 2015a).

Data from the flowback water monitoring program will be collated and analysed and the results interpreted and written up into a detailed technical report (in combination with the produced water program – see Section 4.7) and will include:

- Trend analysis and reporting occurs in respect of:
    - water quality data and several key analytes; and
    - water volume data.
- Several graphical methods to assess the water quality data and apparent trends including:
    - Piper tri-linear diagrams; and
    - time series and trend plots for all analytes.
- Under the EPL conditions, AGL will publish monthly water monitoring reports and compile information into an annual report regarding the water level and water quality trend data.

6. Natural Groundwater

6.1. Source and Estimated Quantity

In drilling and developing shallow water monitoring bores using air-rotary techniques, natural groundwater is brought to the surface as each hole is drilled to the required target depths. Depths are typically less than 250m and most monitoring bores are completed in shallow aquifers in either the alluvium or fractured rock.

Airlifted groundwater volumes vary from site to site depending on the permeability of the sediments and rocks being targeted. A nested water monitoring bore site with three or four monitoring bores could produce up to 1 ML of natural groundwater. Typically water volumes are between 0.1 and 0.3 ML per nested site. Water quality varies from brackish to slightly salty. Water quality characteristics are similar to those described above for produced water although being shallower groundwater systems, water qualities tend to be slightly less saline.

These airlifted waters are captured in above ground tanks and either reused locally (if the water quality is suitable and there are agreements in place with local landowners) or transported back to the Tiedman holding dams for storage and reuse. Since 2010, all natural waters from Gloucester groundwater programs have been transported back to the Tiedman dams for storage and TIP reuse.

6.2. Containment and Treatment Measures

Produced water from monitoring bore construction programs is stored on site in above ground tanks (75,000 L capacity) or open top tanks (40,000 L capacity) and then transferred by road tanker to the Tiedman dams for either industrial use or blended water irrigation (refer Section 4.4, 4.5 and 4.6).

No treatment is required.

6.3. Beneficial Reuse or Disposal

Natural groundwater from monitoring bore programs is usually co-disposed and stored with the produced water at the Tiedman dams.

If the water quality is suitable for local reuse (such as for stock use and dust suppression purposes) it may be beneficially used on the properties where the drilling has occurred. If the water quality is not suitable for local reuse, natural groundwater from groundwater monitoring drilling, development, purging and sampling programs is transferred to the Tiedman dams for storage prior to reuse.

Further details are provided in individual WMP for these programs (such as AGL, 2013).

For the water monitoring bores constructed with air rotary, local reuse for stock use is preferred but would only be undertaken with the agreement of the local landholder and if the following assessment is undertaken:

- If the (airlifted) groundwater salinity is less than 2000 µS/cm (about 1300 mg/L TDS) then water will be either:
    - used for dust suppression;

- transported to selected farm dams/tanks and reused for watering of stock (cattle); and/or
- transported back to the Tiedman produced water dams (if the water is surplus to local requirements).

- If the (airlifted) groundwater salinity is greater than 2000 EC (about 1300 mg/L TDS) but less than 6000 µS/cm (about 4000 mg/L TDS) then the water will be:
  - transported to selected farm dams/tanks and reused for watering of stock (cattle);
  - will only be used for dust suppression if blended with low salinity water so as to achieve a salinity of less than 2000 µS/cm (about 1300 mg/L TDS); and/or
  - transported back to the Tiedman produced water dams (if the water is surplus to local requirements)
- If the (airlifted) groundwater quality is greater than 6000 µS/cm (about 4000 mg/L TDS) then the water will be captured and transported back to the Tiedman produced water dams.

The salinity threshold of 6000 µS/cm is based on the ANZECC (2000) guidelines for beef cattle.

For shallow monitoring bores, the water type is expected to be a (brackish to slightly salty) sodium bicarbonate (Na-Cl-HCO_3) water with neutral pH and low dissolved metals.

Local reuse will also minimise vehicle movements to and from private properties on the local lanes and roads, and along the Bucketts Way.

6.4. Controls

The control measures that are in place to prevent and/or minimise pollution from the above ground tanks on site during groundwater monitoring drilling, development, purging and sampling programs are listed in **Table 6-1**.

Table 6-1: Groundwater monitoring program Control Measures

Containment	Control Measures	Frequency	Responsibility	Procedures and Required Records
Above ground storage tanks (capacity up to 75,000 L) or open top tanks	• Multiple above ground tanks and float controls/ inspection	Pre-commencement	Operations Manager	Completion Records
	• Visual inspection of the tank float / inspection control	Daily	Operations Manager or Supervising Consultant	Daily sheet
Water tankers removing natural	• Inspection of load areas	Daily	Operations Manager	Daily sheet

Containment	Control Measures	Frequency	Responsibility	Procedures and Required Records
groundwater from site	• Tracking volumes delivered to Tiedman dams	As required	Environmental Manager	Transport Dockets

6.5. Records

Records of control measures that prevent and/or minimise pollution from groundwater monitoring programs are listed in **Table 6-1.**

Water quality and volume data from groundwater intersected during the air-lift drilling programs is monitored and collated, and written up into detailed drilling and completion reports.

7. Water Monitoring

This section of the PWMP is an overview of water monitoring requirements associated with the management of produced water, flowback water and natural groundwater within PEL 285. Full details are provided in the specific WMPs for each of the exploration activities (e.g. AGL, 2012, AGL, 2013 and AGL, 2015a).

7.1. Monitoring water quality

In addition to the PEL, the main water quality monitoring requirements arise from the EPL conditions for AGL's exploration activities across the PEL. For pilot testing programs, water quality monitoring will occur at the following locations:

- source water locations (or at the large above-ground water tank located on the main staging area);
- individual wells where fracture stimulation fluid mixtures are monitored in parallel with the fracture stimulation program;
- individual wells where flowback water is monitored;
- centralised AST where flowback water is temporarily stored;
- individual wells where produced water is monitored;
- centralised AST where produced water is temporarily stored;
- TED where flowback water is temporarily stored;
- TED and/or TND produced water is stored;
- seepage monitoring bores surrounding TSD and TND; and
- seepage monitoring inspection sump associated with TED.

For the Waukivory Pilot, full details are provided in the Surface Water and Groundwater Management Plan (AGL, 2015a).

7.2. Monitoring water volumes

There is substantial monitoring of water volumes around pilot testing programs. Metering (or monitoring) of water volumes occurs at the following locations:

- at the site of the source water (required under our water licences);
- at each individual well to monitor the fracture stimulation (injection) volumes;
- at individual wells during flowback;
- at individual wells during produced water extraction; and
- between the above ground tank receiving the flowback water/produced water and at the TED/TND storage dams.

For the Waukivory Pilot, full details are provided in Surface Water and Groundwater Management Plan (AGL, 2015a).

7.3. Data Archival

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

- inspection and status monitoring records for pumps, tanks, pipelines and dams;
- metering information for all pumps and delivery lines;
- transport records for road tanker deliveries to/from the main Tiedman dams (TED and TND);
- calibration records for water meters;
- water sampling records, field parameter checklist and records, and laboratory analytical reports;
- calibration records for field instruments and continuous loggers (water levels and salinity); and
- waste transportation and disposal certificates.

There are numerous water data sets collected in relation to extracted water management programs. It is proposed that:

- water level data from the monitoring bores continue to be archived with our technical specialists;
- water quality data from the monitoring bores continue to be archived with our technical specialists;
- water level data from the surface water locations (and dam storages) continue to be archived with our technical specialists;
- water quality data from the surface water locations continue to be archived with our technical specialists;
- volumes used for drilling and fracture stimulation are tracked and archived in spreadsheets by AGL Operations; and
- volumes used for irrigation and stock use are tracked and archived in spreadsheets by AGL Agriculture.

Field and laboratory data is interpreted and reported by our technical specialists, and reviewed by subject matter experts in AGL.

Trend analysis and reporting occurs in respect of:

- water level data;
- water quality data and several key analytes; and
- water volume data.

Several graphical methods are used to assess the water quality data and any apparent trends including:

- Piper tri-linear diagrams; and
- time series plots.

8. References

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Appendices

Appendix 1: Surface water and Groundwater approvals

Appendix 2: MDR Report Section 1.3 Leak Detector

Appendix 1: Surface water and Groundwater approvals

All groundwater used for beneficial purposes is located within two groundwater systems – the alluvial sediments associated with the unregulated streams, and the sedimentary/fractured bedrock aquifers. The alluvial sediments are managed under the Lower North Coast Unregulated and Alluvial Water Sources Water Sharing Plan (WSP) and the Water Management Act (WMAct), while the deeper sedimentary/fractured rock groundwater systems are currently managed under the Water Act (WAct).

Legislation

Water Act (1912)

The WAct has been in place since 1912. Since 2003 the WAct has been progressively phased out (repealed) and replaced by the WMAct across NSW as new Water Sharing Plans are gazetted.

AGL's bore licences for the GGP have been issued under the WAct as this is the appropriate water regulation for CSG exploration activity at this time for this water source. AGL currently holds 15 production bore licences for exploration (pilot testing) activities across the PEL as at 1 September 2014. Details are provided in **Table A1.1**.

Water Management Act (2000)

AGL holds two Water Access Licences (WALs) for surface water abstractions from the Avon River water source under the current surface water and alluvial Water Sharing Plan (WSP).

There is no WSP for the sedimentary (porous) rocks of the Gloucester Basin at this time and therefore the WMAct currently does not apply to this groundwater source.

Licences

AGL bore licences are for the commercial/industrial/irrigation reuse of groundwater pumped during pilot testing programs across the PEL. Two licences have recently been surrendered with the plug and abandonment of two gas wells. The bore licences are linked into a combined allocation of 20 ML per year (two licenses), 15 ML per year (five licences) together with another six licences with individual allocations of 5 ML per year.

The most recent Waukivory Pilot production bore licences have conditions relating to dewatering volumes (Condition 7); water quality testing (Condition 8); blended water irrigation (Condition 9); use (Conditions 4, 10, and 11); abandonment (Condition 12, 13 and 14); and water injection volumes (Condition 15).

The five Stratford Pilot bore licences have conditions relating to dewatering volumes and irrigation areas (Condition 9); impact assessment prior to taking water (Condition 10); and prepare, implement and report on the findings of a groundwater management plan (Condition 11).

Other individual bore licences have similar conditions.

Produced water from these pilot testing programs (except Waukivory) was historically stored in the three storage dams on the Tiedman property. All stored produced water except for a small residual volume of approximately 1ML has been blended and irrigated.

For the foreseeable future the Tiedman South Dam (TSD) will be used for freshwater irrigation, the Tiedman North Dam (TND) will be used for any residual water and new produced water, while the Tiedman East Dam (TED) will be for storing flowback water and some produced water from the Waukivory Pilot.

Details of the current bore licences are provided in **Table A1-1**.

Table A1-1 Production Bore Licences held for Industrial/Irrigation Purposes

Lot/DP	Licence No.	Issue Date	Period	Purpose	Allocation (ML/y)	Local Bore Names
1/718347	20BL168850	16-Oct-13	5 years	Commercial	20*	Stratford 1
80/979859	20BL168851	16-Oct-13	5 years	Commercial	20*	Stratford 3
85/979859	20BL172557	8-Oct-10	5 years	Industrial / Irrigation	15^	Stratford 4
85/979859	20BL172558	8-Oct-10	5 years	Industrial / Irrigation	15^	Stratford 5
85/979859	20BL172559	8-Oct-10	5 years	Industrial / Irrigation	15^	Stratford 6
83/979859	20BL172560	8-Oct-10	5 years	Industrial / Irrigation	15^	Stratford 8
85/979859	20BL172561	8-Oct-10	5 years	Industrial / Irrigation	15^	Stratford 9
20/1164626	20BL173465	10-May-13	5 years	Industrial / Irrigation	5	Craven 06
31/571522	20BL173466	10-May-13	5 years	Industrial / Irrigation	5	Waukivory 03 #
1/877783	20BL173468	10-May-13	5 years	Industrial / Irrigation	5	Faulklands 03 #
9/804536	20BL173467	10-May-13	5 years	Industrial / Irrigation	5	Weismantels 03
11/841445	20BL173595	22-Aug-14	1 year	Industrial / Irrigation	5	Waukivory 11
251/785579	20BL173599	22-Aug-14	1 year	Industrial / Irrigation	5	Waukivory 12
11/841445	20BL173600	22-Aug-14	1 year	Industrial / Irrigation	5	Waukivory 13
251/785579	20BL173601	22-Aug-14	1 year	Industrial / Irrigation	5	Waukivory 14

Key - * joint allocation between these two licences; ^ - joint allocation between these five licences; # - gas well recently P&A'd

AGL also holds two surface water access licences (WAL) and works and use approvals for slightly different purposes:

- WAL 19521 and works approval (20CA204347) to extract 32 ML/y from the Avon River for irrigation purposes.
- WAL 36616 and works approval (20CA212873) to extract 20 ML/y from a large off river storage dam for irrigation, industrial and stock purposes.

This fresher surface water can be irrigated direct to established irrigation areas. WAL 19521 has been used to obtain freshwater for the (now expired) TIP during 2012/13 and 2013/14, however WAL 36616 has not been used for irrigation purposes at this time.

The access to and use of this surface water is governed by the current WSP. The key features of water availability and use are sourced from the report card for the Avon River water source (DWE, 2009) as outlined below:

- 43 surface water licences;
- 1,997 ML allowed to be extracted annually; and
- water cannot be traded into the Avon from downstream connected rivers (Lower Manning, Lower Barrington and Gloucester).

Under the WSP, permanent and temporary trading of water licences is allowed but can only be sourced from within the licences allocated for the Avon River source. AGL sourced a small amount of water in the 2013/14 water year for irrigation purposes from a local landholder, however further water transfers are unlikely at this time.

The three turkey nest dams on Tiedmans do not require licensing as they are holding dams only, they have no catchment, and the water sources feeding them are licensed. They have relatively small footprints and are deep, and are not designed as evaporation ponds.

Aquifer Interference Approvals

The AI Policy (NOW, 2012) defines exemptions based on the level of risk. The exempt activities are those considered to pose a minimal risk to water sources, their dependent ecosystems and other water users.

The policy also requires those new CSG exploration activities where groundwater is taken (irrespective of volume) to have a water access licence or a volumetric bore licence approval. Details regarding these activities are described in the Surface Water and Groundwater Management Plan (AGL, 2015a). The AI policy also applies to the reuse/disposal of produced water.

The pilot testing proposed at Waukivory (and any future pilots) involves dewatering, and therefore under the policy, new production bore licences are required for this pilot testing program. NOW has issued AGL with a licence for industrial and irrigation purposes for each of the four pilot wells (and each for an annual allocation of 5 ML per annum commencing 1 July). The four bore licences are valid to the 21 August 2015.

The amount of 5 ML for each pilot well is based on the maximum likely extraction from each well during an extended pilot testing program, and includes approximately 1 ML of flowback water recovered immediately after the fracture stimulation program.

Volumes recovered during the pilot testing program may be less than this total volume of 20 ML/y, but based on the early pilot testing programs at Stratford, these volumes are considered to be reasonable upper limits. It is not possible to provide a firmer estimate of the water production profiles at this time without completing the Waukivory pilot testing program.

The flowback water from Waukivory is to be pumped to a large holding tank (AST#2), then pumped to TED, and then disposed offsite at a licensed water recycling facility. The produced

water is to be pumped to the TED and/or TND dams (TND preferred) and then stored for future wellfield industrial uses.

Characterisation of the local groundwater systems

'Highly productive groundwater sources' are defined in the AI Policy (NOW, 2012) as having the following properties:

- total dissolved solids of less than 1,500 mg/L, and
- water supply works that can yield water at a rate greater than 5 litres per second (L/s).

Table A1.2 provides information on the groundwater productivity of aquifers based on water bore and monitoring bore data in the vicinity of the Waukivory site.

Table A1.2: Local characteristics for the Waukivory Pilot Testing Program

Aquifer	Yield (L/s)	Electrical Conductivity (EC) (µS/cm)	(approx) Total Dissolved Solids (mg/L)
Alluvium	<2	2,000 – 7,500 (1)	1,500 – 6,000
Fractured rock	<0.5	3,500 – 5,000 (1)	3,000 – 4,250

Note (1) values based on nearby monitoring bore data

Both the yields from the alluvial aquifer and the fractured rock aquifer are too low, and the total dissolved solids (TDS) of the groundwater are too high to classify local groundwater systems as a highly productive groundwater source. Therefore, aquifer systems at Stratford and Waukivory are classified as 'less productive groundwater sources', as defined by the AI Policy (NOW, 2012).

Appendix 2: MDR Report Section 1.3 Leak Detector

NSW GOVERNMENT | Soil Conservation Service

Manufacturers Data Report

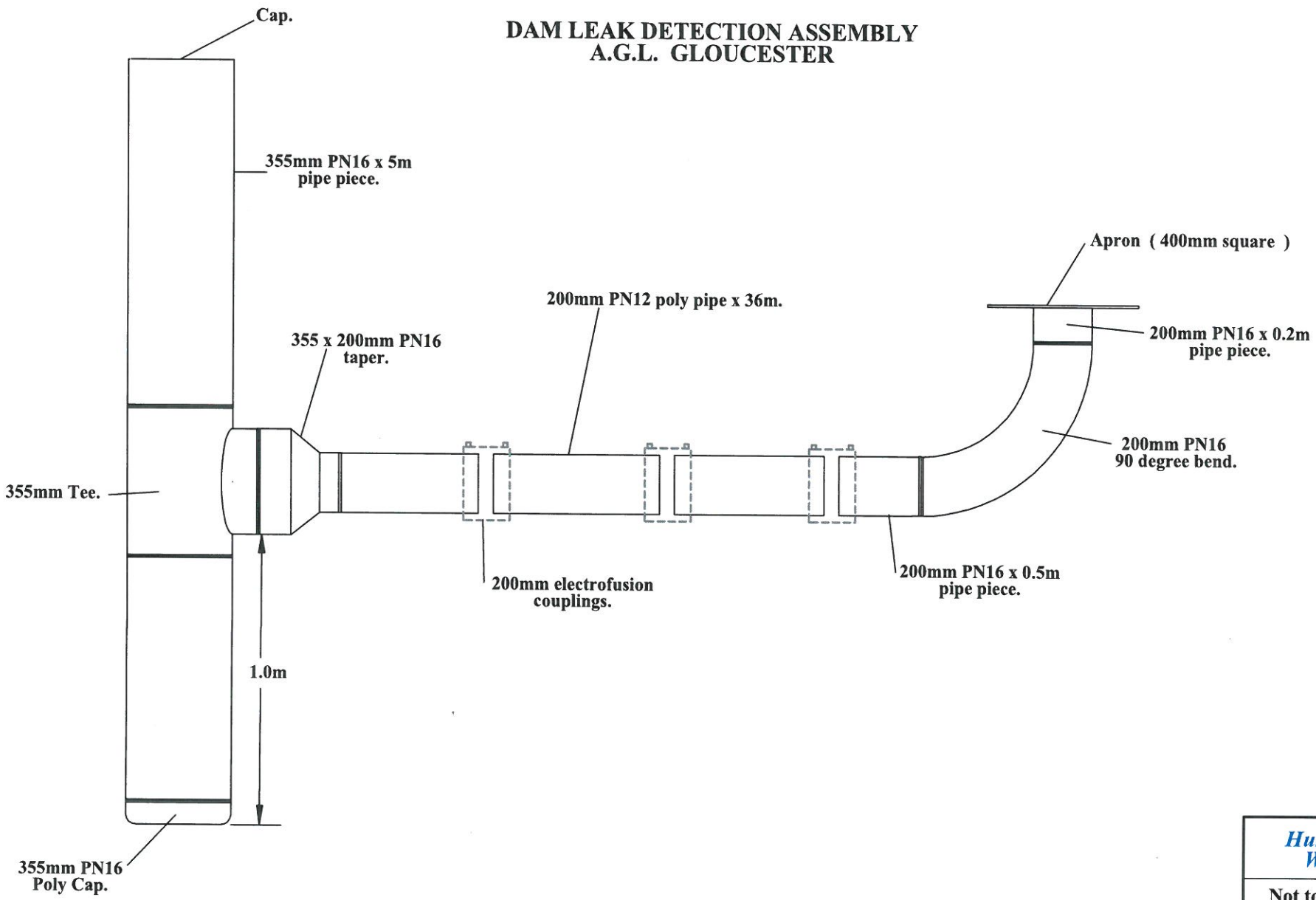
AGL
Gloucester Storage Dam
2012/2013

NSW GOVERNMENT | Soil Conservation Service

DESIGN

1.3 Leak Detector

DAM LEAK DETECTION ASSEMBLY
A.G.L. GLOUCESTER



Hunter Irrigation & Water Solutions	
Not to Scale.	30.1.13

Leak detector installation using 5mm minus crusher dust with a 2% cement incorporation.

Horizontal pipe compaction done with a hand operated whacker packer until heavy compaction equipment could be used.

A 1 metre concrete apron surrounds the pipe inlet.

Pumping from the leak detector prior to the primary liner installation

Position of leak detector to the dam wall and perimeter fence