



# Overview of assessment and approvals process

## Waukivory Pilot Project Petroleum Exploration Licence 285 (AGL: Gloucester)

Activity Approval: environmental impact assessment  
Fracture Stimulation Management Plan compliance  
Environment Protection Licence

### Executive Summary

Petroleum Exploration Licence 285 (PEL285) in the Gloucester Valley is held by AGL Upstream Investments Pty Ltd. The Minister for Resources and Energy renewed PEL285 on 4 August 2014 for a further term of six years.

The proposed Waukivory Pilot Project, within PEL285, includes the fracture stimulation of four existing pilot exploration wells south of Gloucester. It also includes the construction of water and gas gathering lines and water holding facilities. The objective of the Waukivory Pilot Project is to obtain further data in relation to produced water, gas flow and responses to fracture stimulation, before Stage 1 of the Gloucester Gas Project can proceed.<sup>1</sup>

AGL was required to obtain various approvals before the Waukivory Pilot Project could commence.

The Office of Coal Seam Gas (OCSG) has assessed the activities which make up the Waukivory Pilot Project in accordance with Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) which requires the OCSG to consider the environmental impacts of the activities.

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<sup>1</sup> AGL has development consent under the Environmental Planning and Assessment Act 1979 for Stage 1 of the Gloucester Gas Project. AGL has applied to the Minister for Resources and Energy for two Petroleum Production Leases (PPLA11 and 12) for this Project.

The OCSG has determined that the activities are not likely to significantly affect the environment and are not likely to significantly affect any threatened species, populations, ecological communities or critical habitats. On this basis the OCSG has determined that an environmental impact statement is not required under Part 5 of the EP&A Act.

Following the Part 5 EP&A Act determination, the OCSG has granted an activity approval for the Project to AGL under the *Petroleum (Onshore) Act 1991* (POA).

In addition, AGL was required to submit a Fracture Stimulation Management Plan (FSMP) in accordance with the *NSW Code of Practice for Coal Seam Gas: Fracture stimulation activities* (Fracture Stimulation Code). The NSW Government introduced the Code in September 2012. This is the first fracture stimulation activity to be assessed under the Code. The OCSG has assessed the compliance of the FSMP against the relevant requirements of the Code. The OCSG has approved the FSMP on the basis that it complies with the Code.

In the opinion of the OCSG, AGL has undertaken an appropriate level of risk assessment, research and data collection and modelling, including geomechanical earth modelling, and will have in place appropriate controls to ensure that the fracture stimulation of the Waukivory wells can be undertaken safely, with the prospect of any significant adverse impact on the environment, the community or beneficial aquifers being remote.

Under the conditions of the POA Waukivory Pilot Project activity approval, AGL is required to:

- a) have in place a Trigger Action Response Plan (TARP) to deal with atypical events. The TARP is a key management tool that lists the monitoring which will be undertaken during the fracture stimulation activities and sets out planned actions when certain triggers are reached. These triggers and the responses are defined in the TARP; and
- b) undertake groundwater quality and quantity monitoring before, during and after the fracture stimulation activities.

AGL is also required to hold an Environment Protection Licence (EPL) from the Environment Protection Authority (EPA). The EPL imposes additional conditions on the Waukivory Pilot Project.

This report has been prepared to provide an overview of the assessment process and approvals which have been granted to AGL by the OCSG and the EPA.

## 1. Introduction

### What is fracture stimulation?

- 1.1 Fracture stimulation is a process used to increase the flow of gas from hydrocarbon-bearing formations, in this case coal seams. After the well is drilled and multiple layers of casing and cement are installed to isolate beneficial aquifers, holes are shot in the side of the well casing at the level of the relevant target formation (coal seam) that is to be fracture stimulated. This is the perforation process.
- 1.2 Fracture stimulation fluid is then pumped under pressure into the well and through the perforations (or holes) into the target formation. The fracture stimulation fluid (not including sand) is mostly water (**99.67%** for the Waukivory Pilot Project).<sup>2</sup> The fluid also includes a limited suite of chemicals (**0.33%** for the Waukivory Pilot Project), which are required to ensure the effectiveness of the fracture stimulation treatment.<sup>3</sup>
- 1.3 The fluid pressure generates a stress which opens up small fractures within the target formation (coal seam). Sand (approximately **110,500kg** per well for the Waukivory Pilot Project<sup>4</sup>) is pumped into these fractures with the aim of continuing to hold them open once the fluid pressure is reduced, thereby increasing the permeability of the target formation and its potential to flow gas.
- 1.4 Chemical additives are primarily intended to increase the viscosity of the fluid to help it carry more sand further into the target formation; to reduce that viscosity once the sand is emplaced; and control corrosion and the growth of bacteria in the wellbore.
- 1.5 In NSW, all chemicals used in the fracture stimulation process must be identified, including by volume and concentration, in a FSMP. Any risks to human health must also be identified and addressed in a FSMP.

### Petroleum Exploration Licence 285

- 1.6 AGL Upstream Investments Pty Ltd (AGL) holds Petroleum Exploration Licence (PEL) 285, which is located in the Gloucester Valley. Most of PEL285 falls within the Gloucester Shire Council Local Government Area (LGA). Parts of the PEL also fall within the Dungog Shire Council LGA and the Great Lakes Shire Council LGA.
- 1.7 The Minister for Resources and Energy renewed PEL285 on 4 August 2014 for a further term of six years. The renewal included the imposition of a range of conditions on PEL285, including the requirement to comply with the *Code of Practice for Coal Seam Gas: Fracture Stimulation Activities* (Fracture Stimulation Code) and the *Code of Practice for Coal Seam Gas: Well Integrity* (Well Integrity Code). Obligations in relation to groundwater monitoring

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<sup>2</sup> See page 37, Approved Fracture Stimulation Management Plan which is available at: [http://www.resourcesandenergy.nsw.gov.au/\\_\\_data/assets/pdf\\_file/0009/525186/AGL-Fracture-Stimulation-Management-Plan-Waukivory-Pilot-Project-Gloucester.pdf](http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0009/525186/AGL-Fracture-Stimulation-Management-Plan-Waukivory-Pilot-Project-Gloucester.pdf).

<sup>3</sup> Ibid.

<sup>4</sup> See page 37, Approved Fracture Stimulation Management Plan.

and modelling, produced water management and community consultation were also imposed.

- 1.8 AGL (and its predecessors) have drilled 55 exploration wells within PEL285 since 1993 (see **Attachment 1**). Twelve of these wells have previously been fracture stimulated with no known adverse impacts.
- 1.9 AGL's exploration program for PEL285 is focused on the Gloucester Basin. The Gloucester Basin is divided up into three major stratigraphic units: the Alum Mountain Volcanics, the Dewrang Group and the Gloucester Coal Measures. The Dewrang Group and the Gloucester Coal Measures contain 15 coal units and represent the main coal seam gas targets. Exploration activities in the study area will target the Gloucester Coal Measures (which are located at depths of between 320m to over 1000m below the surface). The beneficial aquifer is located at depths of less than 75 metres.
- 1.10 The Gloucester Basin is structurally complex. The Gloucester Basin displays steep dips on its flanks (sides), dipping towards the north-south and flattening towards the centre of the basin. The basin is dissected by several major thrust structures (faults). The Fracture Stimulation Code requires these matters to be taken into account in the design of any fracture stimulation activity.

## 2. Proposed Activities

- 2.1 On 29 September 2013, AGL applied to the Office of Coal Seam Gas (OCSG) for a four-hole pilot production project south of Gloucester for the purposes of coal seam gas exploration (the Waukivory Pilot Project). The application included a Review of Environmental Factors (REF) and a draft FSMP and a range of other plans.
- 2.2 AGL subsequently submitted further addendums to the REF:
- *Waukivory Pilot Project – Addendum to the Review of Environmental Factors – Preferred Activity Report*, submitted by AGL on 6 December 2013;
  - *Waukivory Pilot Project – Further Addendum to the Review of Environmental Factors*, submitted by AGL on 6 June 2014; and
  - *Supplement to the Further Addendum to the Review of Environmental Factors* (dealing with community consultation issues) on 1 July 2014.
- 2.3 AGL submitted several revisions to the draft FSMP in response to:
- issues raised by the OCSG and other agencies;
  - additional data obtained from ongoing diagnostic testing; and
  - the development of a geomechanical earth model.
- 2.4 Two revisions to the FSMP were submitted in December 2013. The final revision of the FSMP, on which the OCSG assessment of compliance with the Fracture Stimulation Code is based, was submitted to the OCSG on 30 June 2014.

- 2.5 The Waukivory Pilot Project is located within the area of PEL285, approximately 5 kilometres south of the township of Gloucester. It does not traverse any of the coal seam gas exclusion zones imposed under the *State Environment Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (Mining SEPP).
- 2.6 The Waukivory Pilot Project includes the following activities (the Proposed Activity):
- the conversion of four existing exploration wells (Waukivory 11 – 14) to pilot wells using perforation and fracture stimulation techniques;
  - pilot testing of the four wells;
  - construction of an above ground water storage area at Waukivory 13 for flowback and produced water (called the water staging point);
  - construction of a buried water pipeline and water and gas gathering lines;
  - construction of three enclosed 20 foot gas flares at Waukivory 12;
  - delivery of equipment, materials and water;
  - lawful disposal of flowback water to an appropriate facility;
  - lawful re-use or disposal of produced water;
  - routine daily operator inspection of wells;
  - monitoring of quality and quantity;
  - workover maintenance during the production testing phase;
  - suspension of exploration wells following completion of pilot production testing; and
  - rehabilitation of disturbed land including construction laydown areas, access tracks and gas gathering pipeline verges.
- 2.7 The objectives of the Waukivory Pilot Project are to:
- a. test the gas production potential of the wells to gain a better understanding of the economics and potential reserves of the area. AGL requires this information to determine whether the project has the potential to be commercially developed;
  - b. gather further information about fracture geometry in the Gloucester Basin to confirm and refine the company's geomechanical earth model and fracture stimulation modelling; and
  - c. to provide groundwater modelling data which are required under the conditions of consent for Stage 1 of the Gloucester Gas Project.<sup>5</sup>

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<sup>5</sup> Gloucester Gas Stage 1 Project Approval (08\_0154) (approved 22 February 2011) (NSW); Gloucester Coal Seam Methane Gas Project Approval, Gloucester Region, New South Wales (EPBC 2008/4432) (approved 11 February 2013) (Cth).

### 3. Obligations under the Petroleum Exploration Licence

#### Assessment under Part 5 of the Environmental Planning and Assessment Act 1979

- 3.1 Under condition 2 of PEL285, fracture stimulation is a “Category 3” activity and requires further environmental assessment and approval. This means that the Proposed Activity (which includes the proposed fracture stimulation activity) must be assessed in accordance with the provisions of Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) prior to the grant of an approval under condition 2.
- 3.2 The environmental risks of the Proposed Activity<sup>6</sup>, including the proposed mitigation measures and controls, have been assessed by OCSG in accordance with Part 5 of the EP&A Act. As part of this assessment, the OCSG obtained advice from the Environment Protection Authority (EPA), the NSW Office of Water (NOW), the Office of Environment and Heritage (OEH) and the Department of Primary Industries (DPI). The OCSG also requested additional information from AGL at various points in the assessment process.
- 3.3 The OCSG has determined that the Proposed Activity is not likely to significantly affect the environment and is not likely to significantly affect any threatened species, populations, ecological communities or critical habitats. On this basis the OCSG has determined that an environmental impact statement is not required under Part 5 of the EP&A Act.
- 3.4 The OCSG has approved the Proposed Activity under condition 2 of PEL285 subject to additional conditions. The OCSG decision and conditions of approval are available on the Department’s website.<sup>7</sup> The assessment of the REF, the analysis of agency submissions and additional information provided by AGL, and the assessment of the draft FSMP are also available on the Department’s website.

#### Fracture Stimulation Code

- 3.5 Condition 6 of PEL285 requires that:

Unless otherwise approved by the Minister, the licence holder must comply with the requirements set out in the following Codes, as amended or replaced from time to time:

  - a) the *NSW Code of Practice for Coal Seam Gas Well Integrity* (NSW Trade & Investment, 2012); and
  - b) the *NSW Code of Practice for Coal Seam Gas Fracture Stimulation* (NSW Trade & Investment, 2012).
- 3.6 The Fracture Stimulation Code is designed to ensure that fracture stimulation activities are conducted in a safe manner and that communities, the environment and water resources are protected.
- 3.7 The Fracture Stimulation Code sets out mandatory requirements, which are characterised as minimum regulatory requirements.<sup>8</sup>

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<sup>6</sup> As noted above at paragraph 2.6, the Proposed Activity includes fracture stimulation activities.

<sup>7</sup> <http://www.resourcesandenergy.nsw.gov.au/landholders-and-community/coal-seam-gas/gloucester-gas-project>

<sup>8</sup> Fracture Stimulation Code, Preliminary (h), p.iv.

- 3.8 Part 1.2(a) of the Code, titled *Mandatory Requirements*, provides that “Fracture stimulation activities must not be conducted except in accordance with a FSMP approved by the department.” Further, Part 1 provides that:
- a. the titleholder will appropriately manage the risks associated with the fracture stimulation activity and comply with the mandatory requirements of the Code;
  - b. the Plan may summarise relevant information from other regulatory documentation requirements and the titleholder’s management systems, provided that the source of this information is identified;
  - c. for most exploration activities, the draft Plan will normally be submitted with a Review of Environmental Factors (REF) as part of an activity approval application; and
  - d. a draft Plan may partially fulfil the content requirements for a REF as set out in *ESG2: Environmental Impact Assessment Guidelines*.<sup>9</sup>

### Well Integrity Code

- 3.9 Under the Well Integrity Code, in order to prevent interconnection between zones of differing pressure and water quality, titleholders must determine and document in their well procedures a minimum required ultimate compressive strength for cement slurries to be used across zones which may be hydraulically fracture stimulated (Part 4.3.2).
- 3.10 Well monitoring and maintenance is required to preserve the well and its component parts in good repair for the life of the well (Part 4.7.1). Further, the titleholder must carry out sufficient monitoring to establish that significant risks have been:
- a) identified;
  - b) quantified;
  - c) avoided; or
  - d) appropriately managed;
- so that residual risks are within acceptable limits before, during and after the fracture stimulation activity (Part 4.7.1).
- 3.11 Part 13.2 of the Fracture Stimulation Code makes it mandatory for the titleholder to ensure that the cement and casing integrity of the subject wells are sufficient for the planned activity. This mandatory requirement is a pre-condition to the conduct of the fracture stimulation activity.

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<sup>9</sup> Fracture Stimulation Code, Part 1, p. 2.

## 4. Advice and submissions in relation to the application

### Agency advice

- 4.1 The OCSG referred the REF and draft FSMP to the EPA, NOW, OEH and DPI for advice. Agency submissions<sup>10</sup> and details of further information provided by AGL in relation to issues raised which were relevant to the OCSG assessment under Part 5 are summarised in Tables 1, 2 and 3 to the **Part 5 Activity Approval Assessment Minute**.<sup>11</sup> The OCSG assessment of each issue is also included in these tables. Where appropriate, additional conditions have been applied to the activity approval.
- 4.2 The EPA submissions dealt with the following issues:
- groundwater and surface monitoring and data collection;
  - measures to ensure that fracturing fluid is removed quickly after injection to the target coal seam (referred to as “target aquifers” in the EPA submission);
  - use of produced water for fracture stimulation;
  - erosion and sediment controls;
  - noise impacts; and
  - bunding and spill management.
- 4.3 AGL is required to hold an Environment Protection Licence issued by the EPA under the *Protection of the Environment Operations Act 1997* (POEO Act) before it commences the Proposed Activity. The EPA issued an Environment Protection Licence to AGL on 6 August 2014.
- 4.4 NOW observed in its submission to the OCSG of 5 November 2013, that the “proposed fracture stimulation program provides an opportunity to collect such important information that would assist AGL in their hydrogeological conceptual model, groundwater model and managing and mitigating potential impacts”.
- 4.5 NOW recommended that AGL undertake additional data collection to ensure the likely distribution of potential depressurisation impacts can be effectively monitored. NOW also recommended that AGL collect water quality data throughout the flow testing period and that additional water quality sampling take place before fracture stimulation activities commence (see Tables 1 and 2 to the **Part 5 Activity Approval Assessment Minute**). Further, NOW recommended that AGL define the flowback water volume at 100% of the fracture stimulation fluid used at each well.
- 4.6 The OCSG has imposed a condition on AGL requiring it to submit and have approved a Groundwater Monitoring and Modelling Plan in accordance with condition 12 of PEL285 by 3 September 2014. The Environment Protection Licence also sets out additional issues which are required to be dealt with in the revised Groundwater Monitoring and Modelling Plan. The Groundwater Monitoring and Modelling Plan needs to be prepared in consultation with

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<sup>10</sup> Agency submissions are available at: <http://digsopen.minerals.nsw.gov.au/?rin=R00070714>

<sup>11</sup> The Part 5 Activity Approval Assessment Minute is available at: <http://www.resourcesandenergy.nsw.gov.au/landholders-and-community/coal-seam-gas/gloucester-gas-project>

NOW. This will ensure the necessary monitoring is undertaken before fracture stimulation activities are undertaken.

- 4.7 AGL accepts that flowback water should be defined as fluid recovery up to the point at which 100% of the injected volume of fracture stimulation fluid is recovered.<sup>12</sup> However, AGL submits that a salinity trigger of 5,000 uS/cm should be used to define flowback versus produced waters on the basis that this kind of trigger is important to deal with those instances (in very low permeability formations) in which not all fracture stimulation water can be recovered.
- 4.8 NOW advised the OCSG on 7 January 2014 that it was satisfied with this response.
- 4.9 It should also be noted that the EPA has imposed a condition in the Environment Protection Licence which requires AGL to:

*Outline a proposed sampling and monitoring program for the detection of fracture stimulation chemical compounds (including THPS, Choline Chloride, Monoethanolamine Borate and Sodium Hypochlorite and any relevant intermediate breakdown products) to monitor their [sic] presence/absence of any fracking chemicals in produced water before being transferred to the Tiedman Irrigation produced water dams.*

*This sampling should be included as part of the operational triggers in [the Groundwater Monitoring and Modelling Plan] that define when the change from flowback water to produced water occurs. The program should include justification for the location and frequency of sampling and the frequency should relate to how the change of flowback water to produced water will be handled.*

- 4.10 OEH and DPI also provided submissions, which are set out in the Tables to the **Part 5 Activity Approval Assessment Minute**.

### **Independent expert advice**

- 4.11 The OCSG referred the draft FSMP to an independent expert in the Australian School of Petroleum at the University of Adelaide. Dr Manouchehr Haghghi was asked to review, evaluate and provide recommendations for improving the fracture stimulation design component of the draft FSMP with a particular focus on geomechanical rock properties and fracture containment within the proposed fracture zones.
- 4.12 Dr Haghghi was also asked to provide advice on whether the draft FSMP complied with the mandatory requirements in the Code for fracture stimulation design (see Part 3.2). Further, Dr Haghghi was asked to review the draft FSMP to determine compliance with the following mandatory requirements in the Fracture Stimulation Code:

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<sup>12</sup> Waukivory Pilot Project – Addendum to the Review of Environmental Factors – Preferred Activity Report submitted by AGL on 6 December 2013, p.22.

Part 4.2: Risk assessment

Part 6.2: Use of chemicals in fracture stimulation

Part 8.2: Management of flowback water

Part 10.2: Monitoring

Part 13.2: Undertaking the fracture activity

Part 16: Application of Australian and international standards

4.13 Dr Haghghi provided advice on these aspects of the draft FSMP on 29 October 2013. The OCSG subsequently asked Dr Haghghi to review certain issues raised by Gloucester Groundswell in its submission entitled *Exposing the Risks*; AGL's revised FSMP and AGL's geomechanical earth model, which was presented and provided to the OCSG on 28 July 2014.<sup>13</sup>

4.14 In his 29 October 2013 advice, Dr Haghghi concluded that all of the mandatory requirements in Parts 3.2, 4.2, 8.2, 10.2, 13.2 and 16 of the Fracture Stimulation Code had been satisfactorily addressed in the draft FSMP. Dr Haghghi made 4 recommendations to improve the first draft of the FSMP:

- a. That the FSMP should address the potential for excessive treating pressures created as a result of fines in the coal seams.

AGL response:

In the revised version of the FSMP AGL notes that: "Based on AGL's experience fracture stimulating gas wells in Gloucester and NSW generally, the effects of coal fines during the fracture treatment are expected to be minimal to nil. There has been no evidence to date in Gloucester that coal fines have interfered with fracturing pressure responses."<sup>14</sup>

In the event of high initial treating pressures AGL proposes a specific engineering response outlined in section 2.4 of the revised FSMP.

Final assessment:

The issue was dealt with to the satisfaction of the OCSG. In addition, the OCSG has imposed a condition on AGL requiring it to implement a Trigger Action Response Plan (TARP) during fracture stimulation activities.

The TARP will be implemented during the fracture treatments as a guideline to AGL's Operator Company Representative and the Fracture Service Engineer to ensure prompt decisions can be made based on real time observations of the diagnostic pressure plots.<sup>15</sup>

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<sup>13</sup> The model was prepared by Schlumberger for AGL.

<sup>14</sup> Revised FSMP, section 2.5.

<sup>15</sup> Revised FSMP, section 2.5.

- b. The Fracture Stimulation Code requires AGL to describe the modelling of the fracture propagation field, including the extent and orientation of the field (Part 3.2(f)). Dr Haghighi recommended that the type of simulation modelling should be addressed.

AGL response:

AGL's fracture stimulation service provider will use 3D fracture simulation software to model designed fracture propagation.<sup>16</sup>

In the final revised FSMP, AGL notes that: [i]n May 2013, AGL carried out additional stress testing on coal (target seam) and sandstone ([a] natural barrier to fracture growth) intervals to complete the data package required to build a geomechanical earth model. In March 2014, this model was completed by an expert petrotechnical service provider. The geomechanical earth model will be used as the basis for simulating predicted fracture propagation, geometry and containment within the target zone (see section 2.6).<sup>17</sup>

Final assessment:

As noted above, Dr Haghighi was briefed with the revised FSMP and AGL's final geomechanical earth model report. Dr Haghighi advised that the geomechanical earth model report shows that the fracture propagation field including the extent and the orientation has been adequately modelled using all available data including core analyses, petrophysical log data, injection falloff tests (IFOT) and image logs.

In Dr Haghighi's opinion, the requirement for modelling of the fracture propagation field has been met. The issue was dealt with to the satisfaction of the OCSG.

- c. The Fracture Stimulation Code requires AGL to discuss any potential for the fracture propagation field to exceed that modelled (Part 3.2(g)). Dr Haghighi recommended that the following issues be addressed in the FSMP given their potential to make the fracture stimulation exceed the modelled design:
- i. Formation damage;
  - ii. Fluid damage; and
  - iii. Leak-off.

AGL response:

In the final revised FSMP, AGL notes that: [p]re-fracture stimulation diagnostic injection tests will be performed on selected zones to calibrate and strengthen the model prior to the main fracture stimulation. Modelling and pre-fracture stimulation diagnostic injection tests will allow fluid leak-off data to be

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<sup>16</sup> Revised FSMP, section 2.6.

<sup>17</sup> Revised FSMP, section 2.4.

incorporated into the fracture design. Formation damage from leak-off will be addressed with an aggressive temperature delayed breaker system run with the gel, and incorporating a low viscosity fluid system. A linear gel with maximum 20lb gel loading will be used and a borate crosslink may be used if higher than usual treating pressures are encountered or if the fracture simulations indicate better fracture sand placement considering such aspects as the geo-mechanical model and the coal seam permeability.<sup>18</sup>

Final assessment:

The issue was dealt with to the satisfaction of the OCSG.

- d. Although it is not mandatory, Dr Haghghi also recommended that AGL consider using lightweight proppants to reduce chemical use.

AGL response:

In the revised FSMP AGL notes that the use of lightweight proppant as an alternative was considered, but is not an economical option for a pilot activity due to the large amounts of proppant required and the high cost of importing the materials.<sup>19</sup>

Final assessment:

The issue was dealt with to the satisfaction of the OCSG. Dr Haghghi also noted that all mandatory requirements for the use of chemicals have been addressed in the draft FSMP.

4.15 Further, Dr Haghghi observed that:

Regarding areas of faulting in section 2.4 of the revised FSMP, AGL notes that the fault zones intersected by the Waukivory Pilot wells are consistent with the structural model and have been confirmed by image logs. I believe this amount of study and this confirmation is enough to be incorporated into the FSMP and to meet the requirement for the identification of areas of faulting.

- 4.16 AGL will avoid those intervals close to faults. It is nonetheless required to have in place, as a further mitigation for the risk of fracture stimulation treatments migrating up faults, in the form of TARP. The TARP includes measures to deal with this potential issue.

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<sup>18</sup> Revised FSMP, section 2.6.

<sup>19</sup> Revised FSMP, section 2.6.

- 4.17 Dr Haghghi concluded that AGL has committed to using a good range of diagnostic tools (used for monitoring fracture geometry and growth) and satisfactorily identified the limitations and degree of uncertainty of these tools. These tools include:
- a) Temperature Logging;
  - b) Geophone monitoring (micro-seismic);
  - c) Nolte-Smith plots (Diagnostic Plots); and
  - d) Pressure Confirmation Test.
- 4.18 Dr Haghghi found that these diagnostic tests are sufficient for fracture geometry monitoring. Further, the OCSG notes that these tests are appropriately integrated within the TARP.
- 4.19 Dr Haghghi concluded that since the beneficial aquifers are all shallow (less than 75 metres) and since AGL has proposed to perform multiple small fracture stimulation treatments, the intervening low permeability formations together with the vertical separation between the target coal seams and the shallow beneficial aquifers make the risk of fractures propagating from coal seams to the shallow aquifers negligible.
- 4.20 Finally, in relation to the identification of the characteristics of intervening strata, including the porosity and permeability of these strata and the extent of natural fracturing, Dr Haghghi noted that AGL has conducted a 3D seismic survey to image the subsurface of the relevant area, including natural fracturing. In addition, the image logs run in pilot wells allow the accurate identification of natural fractures, and the location of faults. In Dr Haghghi's opinion, sufficient analysis has been incorporated into the FSMP on natural fractures and the extent of natural fracturing in those formations.

### **Groundswell Gloucester submission**

- 4.21 The OCSG received a submission from Groundswell Gloucester entitled *Exposing the Risks* (January 2014) in relation to the REF and draft FSMP. Relevant sections of the submission were also sent to Dr Haghghi for review. A summary of the issues raised by Groundswell and responses are set out in **Attachment C to the Part 5 Activity Approval Assessment Minute**.

## 5. Assessment of Compliance with Codes of Practice

### Code of Practice for Fracture Stimulation

- 5.1 The revised FSMP must demonstrate that all risks to the environment, existing land uses, the community and workforce, as a result of the fracture stimulation activity, are managed through an effective risk management process that includes identification of hazards, assessment of risks, implementation of control measures and monitoring of the integrity and effectiveness of the control measures (Part 1.2(c)).
- 5.2 The OCSG is satisfied that AGL has demonstrated that all risks to the environment, existing land uses, the community and workforce, as a result of the fracture stimulation activity, have been identified, assessed and will be effectively managed through appropriate monitoring and controls.
- 5.3 In relation to fracture monitoring, it should be noted that AGL will undertake microseismic monitoring of the fracture stimulation of the Waukivory 13 well. This will be done at Waukivory Monitoring Bore 5 (WKmb05), which is located 180 metres from Waukivory 13. Microseismic monitoring enables AGL to monitor the height and length of the fractures in real time. The TARP sets out actions that AGL must take if the fracture growth is not proceeding as predicted (microseismic monitoring is only one of the diagnostic tools to be used by AGL to monitor fracture growth.)
- 5.4 The data captured through this monitoring will also be used to further develop AGL's fracture stimulation model and geomechanical earth model for the Gloucester basin. These models will be used in the development of the fracture stimulation designs for the production wells in the Gloucester Gas Project.
- 5.5 The use of microseismic technology is relatively new in the petroleum industry. It has been used internationally for about a decade and in Australia for the last 5 years. This will be the first time it has been used in NSW.
- 5.6 As noted above, the Fracture Stimulation Code sets out mandatory requirements, which are characterised as minimum regulatory requirements.<sup>20</sup> The OCSG has assessed the revised FSMP against the relevant requirements of the Code, which must be addressed in the FSMP. The **Fracture Stimulation Management Plan Assessment Minute** is available on the Department's website.<sup>21</sup> The OCSG has approved the FSMP on the basis that it complies with the Code.

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<sup>20</sup> Fracture Stimulation Code, Preliminary (h), p.iv.

<sup>21</sup> <http://www.resourcesandenergy.nsw.gov.au/landholders-and-community/coal-seam-gas/gloucester-gas-project>

## Community consultation

- 5.7 The OCSG is also of the view that AGL has made genuine efforts to consult with and engage the local and broader community in relation to its exploration and proposed production activities in the Gloucester Valley, including the proposed Waukivory Project. These efforts to September 2013 are summarised in the *Waukivory Pilot Project Review of Environmental Factors* at pp.13-26.
- 5.8 AGL provided a further update to its community consultation and engagement efforts in the *Supplement to the Further Addendum to the Review of Environmental Factors* (1 July 2014). This report outlines additional work undertaken by AGL in relation to community consultation and engagement for the Waukivory Pilot between September 2013 (when the initial REF was submitted to the OCSG) and July 2014. It includes:
- a summary of the interest shown in the Waukivory Pilot since the REF was submitted, a summary of the parties (referred to in the ESG2 REF guidelines) who AGL has consulted with, the methods of consultation, issues discussed and outcomes of consultation;
  - ongoing consultation arrangements in accordance with AGL's Gloucester Gas Project Community Consultation Plan, which is regularly updated;
  - a record of consultation since September 2013; and
  - details on stakeholder conflict management and protocols for complaint management.
- 5.9 In addition, AGL has participated willingly and constructively in the Gloucester Dialogue, in particular providing detailed information in relation to the Waukivory Pilot Project, including proposed fracture stimulation activities. The Dialogue provides an opportunity for the Gloucester Shire Council and the community members on the Dialogue to obtain information from regulators and the applicant about exploration and production projects in the Gloucester Valley.
- 5.10 A condition has now been placed on PEL285 in relation to community consultation which requires the licence holder to comply with the *Guideline for community consultation requirements for exploration* (NSW Trade & Investment, 2012) and to report annually on community consultation.

## Code of Practice for Well Integrity

- 5.11 The OCSG is undertaking a review of the cement bond logs for Waukivory Wells 11 through to 14 in accordance with Part 13.2 of the Well Integrity Code. This review is required to confirm which seams AGL will be permitted to fracture stimulate.

## Coal legacy wells

- 5.12 AGL has carried out a program to locate and plug and abandon legacy coal holes within 600m of the Waukivory Pilot wells, which may intersect coal seams also intersected by the Waukivory wells.
- 5.12 The legacy coal holes were drilled under mining titles; not under petroleum exploration licences. Four holes have been identified and decommissioned (or plugged and abandoned). These holes were drilled by BMI/Esso in the 1980s.

- 5.13 A risk assessment has been conducted to determine if the remaining legacy coal holes (which are all less than 70 metres in depth) would intersect any seams common to any of the Waukivory wells.
- 5.14 Taking into account this risk assessment, AGL has advised the OCSG that it has the following controls and mitigation measures in place:
- removal of the Bindaboo seam at ~310 metres as a focus formation in Waukivory 12;
  - development of a geomechanical earth model;
  - microseismic monitoring;
  - continued groundwater monitoring of the Waukivory pilot area throughout flow testing;
  - regular site inspections;
  - periodic fugitive emissions monitoring; and
  - Implementation of a TARP.
- 5.15 AGL has advised that with the mitigation measures and controls in place, the potential for these legacy coal holes to act as conduits for gas or fluids throughout the pilot operations is considered unlikely. The OCSG accepts this assessment given AGL has appropriate mitigation and monitoring strategies and measures in place, including the TARP.

## 6. Chemical risk assessment

6.1 The FSMP identifies the composition of the proposed fracture stimulation fluid as follows (pg 37):

**Volumes and Constituents in Proposed Fracture Stimulation Fluid**  
(Based on information provided by AGL's contracted service provider)

Purpose	Compound Present	Well Pre-Treatment <sup>(1)</sup>	Treated Water	Linear Gel	Cross-Linked Gel	Indicative Quantity <sup>(2)</sup>
		% volume of compound in fluid				
Main Fracture Fluid	Water	88.12%	99.81%	99.65%	99.53%	4,025,771
Clean Perforations	Hydrochloric Acid	10.88%	-	-	-	2,067
Iron Sequesterant	Citric Acid	0.361%	-	-	-	69
Corrosion Inhibitor	Ground Coffee Beans	0.036%	-	-	-	7
pH Adjusting Agent	Acetic Acid	0.60%	0.03%	0.03%	0.03%	1,320
Bactericide	THPS Tetrakis(hydroxymethyl) Phosphonium Sulfate <sup>(3)</sup>	-	<0.01%	<0.01%	<0.01%	302
Gelling Agent	Guar Gum	-	-	0.163%	0.163%	4,916
Gel Breaker	Hemicellulase enzyme concentrate	-	-	<0.01%	<0.01%	60
Clay Stabiliser	Choline Chloride (only used on 2 wells)	-	0.15%	0.15%	0.15%	2,550
Cross-Linker	Monoethanolamine borate	-	-	-	0.108%	1,836
pH Buffer	Sodium Hydroxide	-	-	-	<0.01%	102
<b>Total</b>		<b>100.00%</b>	<b>100.00%</b>	<b>100.00%</b>	<b>100.00%</b>	<b>4,039,000</b>

Indicative Volume of Fluid <sup>(2)</sup>	Well Pre-Treatment <sup>(1)</sup>	Treated Water	Linear Gel	Cross-Linked Gel	Total Treatment
Average per well (L)	4,750	252,500	327,500	425,000	1,009,750
Total for all 4 wells (L)	19,000	1,010,000	1,310,000	1,700,000	4,039,000

Quantity of Proppant - quartz silica sand	Total Treatment
Average per well (kg)	110,500
Total for all 4 wells (kg)	442,000

**Notes:**

<sup>(1)</sup>Well pre-treatment is conducted to clean perforations prior to fracture stimulation.

<sup>(2)</sup>The volumes of each fluid are indicative only and actual volumes cannot be determined until fracture stimulation treatment occurs. This is because during the fracture stimulation treatment AGL monitors the fracture growth using a variety of diagnostic tools. This allows AGL to analyse the fracture geometry and fine-tune the final volumes. In addition, information gained from the initial treatments will enhance design of subsequent treatments.

<sup>(3)</sup>As an alternative to using THPS as a bactericide, AGL may use a mixture of sodium hypochlorite and sodium hydroxide in treated water, linear gel and cross-linked gel recipes at a concentration by volume of 0.015% sodium hypochlorite and 0.001% sodium hydroxide, which will represent a total volume of 605 litres sodium hypochlorite and 40 litres of sodium hydroxide. The HHERA Table 8 has also assessed these compounds in the alternative bactericide.

- 6.2 As an attachment to the FSMP, AGL submitted a report entitled *Human Health and Ecological Risk Assessment – Hydraulic Stimulation Activities, Gloucester Gas Project* (EnRiskS, 19 September 2013). This report concludes that:
- a. *“most of the chemicals used.....are associated with negligible to low/moderate hazards to human health and/or the environment. There are some chemicals which are of greater concern (including sodium hypochlorite, THPS, sodium hydroxide, monoethanolamine borate, hydrochloric acid and choline chloride) should they be released directly to an environment (where they may be present in undiluted fracturing fluids) where exposure may occur. The overall risk of these chemicals depends not only on theses (sic) hazards, but the likelihood that exposure may occur”.*
  - b. *“No pathways of exposure have been identified by which subsurface operations associated with hydraulic fracturing can result in the discharge or release of chemicals to an overlying freshwater aquifer that may be used for any beneficial use or discharge to a receiving waterbody” (pg 24).*
  - c. *“[T]he pathways by which chemicals used in hydraulic fracturing activities may be released to the environment where exposures may occur...is via accidental spill and releases of fluids, products and flowback water... as a result of aboveground operations” (pp.24). “Based on the implementation of a range of risk management measures by AGL, accidental spills and releases of these chemicals/fluids is considered to be unlikely” (pp.24).*
- 6.3 In summary, risks to human health and the environment are considered to be negligible or low and can be adequately managed through the implementation of existing operational management measures outlined in the FSMP and associated management plans. The OCSG concurs with this assessment and notes that the EPA has incorporated a number of conditions in the EPL to ensure that regulatory controls are in place to adequately monitor and control chemical use.

## 7. Groundwater protection

- 7.1 The following groundwater protections are in place or have been imposed and are designed to ensure that the risks of contaminating beneficial aquifers are remote:
- A requirement to prepare a Groundwater Modelling and Monitoring Plan;
  - The requirement to construct, maintain and operate wells in accordance with the Well Integrity Code of Practice;
  - Fracture stimulation design regulatory standards under the Fracture Stimulation Code, including:
    - identification and understanding of the characteristics of the intervening strata, including porosity and permeability and the extent of natural fracturing;
    - determination of the distance between the beneficial aquifer and the target coal seams;
    - determination of the geological stress fields and areas of faulting;
    - modelling of the likely fracture propagation field, including the extent and orientation of the propagation field; and

- Groundwater monitoring for quality and quantity (pressure); and
- The requirement to have in place a TARP in the event that the fracture stimulation activity does not proceed as expected. The TARP sets out triggers at which point certain action must be taken.

7.2. More information on these protections is set out in **Attachment 2**.

## 8. Traffic impacts

- 8.1 The traffic-related impacts of AGL's proposal comprise additional heavy vehicle and other traffic on Bucketts Way and Fairbairns Road. This traffic is initially associated with site preparation works, delivery of materials (sand, chemicals etc) and fracture stimulation plant etc. to the well sites.
- 8.2 Water to be injected during the fracture stimulation will be supplied via pipeline from either the Pontilands or Tiedmans dams rather than via road. However, disposal of 6ML of flowback water to a licensed waste facility will require up to 240 truck movements over 16 weeks during standard work hours at an average of 3 truck movements per day (since revised downwards to 4ML with a likely proportional decrease in truck movements). School times will be avoided.
- 8.3 Traffic-related impacts and their management are set out in AGL's Flowback Water Transport Management Plan (Appendix B of Volume 2: Waukivory Pilot Project Addendum to the Review of Environmental Factors Preferred activity report (AGL Energy December 2013)).

## 9. Incident and emergency response

- 9.1 AGL is required to have in place an Emergency Response Plan (ERP), prepared in accordance with clause 43 of the *Work Health and Safety Regulation 2011*; the mandatory requirements of the Fracture Stimulation Code (Part 11.2), and the Well Integrity Code (see Part 2.2.3).
- 9.2 The ERP is generally consistent with AS3745 *Planning for Emergencies in Facilities* and covers the safety of occupants of AGL facilities within PEL285 and its visitors leading up to and during an evacuation. In the event that the emergency escalates and cannot be contained by AGL Gloucester employees, the AGL Code Red Management Plan is activated.
- 9.3 Among other emergency situations, the ERP includes procedures for:
- a) well blow out;
  - b) unplanned ignition of methane;
  - c) explosion emergency at a well site;
  - d) bush fire;
  - e) flooding;
  - f) oil or chemical spill; and
  - g) security breach.

- 9.4 The ERP defines key stakeholders to include relevant emergency services and Gloucester Shire Council (amongst others) who will be consulted and/or informed as necessary. The ERP also provides that “all significant incidents shall be made public through the Gloucester Community Consultative Committee”.

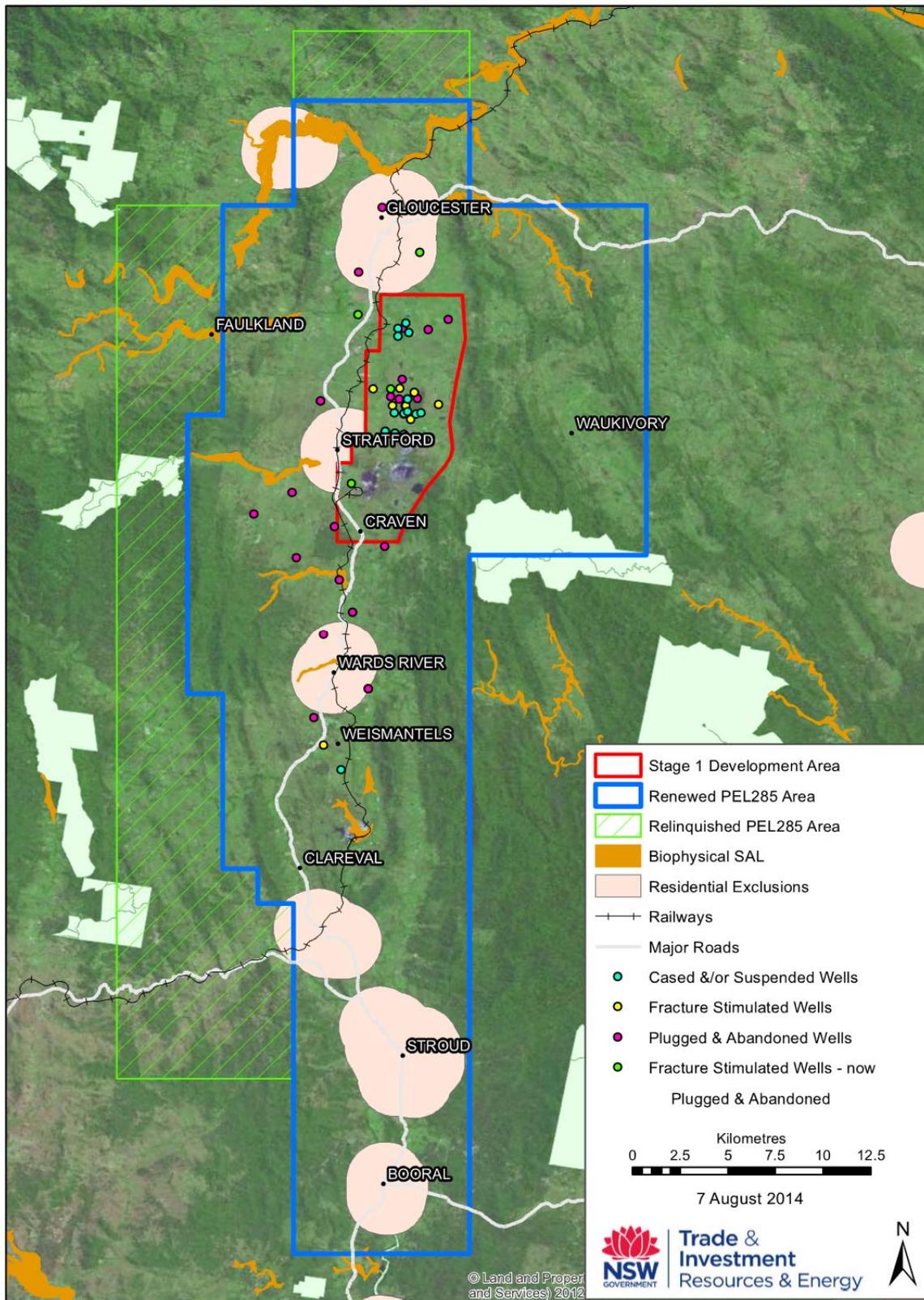
## **10. Conclusion**

- 10.1. The OCSG has assessed the activities which make up the Waukivory Pilot Project in accordance with Part 5 of the EP&A Act.
- 10.2. On the basis of this assessment, the OCSG has determined that the activities are not likely to significantly affect the environment and are not likely to significantly affect any threatened species, populations, ecological communities or critical habitats. On this basis, the OCSG has determined that an environmental impact statement is not required under Part 5 of the EP&A Act.
- 10.3. On the basis of this assessment, the OCSG has granted an activity approval for the Project to AGL under condition 2 of PEL285.
- 10.4. In addition, AGL was required to submit a Fracture Stimulation Management Plan (FSMP) in accordance with the NSW Code of Practice for Coal Seam Gas: Fracture stimulation activities. The OCSG has assessed the compliance of the FSMP against the relevant requirements of the Code on the basis set out in the Fracture Stimulation Assessment Minute. The OCSG has approved the FSMP under condition 6 of PEL285 on the basis that it complies with the Code.
- 10.5. In the opinion of the OCSG, AGL has undertaken an appropriate level of risk assessment, research and data collection and modelling, including geomechanical earth modelling, and will have in place appropriate controls to ensure that the fracture stimulation of the Waukivory wells can be undertaken safely, with the prospect of any significant adverse impact on the environment, the community or beneficial aquifers being remote.
- 10.6. AGL will be required to have in place a Trigger Action Response Plan (TARP) to deal with atypical events. The TARP is a key management tool that lists the monitoring which will be undertaken during the fracture stimulation activities and provides planned actions when certain triggers are reached. These triggers and the responses are defined in the TARP.

**Rachel Connell**  
**Office of Coal Seam Gas**  
**31 August 2014**

### Attachment 1: Map of Gloucester PEL 285 - Exclusion Zones

#### Gloucester PEL 285 - Exclusion Zones



## Attachment 2: Groundwater protections: additional information

### A. Groundwater resources in the Gloucester Basin<sup>22</sup>

There are limited beneficial groundwater resources in the Gloucester basin with typically poor water quality and low yields from bores.

The map at **TAB A** shows where the bores are in this area and what their purpose is. It also shows the currently allocated water rights in the basin. The blue dots are licensed irrigation bores and the orange dots represent stock and domestic bores. NSW Office of Water records show that there are about 22 volumetric licences within the basin extracting groundwater from 27 bores. There are an additional 48 stock and domestic bores. There are also 108 surface water licences within the Gloucester Basin.

The total of all water rights in this system is relatively small at 9.9 GL/yr , with 7.9 GL/yr being **surface water rights** and 2 GL/yr being **groundwater rights**.

The pie chart at **TAB A** shows the 2 GL of **groundwater rights** broken down by purpose with water rights predominantly being held for industrial and mining purposes.

Petroleum companies need licences to take water. Unassigned groundwater rights can be granted via an application under the *Water Act 1912*. Once the water sharing plans commence, unassigned water can be granted by Government through a tender process under a 'controlled allocation' order.

Anyone (mining, irrigators etc) can tender for this water. The total volume put up for tender is 'controlled', and is generally less than 5% of the unassigned water in a system each time.

The Gloucester Basin is a very small system. Prior to mining, there were very limited groundwater rights (less than 285 ML – or 0.285 of a GL) for the entire system. There is currently no government groundwater monitoring in the Gloucester Basin, but installation of bores is planned. Both the mines and AGL do undertake monitoring in the basin, and this is comprehensive at a local scale.

### B. Requirement to prepare a Groundwater Monitoring and Modelling Plan

PEL285 requires AGL to prepare and have approved a Groundwater Monitoring and Modelling Plan following consultation with the NSW Office of Water (NOW).

NOW has prepared a guideline on preparing a GWM&MP which is available at:  
[www.water.nsw.gov.au/.../law\\_key\\_aquifer\\_interference\\_groundwater-monitoring-modelling-project-info-mining.pdf.aspx](http://www.water.nsw.gov.au/.../law_key_aquifer_interference_groundwater-monitoring-modelling-project-info-mining.pdf.aspx)

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<sup>22</sup> Based on advice from Liz Webb, consultant hydrogeologist to the OCSG.

The Plan must:

- describe methods for identifying aquifers, their depths, behaviour, containing layers and connectivity with surrounding aquifers or surface water systems;
- describe methods for collection of data relevant to the type, quantity and quality of water contained within aquifer systems likely to be encountered during prospecting operations;
- provide for the future development of a conceptual model of regional groundwater behaviour;
- provide for the future development of a calibrated computer model of regional groundwater behaviour, to enable the impacts of any proposed production operations to be assessed;
- describe how records of all data collected will be maintained; and
- describe the staging process for implementation of the plan.

Under the conditions of PEL285, AGL is required to submit a GWM&MP for approval by 3 September 2014.

### **C. Well Integrity**

A critical area of concern in relation to potential underground risks to water quality is the drilling and construction of the well itself. The well is the foundation of the operation and it is in the best interests of the operator to construct wells properly.

Leakage of gas from wells is the most likely cause of groundwater contamination by methane through:

- gaps between the rock formation and cement;
- gaps between the cement and steel casing; and
- damaged gas-well casing.

For these reasons wells must be constructed and maintained to the standards set out in the Well Integrity Code. Detailed plans for drilling and construction need to be submitted to the OCSG for approval prior to any drilling activities taking place. The OCSG undertakes announced and spot inspections throughout the drilling and construction process. Once constructed, wells are subject to ongoing testing and integrity reporting as well as incident reporting.

Beneficial aquifers need to be completely isolated and sealed. Wells are required to be constructed in a way that ensures there is no vertical connection between different rock layers and that gas and fluids are contained and managed throughout the drilling, construction and operation phases.

The initial step is to drill through the base of the beneficial aquifer and install steel casing. Engineered cement designed for the exact conditions of the rock and water at this location is then injected under pressure into the annulus of the well.

Testing of the pressure cementing job is then undertaken to ensure the bonds between the cement and rock, as well as the cement and the steel casing themselves are solid. Any issues

determined at this time must be addressed and fixed before going any further with the construction of the well.

Drilling then continues through the low permeability sandstone rocks and into the target coal seams (at depths of between 320m to over 1000m below the surface for the **Waukivory Pilot Project**). Once the target depth has been reached, a second string of steel casing is lowered into the hole, and pressure cemented in place. Cement bond logs and pressure testing are again undertaken to ensure there are no gaps or areas of weakness. Again, if these are identified they can be fixed using a variety of techniques.

The well integrity and risk management processes for the management and mitigation of well control events are described in AGL's approved FSMP. In addition, the OCSG is reviewing the cement bond logs for each of the Waukivory Pilot wells.

#### **D. Fracture Design**

Vertical distances between beneficial aquifers and target coal beds must be sufficient to ensure there are no potential gas or fluid migration pathways (see further above at paragraph 4.14).

The FSMP must identify the characteristics of the intervening strata, including the porosity/permeability and the extent of natural fracturing (see further above at paragraph 4.14).

Through identification of the characteristics of intervening strata via testing of core samples and other means, AGL has identified that the target formations are low permeability formations in which there is negligible risk of connection between the targeted coal seams and the shallow beneficial aquifer zones. The intervening strata are also considerably tighter and harder than the target reservoir, properties which should limit vertical fracture growth into these strata.

AGL also conducted a 3D seismic survey to image the subsurface, including natural fracturing (FSMP pg 15). Well image logs have also allowed accurate identification of natural fractures, and the location of faults. Sufficient study has been incorporated in the FSMP on natural fracturing to conclude that there is negligible risk of contamination of beneficial aquifers.

The FSMP includes an analysis of the geological stress fields and areas of faulting (see further above at paragraph 4.14):

- The FSMP demonstrates that significant work has been done by AGL to identify areas of faulting;
- The fault zones intersected by the Waukivory Pilot wells are consistent with the structural model and have been confirmed by image logs; and
- AGL has designed the fracture stimulation zones to avoid those intervals close to faults and as a further mitigation for any risk of fracture stimulation treatments to migrate up faults, the Trigger Action Response Plan (TARP) includes measures to deal with this issue.

The FSMP includes an analysis of the modelling of the likely fracture propagation field, including the extent and orientation of the propagation field (see further above at paragraph 4.14). The mechanical earth modelling study reported by AGL on 28 July 2014 shows that the fracture propagation field including extent and the orientation has been adequately modelled to understand the potential groundwater impacts. In this study all available data including core analysis, petrophysical log data, IFOT test and image logs have been used.

### **E. Groundwater Monitoring: quality and quantity<sup>23</sup>**

Monitoring of nested groundwater bores within the different systems is important to fully understand system dynamics and the potential for vertical connectivity. This in turn enables impacts to be predicted, and to measure if they actually occur.

AGL monitoring seeks to fully understand the groundwater system at the local project scale. AGL currently has over 45 monitoring bores in the Gloucester Basin, and this number is gradually increasing.

While the monitoring data is not long term, it is comprehensive. AGL have nested monitoring bores that intersect the alluvium and the deeper underlying coal and interburden layers.

The most recent AGL report (AGL Upstream Investments Pty Ltd 2013 Gloucester Groundwater and Surface Water Monitoring Annual Status Report dated 11 October 2013 is available at: [http://www.agl.com.au/~media/AGL/About%20AGL/Documents/How%20We%20Source%20Energy/CSG%20and%20the%20Environment/Gloucester/Assessments%20and%20Reports/2013/2013 GloucesterAnnualStatusReport.pdf](http://www.agl.com.au/~media/AGL/About%20AGL/Documents/How%20We%20Source%20Energy/CSG%20and%20the%20Environment/Gloucester/Assessments%20and%20Reports/2013/2013%20GloucesterAnnualStatusReport.pdf)

AGL undertakes detailed groundwater chemistry monitoring. Isotopes are now more routinely used to better understand the age of groundwater and the flow dynamics. Fingerprinting of waters can assist with determining the degree of groundwater mixing between overlying and underlying groundwater systems.

The frequency of sampling is dependent on the hydrogeology, and the stage of project development, ranging from monthly to annually. More responsive systems such as alluvium and surface waters are generally sampled more frequently than groundwater in deep slow moving porous rocks.

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<sup>23</sup> Based on advice from Liz Webb, consultant hydrogeologist to the OCSG.

### F. Incident Response – TARP

Under the conditions of the *Petroleum (Onshore) Act 1991* Waukivory Pilot Project activity approval, AGL is required to:

- a) have in place a Trigger Action Response Plan (TARP) to deal with atypical events. The TARP is a key management tool that lists the monitoring which will be undertaken during the fracture stimulation activities and provides planned actions when certain triggers are reached. These triggers and the responses are defined in the TARP; and
- b) undertake groundwater quality and quantity monitoring before, during and after the fracture stimulation activities.

Tab A: Gloucester Basin Water Rights

