Fracture Stimulation Management Plan Waukivory Pilot Project, Gloucester NSW

AGL Upstream Investments Pty Limited

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Document Revision History

Date	Version	Author	Reviewers	Comment
26/06/2014	(ii)	R Braikenridge, J Ross, J Delvecchio	M Roy, S Westgate, R Walker, M Moraza	• Updated information from continued studies; • updated fluid additives table due to refinement of pump schedules; • updated trigger for transition from flowback water to produced water; and • updated response to increase in sensitivity of potentially affected community
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1 Introduction

What is a Fracture Stimulation Management Plan?

[Code of Practice, Sections 1.1, 1.2 and Section 1.3 *Leading Practice*]

This Fracture Stimulation Management Plan (**FSMP**) identifies and explains hydraulic fracture stimulation activities carried out in the Gloucester Gas Project (GGP), in compliance with the *Code of Practice for Coal Seam Gas – Fracture Stimulation Activities* (**Code of Practice**).

The FSMP is a non-technical document which is designed to demonstrate to the NSW Government and other stakeholders that the titleholder will appropriately manage the risks associated with the fracture stimulation activity and comply with the mandatory requirements of the Code of Practice.

This FSMP identifies risks (health, safety and environmental) and risk mitigation methods to facilitate safe execution of fracture stimulation activities. It also describes fracture diagnostic tools that are used to understand fracture growth (geometry) in the selected coal seams being stimulated. All fracture treatments are to be conducted in accordance with the FSMP.

The Code of Practice sets out the principles, mandatory requirements and leading practice targets to be adopted in FSMPs. Overarching mandatory requirements of the FSMP are:

a) fracture stimulation activities will not be conducted except in accordance with the approved FSMP;
b) the FSMP describes the nature, location, scale, timing, duration hours of operation and other relevant features of the fracture stimulation;
c) the FSMP demonstrates 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;
d) the FSMP identifies how AGL will address and comply with each requirement of the Code of Practice;
e) compliance - the FSMP will be reviewed and as necessary revised by AGL in certain circumstances (see Section 3);
f) the detail provided in the FSMP is appropriate to the nature, scale, intensity and potential impacts of the proposed fracture stimulation activities; and
g) commercially sensitive and personal information is not included in the FSMP, unless specifically required by the Code of Practice.

A number of the requirements in the Code of Practice duplicate other regulatory document requirements or systems adopted by AGL. To avoid duplication and ensure that the FSMP is properly integrated into AGL's environmental management system, the FSMP will form part of the Gloucester Gas Project Environmental Management System.

Where relevant this FSMP also makes reference to other key documents including Management Plans and Codes of Practice (section 1.3 of the Code of Practice).

1.1 Operations

This FSMP covers fracture stimulation activities at the Waukivory Pilot Project (Waukivory Pilot), Gloucester, NSW. The *Review of Environmental Factors* (October 2013) (REF) that this FSMP relates to describes the Waukivory Pilot as:

- the conversion of four existing exploration wells to pilot wells using perforating and fracture stimulation techniques;
- pilot testing four wells;
- construction of water storages for flowback and produced water;
- construction of associated infrastructure including water pipelines, gas gathering lines and associated underbores;
- enclosed central gas flare/s;
- delivery of equipment and water;
- lawful disposal of flowback water to an appropriate facility;
- transfer of produced water;
- suspension of exploration wells; and
- site rehabilitation of surplus land.

The *Preferred Activity Report* (December 2013), which AGL prepared in response to submissions from the Office of Coal Seam Gas (OCSG) and other regulatory authorities, describes the preferred activity as including:

- conversion of four existing exploration wells (WK11, WK12, WK13 and WK14) to pilot wells using perforation and fracture stimulation techniques;
- pilot testing of the four wells;
- construction of a water storage area at WK13 for flowback and produced water, called the 'water staging point';
- construction of a buried water pipeline and water and gas gathering lines;
- construction of an enclosed central gas flare at WK12;
- delivery of equipment (and water) to undertake the activity;
- lawful disposal of flowback water;
- lawful re-use or disposal of produced water;
- suspension of exploration wells following completion of pilot testing; and
- site rehabilitation of disturbed land including construction laydown areas, access tracks and gas gathering pipelines verges.

After additional consultations with relevant stakeholders and further engineering review, AGL proposed further changes to the activity. These proposed changes were assessed in the *Further Addendum to the Review of Environmental Factors* (June 2014). The changes were:

- water and gas gathering lines between WK13 and WK14 are to be installed by HDD under Waukivory Creek rather than an above-ground crossing;
- in relation to Waukivory 13, two 1.5 ML above-ground tanks will be used at the water staging point rather than a turkeys nest dam and a 10 x 25 m area will be added to the 100 x 100 m footprint of Waukivory 13 to accommodate infrastructure during the perforation, fracture stimulation and initial flow testing phase; and

- in relation to Waukivory 12, three enclosed 20 foot flares will be used for flow testing all pilot wells instead of a single central flare (40 foot) and secondary flare (20 foot).

The proposed activity (subject of AGL's application for an activity approval) includes:

- the conversion of four existing exploration wells to pilot wells using perforating and fracture stimulation techniques;
- pilot testing 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 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, and workover maintenance during production testing phase;
- suspension of exploration wells following completion of pilot production testing; and
- site rehabilitation of disturbed land including construction laydown areas, access tracks and gas gathering pipeline verges.

The general operation details of the fracture stimulation activity are set out in the following table.

Nature of Fracture Stimulation Activities	Water based linear and cross-linked gel fluids
Exploration Area	Gloucester Basin, NSW
Petroleum Exploration Licence (PEL)	PEL 285
Well Names and Numbers	Waukivory 11, 12, 13 and 14
Anticipated Execution Date	Q4 2014
Duration	60 days*
Hours of Operation for noise producing activities during fracture stimulation	7am-6pm Monday to Friday 8am-1pm Saturday Not on Sundays or public holidays
Scale of fracture stimulation activity	One fracture stimulation fleet complete with qualified personnel and auxiliary equipment to perform work specified by AGL. Equipment and materials (see section 7) Source water storage tanks to store 420kL at individual wellsites Central water storage facility 2 x 1.5ML (including freeboard) above-ground double

	lined tanks Perforating Services with crane support services Geophone Monitoring

*The REF describes 7 days for perforating, and 5-7 days for fracture stimulation per well. However when completing these items in conjunction with each other, including securing the well and mobilising equipment between each wellsite, and the delivery of materials and water for each wellsite, the perforating and fracture stimulation of the four pilot wells are estimated to take approximately 60 days.

1.2 Objectives of Fracture Stimulation

AGL employs multiple techniques to enhance gas production from its natural coal seam gas (CSG) activities; horizontal drilling, under-reaming, and hydraulic fracture stimulation. The stimulation or production enhancement technique used depends on the properties of the coal formation, and the number of targeted coal seams in a well.

Within AGL's New South Wales CSG activities, 123 wells from a total of 160 wells drilled (as at August 2012) have been hydraulically fracture stimulated.

Hydraulic fracturing creates a more efficient flow path for the CSG thereby increasing its production. By increasing the CSG produced by each well, AGL can:

- Reduce the number of wells required for drilling and production
- Minimise the surface or visual impact of the project
- Increase the reservoirs economic lifetime
- Increase recoverable reserve

Understanding fracture design and geometry enables AGL to optimise well spacing and number of wells, and risks associated with hydraulic fracture stimulation.

This FSMP outlines the methodology to be used in hydraulic fracture stimulations in AGL's CSG development from planning design phase, job execution phase and post-job monitoring including flowback of fracture stimulation fluids. The objective is to facilitate best practice and minimise health, safety and environmental risks associated with hydraulic fracture stimulation.

[Code of Practice, Sections 16.1, 16.2 and Section 16.3 *Leading Practice*]

Other CSG specific industry Code of Practices or guidelines applicable to this document are:

- NSW *Code of Practice* for Coal Seam Gas Well Integrity 2012
- American Petroleum Institute (API) Guidance Document HF 1 *Hydraulic Fracturing Operations* – Well Construction and Integrity Guidelines October 2009
- API Guidance Document HF 2 *Water Management Associated with Hydraulic Fracturing June 2010*
- API Guidance Document HF 3 *Practices of Mitigating Surface Impacts Associated with Hydraulic Fracturing January 2011*

- API RP 51R *Environmental Protection for Onshore Oil and Gas Production Operations and Leases July 2009*
- API std 65-2 *Isolating Potential Flow Zones During Well Construction December 2010*
- AS/NZS ISO 31000:2009 Risk management – Principles and guidelines

These are available at http://www.api.org/policy/exploration/hydraulicfracturing/

What is Hydraulic Fracture Stimulation?

During a hydraulic fracture stimulation treatment, fluid (typically over 99% water) is pumped down the wellbore into the selected coal seam (also called a formation). The fluid is pumped at a pressure high enough to widen existing natural fractures (cleats) in the coal seam. When fracturing a coal seam, the fracture follows existing cleats or pathways along the coal seam.

As pumping continues, the fracture extends from the wellbore and grows. Once the desired geometry of the fracture is created, proppant (sand) is added to the fluid and pumping continues until the proppant is placed into the fracture. When all the proppant is in the fracture, pumping is stopped. The pressure inside the fracture drops, allowing the fracture to close. The closing fracture traps the proppant inside the formation and helps to maintain a permeable and conductive path through the coal seam to the wellbore.

The permeable path left in the formation is the main objective of the fracture stimulation. This proppant flow path enhances production by allowing groundwater from the coal seam (produced water) and gas to flow from the coal seam to the wellbore with minimised resistance.

Typical hydraulic fracture stimulations performed for AGL create fractures that are estimated to be 5 - 20 millimetres wide and extend laterally (fracture stimulation length) for 20 to 60 metres within the coal seam. The height of the fracture may vary from field to field. Fractures are typically contained within the coal seam. This is because the sealing rocks above and below the coal seam, which are significantly harder than a coal, limit the vertical height growth of the fracture.

In certain formations a fracture may grow vertically beyond the coal seam, adjacent to the wellbore. The extent of this vertical height growth would be minimal due to the relatively small (in terms of fluid injected and pressures applied) fracture treatments conducted on CSG wells. The intention is to optimise the fracture in the coal seam and not the bounding layers. Fracture geometry (pressure diagnostics) is monitored during fracture stimulation and adjustments will be made if necessary to minimise excess vertical growth. These measures are discussed further in section 2.6 and section 8 of this FSMP. The geomechanical earth model of Waukivory Pilot indicates that vertical height growth out of seam may occur in zones deeper than approximately 600m. Shallower than approximately 600m, vertical height growth out of seam is contained by high horizontal stresses in the interburden. This prevents fracture stimulation zones shallower than approximately 600m growing vertically out of the targeted coal seam. (See section 2.4)

Why Use Hydraulic Fracture Stimulation?

Hydraulic Fracture Stimulation has been used in the oil and gas industry since the 1950s as a technique for enhancing production. The basic premise behind hydraulic fracture stimulation is that it creates a higher permeability pathway within the coal seam connected back to the cased wellbore. It is particularly effective in low-permeability formations.

Hydraulic fracture stimulation has evolved into a suitable technique to stimulate most wells under extremely varying circumstances. Originally developed for conventional low-permeability oil and gas wells around 65 years ago, it still plays a crucial role in developing low-permeability conventional reservoirs and is increasingly used to produce higher levels of gas from unconventional low-permeability carbonates, shales and coal seam reservoirs.

1.3 Responsibilities

AGL Upstream Investments Pty Ltd (AGL) is responsible for compliance with this FSMP. The fracture treatment is designed based on coal reservoir properties, fracture-engineering guidelines, previous experience, fracture stimulation modelling and post job analysis. The fracture design is done in close consultation with the geology and reservoir departments and the selected fracturing service provider (also the principal contractor).

The gas production well monitoring (water quality sampling and tracking of pumped volumes) is undertaken by the AGL Operations and consultants specifically engaged to monitor water levels and water quality (see separate Groundwater Management Sub-Plans).

2 Background

The GGP is located within the Gloucester Geological Basin. The Gloucester Basin is sedimentary in origin with the deposition of sediments occurring from the early Carboniferous (290 million years ago) to likely the latter part of the Triassic (200 million years ago) though Permian sediments currently remain in the Basin. The Gloucester Basin is small in size and has undergone a significant amount of deformation associated with the New England Fold Belt.

2.1 Geology

[Code of Practice, Section 3.2(a)]

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 laterally extensive 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 from surface to over 1000m). Gas content of the coal is commonly of the order of 1-20m^3/tonne with gas content increasing with depth. The stratigraphy of the Gloucester Basin is presented in Figure 1 *(adapted from* Lennox, M., 1991).

The Gloucester Basin is a north south trending synclinal shaped trough containing Permian volcanics and sediments. Basement comprises Carboniferous sedimentary rocks and volcanic units. The basin sequence is capped by Late Permian fluvial-deltaic sediments of the Dewrang Group and Gloucester Coal Measures. The top of the Permian section has been exposed to erosion.

Throughout the evolution of the Gloucester Basin, sandstones, mudstones, conglomerates and coals were deposited in fault-controlled troughs. The preserved basin stratigraphy is up to 4000m thick. Widespread Early Permian volcanic activity may be related to thermal upwelling beneath the base of the continental lithosphere in a retroarc basin setting. Due to the Late Permian fall in relative sea level, shallow water and fluvial conditions prevailed. The complex interplay of tectonics extensional faulting, high rates of sediment supply produced significant lateral stratigraphic variability throughout the Gloucester Basin.

The Gloucester Basin exhibits a complex structural history. Early normal and syn-depositional faults occur and in many cases have been reactivated by the later Hunter-Bowen orogenic events. The Gloucester Basin displays steep dips of up to 80° on its flanks, dipping towards the north-south trending basin axis and relatively flattening towards the centre of the basin. The basin is dissected by several major thrust structures.

Stratigraphy of the Gloucester Basin

Period	Group	Subgroup	Formation	Seam	Depositional Environment
UPPER PERMIAN	GLOUCESTER COAL MEASURES	CRAVEN SUBGROUP	Crowthers Rd Conglomerate	Conglomerate, minor sandstone	Distal Alluvial Fan
			Leloma Formation	Sandstone, minor siltstone and coal	Alluvial Plain
				Linden Coals	
				Marker/JD Coals	
				Jo Doth Tuff	
				Bindaboo Coals	
				Deards Coal	
				Sandstone, minor siltstone and coal	
			Jilleon Formation	Cloverdale Coal	Hiatus Coal
				Conglomerate, sandstone and siltstone	Alluvial Plain
				Roseville Coal	
				Tereel Coals/Fairbairns Lane	
			Wards River Conglomerate	Conglomerate and sandstone	Distal Alluvial Fan
			Wenhams Formation	Bowens Rd Coal	Hiatus Coal
				Siltstone	Marsh
				Bowens Rd Lower Coal	Back Barrier Coal
			Speldon Formation	Marine influenced sandstone	Marginal Marine, prodelta, beach
		AVON SUB GROUP	Dogtrap Creek Formation	Glenview Coal	Back Barrier Coal
				Sandstone, siltstone	Lower Delta Plain
			Waukivory Creek Formation	Avon Coals	Hiatus Coal
				Triple, Rombo, Glen Rd	Upper Delta Plain
				Sandstone and siltstone	Upper Delta Plain
				Parkers Rd and Valley View Coals	Hiatus Coal
				Siltstone and mudstone	Transitional
	DEWRANG GROUP		Mammy Johnsons Formation	Sandstone and siltstone	Marginal Marine, Barrier, Wave Dominated Delta
				Intra Mammy Johnsons Coal	Back Barrier Coal
				Bioturbated sandstone	Marginal Marine, Barrier, Wave Dominated Delta
			Weismantels Formation	Siltstone and mudstone	Back Barrier Lagoon
				Weismantels Coal	Back Barrier Coal
			Duralie Road Formation	Marine Sandstone, conglomerate	Marginal Marine, Fan Delta
LWR PERM			Alum Mountain Volcanics	Clareval Coal	Hiatus Coal
				Conglomerate and coal	Distal Alluvial Fan
				Rhyolite, basalt, welded tuff	Bimodal Terrestrial Volcanics
				Basal Coal	

Figure 1: Stratigraphy of the Gloucester Basin

2.2 Hydrology and Hydrogeology

[Code of Practice, Section 3.2(b), 7.2(a)]

Surface water

The Waukivory site is within the Manning River Catchment (approximately 8,200 km^2 in size) and the Avon River Sub Catchment. The Avon River originates to the south west of Gloucester and joins the Gloucester River to the north of the township of Gloucester. Waukivory Creek, Dog Trap Creek and Avondale Creek are also located within the Sub Catchment.

The Avon River is a gaining stream in this area i.e. there are groundwater seepage discharges to the river. Baseflow accessions from the shallow alluvium are expected in this area based on data from the nearby Waukivory gauging station (PB, 2012b). The Avon River is mostly a permanent stream although during low rainfall periods there is negligible flow and the river can be reduced to a succession of waterholes.

Water quality is highly variable ranging from fresh (after periods of rain) to brackish (after extended dry periods).

Groundwater

The broader (ridgeline) areas of the Gloucester Basin south of Gloucester are underlain by Carboniferous volcanics, the hillsides by a variety of Permian sedimentary rocks while the valley floors are underlain by Quaternary alluvium associated with the Avon River and other minor tributaries.

Groundwater in the Permian rocks is a low value water resource and is rarely used for agricultural and other consumptive uses. Rock permeabilities are generally low, aquifers are mostly bedding and fracture zones, bore yields in rocks and fracture zones are very low and water quality is generally brackish to slightly saline.

Based on the latest water level, water quality and isotope data from the Phase 2 studies (PB, 2012a), there is a good appreciation of groundwater recharge, discharge and flow processes through the different hydrogeological units of the Gloucester Basin. These units (based on SRK Consulting, 2010) are confirmed as:

- Alluvial aquifers;
- Fractured bedrock aquifers;
- Coal seam water bearing zones;
- Confining units.

Only the first two units are aquifers. The deeper rock types being either very poor aquifers/aquitards (coal seams, siltstones and sandstones) or confining aquitard/aquiclude layers (claystones or indurated sandstones).

The **alluvium** is relatively shallow (maximum 15m thickness) and in some areas contains an unconfined (sand and gravel) aquifer. Water tables are generally less than 5m below surface. 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 **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 greater than 10m below surface 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 aquifers).

Therefore, the only beneficial aquifers in the region are the shallow alluvial groundwater source and shallow semi-confined sedimentary/fractured aquifers to around 75m depth. Deeper zones are water bearing zones but rarely aquifers.

There are no known groundwater dependent ecosystems (GDEs) (apart from stream baseflow accessions) in the vicinity of the Waukivory Pilot, 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 the stream salinity increases during dry periods. Groundwater discharge is diffuse and discharge does not occur at any one point in the landscape.

2.3 Target Formations (Coal Seams)

[Code of Practice, Section 3.2(b), 3.2(c)]

Definition of the distances between targeted formations and aquifers

As outlined in Section 2.2, the beneficial aquifers at the area subject of the Waukivory Pilot are all shallow aquifers that occur either in the very shallow alluvial sediments or the shallow fractured bedrock. The bedrock contains mostly tight siltstone and indurated sandstone rock types with occasional thin semi-confined sedimentary/fractured aquifers (typically to around 75m depth). The deepest water supply bore known in the Waukivory Pilot area has a depth of 66m.

The target coal measures for CSG development for the Waukivory Pilot sites are within the Late Permian Gloucester Coal Measures at depths ranging from approximately 300 to 1000m from the surface. This variation of depth will not be fully covered by fracture stimulation treatment(s). Instead, multiple small fracture stimulation treatments will be performed, each one initiated at a coal seam target depth.The formations to be targeted are the Leloma, Jilleon, Wenhams, Dogtrap Creek and Waukivory Creek Formations. These formations contain cemented sandstones, siltstones and claystones interbedded with the coal seams. These low permeability formations, together with effective separation intervals of over 200m between the target CSG coal measures and the shallow beneficial aquifers, means there is negligible risk of fractures propagating from the targeted coal seams to these shallow beneficial aquifer zones. In addition, the geomechanical earth model indicates that any fractures initiated in target coal seams shallower than approximately 600m would result in a T-shaped fracture which would be contained by the overburden and remain in the targeted zone. (See section 2.4)

2.4 Rock Mechanics

Rock Characteristics and Extent of Natural Fracturing and Faulting

The targeted coal seams are interbedded with sandstones, siltstones and mudstones with similar lithologys above and below the target coal seams. These intervening strata are considerably tighter and harder than the target reservoir and should limit vertical fracture growth into these zones. Modelling of this is discussed further in section 2.6 of this FSMP.

To identify faulted areas prior to drilling AGL conducted a 3D seismic survey to image the subsurface, including natural fracturing. This was used to assist in well placement. The resulting geological model including major faults and natural fracturing has allowed AGL to characterise the area structurally and risk assess these features accordingly.

The fault zones intersected by the Waukivory Pilot wells are consistent with the structural model and have been confirmed by image logs acquired as part of the logging of the wells. Image logs run in the Waukivory Pilot wells allow accurate identification of natural fractures, and the location of faults.

Completion intervals were then selected for the fracture stimulation at a separation distance relative to the type and size of the fault. These faults are interpreted to be barriers to flow, and not transmissive at depths greater than 150m. Therefore any risk of migration of fracture stimulation treatments is minimised.

In addition, any faults intersected by a well are identified on the image logs and fracture stimulation zones avoid these intervals, further minimising the risk of migration.

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 measures include:

- Real-time pressure monitoring will occur throughout the program. This allows AGL and Principal Contractor engineers to monitor fracture geometry as it propagates in real-time through the monitoring of treating pressure during the fracture stimulation to assess whether the hydraulic fracture treatment is migrating up faults, which would be indicated by rapidly reduced treating pressure.
- Also, the additional information from a nearby geophone monitoring bore during the fracture treatment of Waukivory 13 (the first well in the pilot to be fracture stimulated) will refine the fracture modelling process and real-time assessment of fracture geometry.

The fracture geometry will be monitored in real time and adjustments made to the treatment to reduce vertical growth, and achieve a longer fracture within the target coal seam. The geomechanical earth model for Waukivory Pilot indicates a T-shaped fracture developing for fractures initiated shallower than approximately 600m. This will contain vertical growth as the fracture will initiate vertically within the coal and then turn horizontal at the boundary with the interburden and not propagate vertically above the target. (See below)

Stress Fields and the Geomechanical Earth Model

[Code of Practice, Section 3.2(d) and Section 3.3 *Leading Practice*]

Direction of minimum and maximum stresses is used to determine the likely direction of the hydraulic fracture propagation. The fracture will propagate along the direction of maximum horizontal stress (opening against the minimum stress direction). Interpretation of image logs by AGL show the principal horizontal stresses in the Waukivory Pilot, allowing geologists and engineers to predict the orientation that the fracture will propagate.

In May 2013, AGL carried out additional stress testing on coal (target seam) and sandstone (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 services 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).

The geomechanical earth model studied the 3 principal stresses – vertical (overburden), and maximum and minimum horizontal stresses – through changing depth and rock strata to predict hydraulic fracture azimuth and geometry. The pertinent results are as follows:

- at all depths between 300m and 1000m, the hydraulic fracture will initiate in the targeted coal rather than the interburden;
- at depths deeper than approximately 600m, the hydraulic fracture will initiate vertically in the coal and may experience some limited vertical growth out of the targeted coal zone near the wellbore; and
- at depths shallower than approximately 600m, the hydraulic fracture will initiate vertically in the coal. However, a vertical fracture is not able to be supported by the interburden which is under greater horizontal stress than the coal, and the fracture will turn horizontal at the interburden, creating a T-shaped fracture. This means that vertical growth of the fracture will be contained in the coal seam, at the boundary with the interburden.

The outcome of the geomechanical model confirms data analysis on previous fracture stimulation conducted in the Gloucester area which indicated T-shaped or complex fractures in shallow target coal zones.

The containment of vertical growth by the T-shaped fracture at depths shallower than approximately 600m prevents the fracture growing vertically out of the targeted coal seam.

The use of geophone monitoring during the hydraulic fracture stimulation operation at Waukivory 13 will allow further information to be gathered about fracture geometry, and confirm and refine existing geomechanical earth model and fracture stimulation modelling. This includes the occurrence of T-shaped fractures created where the overburden stress is less than the minimum horizontal stress. A T-shaped fracture has both a vertical and a horizontal component, as opposed to a more simple hydraulic fracture, which has a vertical component only. A T-shaped fracture exhibits less vertical growth as the fracture is contained at the boundary between the coal and the interburden. This phenomenon is predicted by the geomechanical earth model built using actual Waukivory data, and is supported in general by extensive studies into hydraulic fracture stimulation in coal conducted by CSIRO.

2.5 Pressures for Fracture Stimulation

[Code of Practice, Section 3.2(e) and Section 10.3 *Leading Practice*]

The maximum pressure required to initiate and propagate a fracture varies with the depth of the target zone, rock mechanics, and geological stress profiles. Additional stress testing on zones of interest and bounding layers were carried out to build a geomechanical earth model to complement geophysical logging and laboratory rock mechanics to then use this information for fracture stimulation modelling (see section 2.4). Fracture stimulation modelling is used as a predictive tool for well design purposes and fracture geometry (see section 2.6). The pumping pressure of the fracture stimulation treatment will be monitored in real time in conjunction with other diagnostic tools to ascertain fracture geometry to optimise the well design.

AGL has gained knowledge of the rock mechanics of the zones of interest through previous exploration and fracturing activities (see section 2.7). Based on previous experience in this geological region, average treating pressures are expected to range from 2400 to 4300 psi. The wellbore and surface treating equipment is designed, with safety factors built-in, to withstand pressures higher than the maximum operating surface treating pressures of up to 4680 psi.

The geomechanical earth model was developed using actual core and log data from the Gloucester strata. 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. This is also the case in AGL Camden asset where over 100 wells have been fracture stimulated. The OCSG has raised the issue of whether coal fines may change the viscosity of fracture stimulation fluid, resulting in elevated pressures due to formation damage. While this has never occurred to AGL's knowledge during fracture treatments in NSW, in the unlikely event that coal fines interact with the fracture stimulation fluid and create formation damage/elevated pressures, any changes would be seen and accounted for after analysing diagnostic injection tests prior to the main fracture stimulation, as well as the fracture stimulation engineer responding in real time to treating pressures during the treatment.

While there is no evidence that coal fines interfere with fracturing pressure responses, the fracture geometry due to horizontal and vertical stress components may affect treatment pressures. The geomechanical earth model that AGL has developed for the Waukivory Pilot highlights the effect of the rock mechanics and stress regime for the area (see section 2.4).

On rare occasions, perforating may shatter the coal seam near wellbore which may result in higher than normal initial fracture treating pressures. In the event of high initial treating pressures, a 100 mesh sand slug, or an increase in viscosity of the fracture fluid, may be used to reduce near wellbore tortuosity and the treating pressure. These measures are captured in the TARP.

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.

A 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 diagnostics pressure plots.

2.6 Modelling

[Code of Practice, Sections 3.2(f), 3.2(g) and Section 3.3 *Leading Practice*]

The ability to model the fracture propagation including extent and orientation in an exploration area in complex rock such as coal requires various techniques to better understand the behaviour of the fracture within the coal seam. AGL proposes to use geophone monitoring technology in each of the fields proposed for fracture stimulation. This will provide real time data including the fracture geometry (extent and orientation), and can then be used and incorporated to refine future fracture modelling. As more information is obtained from the various diagnostic techniques deployed (refer to diagnostic tools, section 8.1) the ability to accurately model fracture propagation including extent and orientation using a numerical simulator will provide a higher level of accuracy. This will strengthen the reliability of the model and minimise potential for the actual fracture propagation field to exceed that modelled.

In May 2013, AGL obtained cores from both formations of interest and bounding layers for testing mechanical rock properties, as well as in-situ stress testing of different depth intervals at a nearby well. Further in-situ stress testing was conducted at Waukivory in January 2014 to supplement this data. The subsequently completed geomechanical earth model, will be incorporated into fracture stimulation modelling.

The geomechanical earth model allows stress contrast between different rock layers to be modelled, providing key data used in fracture stimulation modelling to ascertain how different fracture program designs will affect fracture growth and geometry during pumping of the fracture stimulation.

The goal is to design a hydraulically induced fracture that effectively stimulates whilst being contained within the treatment zone, and will not grow vertically toward the shallow beneficial aquifers (see section 2.4). Similar stress models can then be built for subsequent fracture stimulation target wells in the region. A model can be built for each well by using the same correlation algorithms obtained at AGL's core test well to correlate the dipole sonic logs run on individual target wells.

AGL's fracture stimulation service provider will use a 3D fracture simulation software to model designed fracture propagation. Pre-frac diagnostic injection tests will be performed on selected zones to calibrate and strengthen the model prior to the main fracture stimulation. Modelling and pre-frac diagnostic injection tests will allow fluid leak-off data to be incorporated into the fracture design. Formation damage from leakoff will be addressed with a temperature activated breaker system run with the low viscosity gel fluid system. A linear gel with maximum 20lb/1000 gal (2.4g/L) gel loading will be used and a borate crosslink may be used if higher than usual treating pressures are encountered or on selected zones where the fracture simulations indicate better fracture sand placement considering such aspects as the geo-mechanical model and the coal seam permeability.

2.7 Exploration Activities and Fracturing

The exploration target wells selected in the Gloucester Basin have undergone significant review. An offset core hole has been drilled retrieving core samples of the coal and strata. Geophysical logging and permeability testing have also been conducted. The data set of information obtained from the offset core hole provides essential information to assist with the fracture design.

Hydraulic fracture stimulation has previously been utilized by AGL and previous explorers within the basin on 8 Stratford Pilot wells, located to the south of the Waukivory Pilot and on Waukivory 3 and Faulkland 3 located to the north and west of the pilot respectively. Two other wells in the basin, Craven 6 and Weismantel 3, have also been fracture stimulated.

Since AGL became operator of this PEL, four wells were fracture stimulated in May and June 2009 as part of the ongoing Gloucester exploration program. These were: Stratford 7, Craven 6, Stratford 10, and Waukivory 3. The Gloucester fracture stimulation fluid consisted of about 99.4% water and sand. The remaining 0.6% was made up of additives to increase the fluid's viscosity. In total for the four wells, 4.4 ML of water, 533 tonnes of sand, and 25,280 litres of additives were used. There have been no identified impacts of groundwater or surface water resources from these activities. The target coal seams for the Waukivory program are the same as for these previous pilot test wells.

Fracturing targets the coal seams, more than 200 metres below the shallow aquifers. Shallow aquifers are protected by four barriers within the well construction: two steel and two cement barriers. The well construction design incorporates numerous contingencies to ensure zonal isolation between coal seams and other formations including aquifers. Aside from the important environmental consideration, zonal isolation is important for gas production, as water migration from any other source will hinder gas production, so all precautions are taken to ensure no connection between other formations can exist.

To check the integrity of well construction and any potential impacts associated with targeted fracture stimulation, groundwater monitoring networks (mostly in shallow aquifers) have been installed in reasonable proximity to selected gas wells to assess whether there are water level drawdown or water quality changes that would indicate connectivity. In addition to the established shallow monitoring network, AGL has obtained separate approval to establish a geophone (deep water monitoring) borehole to assess the impacts of the fracture stimulation program. The borehole will be converted to a water monitoring bore using a number of vibrating wire piezometers (VWPs) immediately after the fracture stimulation programs and prior to the flow testing programs.

The fluid used during fracture stimulation is recovered from the well through the 'flowback' and dewatering processes. This is done by using a "breaker" to react with the gel, breaking down its viscosity back to that of plain water so that the fluid's ability to flow is increased, allowing it to be produced back to surface.

The flowback water is then captured into open-top tanks. The fluid will then be held at a temporary storage facility prior to being lawfully disposed of to an appropriate facility in accordance with the requirements set out in AGL's Waukivory Pilot REF.

Although critical geological and reservoir information are gathered during the exploration corehole drilling and stratigraphic wells, the flow characteristics of the reservoir are not fully understood. This is why the stimulation process is conducted, testing the well production potential to complement the data set and have a better understanding of the economics and potential reserves of the area. This information assists AGL in determining whether a field has the potential to be commercially developed.

3 Compliance

[Code of Practice, Section 1.2(e)]

This FSMP is to be updated, reviewed and revised by AGL as necessary. The following are examples in which the FSMP would need to be reviewed and revised:

- Prior to making significant changes to an approved fracture stimulation design and operating procedure.
- If the level of risk to health, environment, land, and/or community from fracturing activities significantly increases.
- If control measures are not adequately mitigating the consequences of identified risks.

4 Planning and Risk Assessment

4.1 Notification

[Code of Practice, Sections 12.1, 12.2]

At least 10 days before starting hydraulic fracture stimulation activities AGL is to lodge a Notice of Intent to Carry out Fracture Stimulation with the Department of Trade and Investment Regional Infrastructure and Services (DTIRIS).

In the event of an unforeseen significant technical deviation from the work program, which may be the result of well integrity issues, significant incident on location, or abnormal fracture treating pressure response, the AGL Head of Field Development or designated engineer will notify the OCSG as soon as is practicable, and within the same day this event has occurred.

4.2 Stakeholder Consultation

[Code of Practice, Sections 2.1, 2.2, and Section 2.3 *Leading Practice*]

The objective of community consultation for the GGP is to provide clear, effective information on our projects and engage in open dialogue by listening, recording and responding to issues where appropriate. The approach includes working with individuals and groups in the local community, as well as directly affected landowners.

AGL has conducted appropriate consultation with stakeholders to ensure that those potentially affected are informed about fracture stimulation activities, and are informed of the risk assessment and development of management plans.

The proposed Waukivory Pilot exists within a complex community environment. A detailed understanding of stakeholder concerns and interests recognises that issues related to the Waukivory Pilot cannot be separated from the broader coal seam gas industry and AGL's approach to development within the Gloucester region.

Who did AGL consult with?

AGL has discussed and sought feedback on the Waukivory Pilot, including the proposed fracture stimulation activity, from the Gloucester Shire Council, the Gloucester Community Consultative Committee (**GCCC**), affected and nearby landholders, Gloucester Dialogue (chaired by the NSW Land and Water Commissioner) and the broader community.

The GCCC was formed in September 2008 to provide a forum for discussion and exchange of information between the community, sovernment agencies and AGL. The GCCC assists AGL in identifying project related local issues for consideration during the development, environmental, construction and operational phases of the project. It also acts as a communication link between AGL, the community and other stakeholders. The GCCC includes representatives from the community, local residents groups, the local Landcare Group, two action groups, Gloucester, Great Lakes, Port Stephensand Dungog councils, MidCoast Water, Local Aboriginal Land Councils as well as representatives from AGL. The GCCC meets at least six times a year and representatives are provided with project updates/briefings from key project staff and minutes from the GCCC meetings are also available to individuals on the GGP web site (www.agl.com.au/gloucester).

The *Gloucester Dialogue* was formed on 30 January 2014 and brings together community, industry and local and state government agencies to explore issues surrounding the exploration and extraction of CSG in the Gloucester Basin. Chaired by the NSW Land and Water Commissioner, members of the Gloucester Dialogue include Gloucester Shire Councillors and officers, independent community members, senior AGL representatives and senior agency officers from the OCSG, NSW Division of Resources and Energy, NSW Environmental Protection Authority, NSW Office of Water and NSW Department of Planning and Environment.

Other stakeholders engaged in the process include the Forster and Karuah Local Aboriginal Land Councils (LALC) in the development of the cultural heritage assessment.

The GGP has 1,293 individual stakeholders and community organisations registered in AGL's records as having an interest in the project. Stakeholder consultation is prioritised to those stakeholders who will be most impacted by the project and project related activities. However, AGL understands that diversity of opinions and perspectives is important in delivering a project that meets community expectations across a region broader than those who live next door.

To address this, AGL has implemented a broad communication and engagement strategy utilising local and regional media and advertising and an online engagement platform. This platform includes a dedicated website and associated twitter account which reaches approximately 8,000 stakeholders daily. The website is dedicated to communicating the latest project information, providing direct access to data and reports, and responding to questions posed from interested stakeholders from across the state.

What channels of engagement were used?

AGL has provided ongoing informational mail-outs regarding AGL's exploration activities within the area. Regular community updates are also published in regional papers such as the Gloucester Advocate and posted on AGL's Gloucester project website.

This is in addition to a number of other ways AGL engages with the local Gloucester community:

- AGL has an office in Gloucester. Members of the community are welcome to drop in and speak with AGL project officers, and view the information display and fact sheets;
- AGL has a Community Relations Manager dedicated to the GGP, whose role is to continue to communicate and engage relevant stakeholders throughout the project. AGL has taken a

proactive approach to dispute resolution, in assigning key team members to liaise directly with landholders and adjacent residents. AGL team members work proactively with stakeholders to identify issues early, address issues in an appropriate and timely manner, and to keep the affected stakeholder informed throughout the resolution process;

- AGL has established the *Your Say* AGL website has been established to facilitate two-way feedback with the community;
- AGL has and will continue to undertake letterbox drops and door knocking of neighbours to provide information and take feedback on project activities;
- AGL has established a project information line provides 24 hours point of contact for the community (1300 886 170);
- AGL regularly arranges site visits to other AGL projects and to local project work activities for the GCCC, Gloucester Water Steering Committee, neighbours and all interested members of the community. AGL has provided fracture stimulation fluid demonstrations at some of these presentations;
- AGL regularly holds project briefings with key stakeholders including Gloucester Shire Council, GCCC, Gloucester Dialogue and MidCoast Water;
- AGL distributes fact sheets to the community via letterbox drops, mail-outs, and on the project website outlining the nature of activities, scale, timing duration and hours of operation for local work activities. Project newsletters are published and distributed to all of the 2422, 2425 and 2415 postcode areas for Gloucester, Stroud and region, along with being published to AGL's Gloucester project website;
- AGL regularly holds information sessions in Gloucester and surrounding villages to provide project updates and information about specific project activities.;
- AGL engages the local media through media releases and advertisements in local newspapers; and
- AGL has held four specific information sessions at the Gloucester Country Club to inform the community about our plans for the Waukivory Pilot with scientists and experts available to answer questions about the fracture stimulation process, land use, water, and ways we mitigate risk. These questions and answers were reflected online for those unable to attend the meetings.

A full description of consultation undertaken and proposed to be undertaken is provided in section 2.5 of the REF.

What were the themes of AGL's engagement?

Central to the consultation has been the communication of the risk assessment and management plans.

Communication has focussed on areas of risks and management plans to address these risks including:

- protecting water;
- ensuring well integrity; and
- fracture stimulation fluid additive composition.

Examples of engagement activities focussed specifically on risk communication include:

- preparing and publishing an easy to read overview of the REF which outlined the Waukivory Pilot and a guide to those parts of the REF that have been raised most frequently by stakeholders;
- information sessions listed above which specifically addressed risks. The room was set up with "stations" covering the key risks – i.e., water, the environment, fracture stimulation, well integrity, geology and land access. Full copies of the REF were available for the community to review and all experts responded to detailed questions over a 2 hour period; and
- AGL was invited and accepted an invitation from a group opposed to natural gas extraction, the Barrington Gloucester Stroud Preservation Alliance to present to a large community meeting on AGL's plans for Gloucester. The meeting, attended by more than 300 people and independently facilitated, included a specific AGL presentation on safety and risks, and how risks are managed. There were a range of presenters (including AGL) with different perspectives on hydraulic fracturing. The meeting included an extended period where all presenters fielded detailed questions from the community. Participating in this forum is one of the many ways AGL engages with people who have expressed concerns about our activities. The presentation from this event can be found on AGL's GGP website.

How has AGL taken community feedback on board?

Feedback from members of the GCCC, the Gloucester Dialogue, and other individuals and groups within the community have informed amendments to the proposed activity.

Since the submission of the REF, AGL has continued to develop the design of the proposed activity having regard to the stakeholder comments and concerns. For example, the *Preferred Activity Report* (December 2013) was lodged with the OCSG to address issues raised by relevant regulatory authorities. Further to consultations with the GCCC and the Gloucester Dialogue, AGL proposed additional changes to the proposed activity which would bring about community, operational and environmental benefits (see *the Further Addendum to the Review of Environmental Factors* (June 2014)).

Logging and recording feedback

Stakeholder engagement and contact with the community is recorded in the Consultation Manager database (i.e., a tool to capture community engagement), and response times and actions will be tracked via this tool to ensure issues, responses and outstanding actions can be tracked.

Engagement timeline

AGL will using the same **channels of engagement listed above for** fracture stimulation activities.

AGL's objectives in future stakeholder consultation will be to:

- increase awareness and transparency of additives used in the hydraulic fracturing process;
- give prominence to existing information on fracture stimulation fluids already on our websites;
- use a range of methods to communicate about the Waukivory Pilot in plain English including, for example, animation and videos;
- linking to CSIRO fact sheet on hydraulic fracturing;
- advertise further in local newspapers; and
- provide stakeholder and media briefings on hydraulic fracturing.

4.3 Risk Assessments

[Code of Practice, Sections 4.1, 4.2, 8.1, 8.2, 16.1, 16.2 and Section 8.3 Leading Practice]

AGL conducted risks assessments in accordance with AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines. This assessment is documented in the Risk Assessment Report for AGL Energy's Fracture Stimulation Activities in Gloucester (AGL Energy, March 2013) (**Risk Assessment Report**) which is enclosed as **Appendix L** of the REF.

The Risk Assessment Report was broken up into thirteen categories;

a) workplace health and safety;
b) public safety;
c) chemical risk assessment;
d) land contamination;
e) air pollution;
f) localised temporary noise and vibration;
g) induced seismicity;
h) induced subsidence and other induced ground movements;
i) impacts on water resources;
j) conflicts with existing land uses;
k) flowback and waste management;
l) loss of well integrity; and
m) other risks.

The framework of the risk management principles as defined by the ISO 31000:2009 is illustrated in **Figure 2** and the process is illustrated in **Figure 3**.

One of the categories in the Risk Assessment Report is chemical risk assessment. This assessment is documented in the Human Health and Ecological Risk Assessment: Hydraulic Stimulation Activities, Gloucester Gas Project (EnRisks, April 2013) (**HHERA**) which is **Appendix C** of the REF.

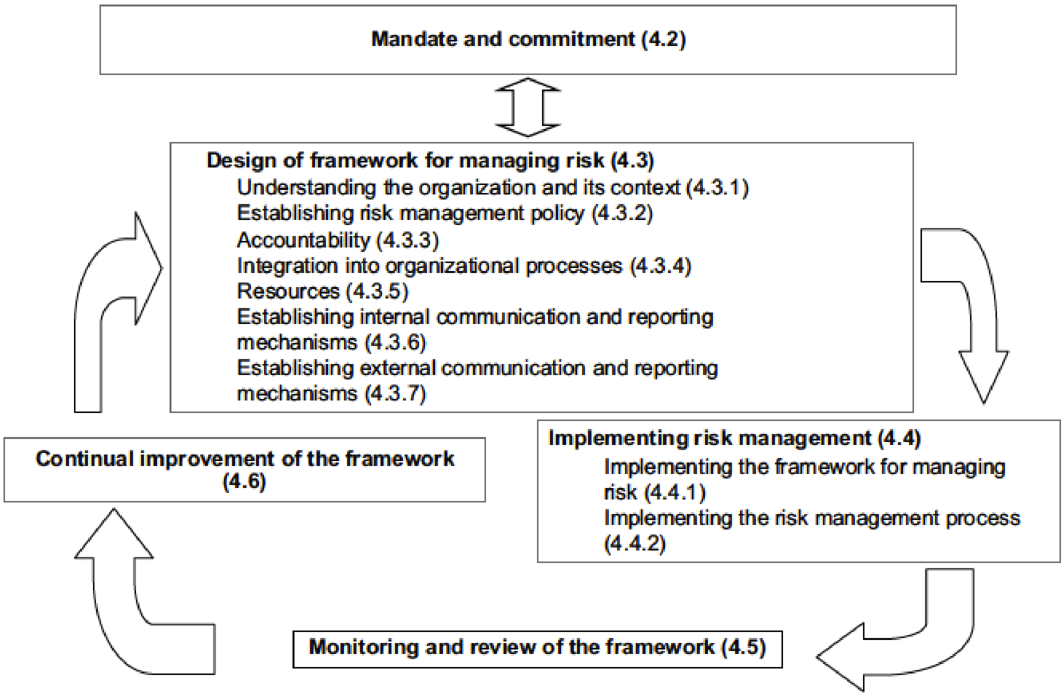


Figure 2. Relationship between the components of the framework for managing risk (ISO, 2009)

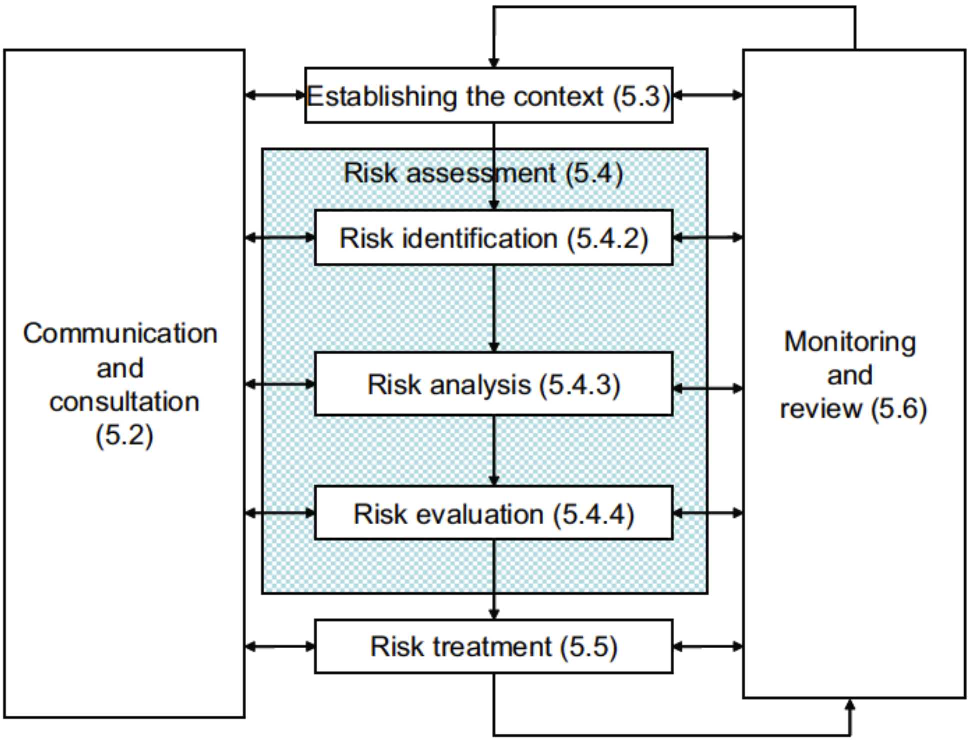


Figure 3. Risk management process (ISO, 2009)The table below identifies the risks which have been assessed, and for which mitigation measures have been proposed, in the REF, Risk Assessment Report, HHERA and other documents (e.g., Environmental Management Plan, Surface Water and Groundwater Management Sub-plan).

Risks which have been assessed in accordance with section 4.2 of the Code of Practice	Document which assessed the risk and summary
Workplace health and safety assessment	REF: includes section 8.5 Risk Assessment Report: item i in table under section 4.1. This report concluded that the risks relating to workplace health and safety are: - heavy vehicle movements through local townships and access roads to sites raising a risk of vehicle related accidents: moderate risk; - incorrectly secured loads raising risk of accidents for other road users: moderate risk; - equipment damage during rig up: low risk; - injury to onsite personnel due to rig up: moderate risk; - excessive occupational noise to onsite personnel during job execution: low risk; - failed or uncontrolled pressure release to onsite personnel causing injury during job execution: moderate risk; - failed or uncontrolled pressure of the flowback line causing injury to personnel: moderate risk; - well control failure causing injury: low risk; - fire due to machinery causing injury: low risk; - additive mishandling or inadvertent contact with additives which may cause injury: moderate risk; and - site and equipment may be sabotaged by unauthorised or illegal entrants resulting in injury: low risk. HHERA: see section 3.4.2, Table 6
Community impacts assessment	REF: includes sections 6.8, 8 and 9 Environmental Management Plan (EMP): European Heritage Management Sub-Plan (section 3), Fire Management Sub-Plan (section 3 – bushfire relates to community), and Traffic Management Sub-Plan (section 3) Risk Assessment Report: items ii, vii, and xii, in table under section 4.1. The risks identified in this report are: - public safety: moderate risk; - conflict with existing land uses (risk of air pollutants damaging neighbouring occupied properties): low risk; - conflict with existing land uses (risk of localised temporary visual and noise impacts to neighbouring properties): high risk; and - localised temporary noise and vibration due to heavy

Risks which have been assessed in accordance with section 4.2 of the Code of Practice	Document which assessed the risk and summary
	vehicles, operational equipment and flow back operations: moderate risk.
Fracture stimulation fluid assessment	REF: includes sections 2.8.7 and 6.5 This FSMP: The list of approved fluids for use can be found in section 7.5 of this FSMP and in the HHERA (section 3.3 and Appendix C to the REF). The FSMP addresses the issue of using additives in fracture stimulation fluids. Fracture stimulation fluids are screened for all the additives that are proposed to be used. EMP: Dangerous Goods and Hazard Material Management Sub Plan (Section 3 and Table 4-1). HHERA: section 4. The HHERA concluded as follows: - risks to human health and the environment are considered to be negligible or low; - the highest identified risk level is low which is considered to be a level of risk that can be adequately managed through the implementation of existing operational management measures; - no significant risk issues have been identified that require detailed quantification of risks; - based on the available information there are no pathways by which hydraulic fracture stimulation fluids injected into the CSG well can migrate to any freshwater body that may be of importance with respect to future beneficial uses of these freshwater aquifers or the discharge of water into aquatic environments.
Environmental assessment	REF: includes sections 6.7 and 8 EMP: Air Quality Management Plan (section 3), Soil and Water Management Plan (sections 2 and 3), and Flora and Fauna Management Plan (section 3). Risk Assessment Report: items iv, v and vi in table under section 4.1. The risks identified in this report are: - land contamination (spills and leaks of materials): moderate risk; - land contamination (noxious weeds from offsite may be transported by vehicles and contaminate the local area): moderate risk; - air pollution (excessive exhaust emissions and surface dust

Risks which have been assessed in accordance with section 4.2 of the Code of Practice	Document which assessed the risk and summary
	generated from road movements): moderate risk; - air pollution (fines and fluids mists may blow into the atmosphere during operations): low risk; and - source water spill during transport to site: low risk; - flow back water incorrectly transported, captured or removed which may result in a spill: low risk. HHERA: Table 6
Geological assessment	REF: includes sections 4.1.4, EMP: section 3.1 Risk Assessment Report: items iv, x and xi in table under section 4.1. The risks identified in this report are: - induced seismicity (risk of inducing seismicity that could, for example, disrupt a nearby fault): low risk; - induced subsidence and other induced ground movements (risk that there may be surface ground movement): low risk; and - fracture growth containment - fracture diagnostics (risk of connectivity and cross contamination between coal seams and beneficial aquifers, and risk of surface water/groundwater connectivity): low risk.
Groundwater and surface water assessment [Code of Practice, Section 7.1 and 7.2]	REF: includes sections 4.2, 6.2, and 6.5.2 REF Addendum: sections 2.7.4, 4.2, 4.3, and 4.4 This FSMP: section 2.2. The major focus is the beneficial aquifers which mainly occur in the shallow sandy alluvium which is less than 15m depth, although other minor aquifers also occur in the shallow bedrock to depths of around 75m. EMP: Dangerous Goods and Hazard Material Management Plan, section 3 Surface Water and Groundwater Management Sub-Plan for the Waukivory Pilot Testing Program: Gloucester Gas Project Risk Assessment Report: item iv in table under section 4.1. Four primary risks were identified in this report: - source water spill: low risk - flow back water may be incorrectly transported, captured

Risks which have been assessed in accordance with section 4.2 of the Code of Practice	Document which assessed the risk and summary
	or removed which may result in a spill: low risk - causing connectivity and cross-contamination between coal seams and beneficial aquifers: low risk - induce changes to groundwater pressure and levels, and changes to surface water levels and flow: low risk. Note The assessments in the documents listed above address: - spills of raw (source) water for the fracture stimulation programs and flow back water; - beneficial aquifers versus deeper coal seam water bearing zones; - groundwater contamination from either additives used in fracture stimulation fluids or from cross-contamination of water sources from separate water bearing formations; - changes to groundwater levels and pressures; - changes to surface water levels; and - changes to groundwater quality. Further to section 7.2(f) of the Code of Practice, the consultations undertaken with the NSW Office of Water (NOW) included several meetings with NOW staff, in Newcastle in 2012, from their Major Projects and Licensing Units. More recently there have been 6-monthly update meetings in various NOW offices. Discussions have revolved around the nature of the exploration (appraisal) programs, the local hydrogeological environment and associated risks, monitoring and reporting requirements, and the necessary licensing requirements to complement the approvals under Part 5 of the *Environmental Planning and Assessment Act 1979* (NSW) from DTIRIS for this program.
Flowback and Waste Management [Code of Practice, Sections 8.1, 8.2 and Section 8.3 *Leading Practice*]	REF: includes sections 2.7.7(iv) and (vi) and 6.6 REF Addendum: sections 2.7.2, 2.7.3, and 4.5 This FSMP: sections 10 and 11 EMP: Waste Management Plan (section 3) Surface Water and Groundwater Management Sub-Plan for the Waukivory Pilot Testing Program: Gloucester Gas Project Risk Assessment Report: item viii in table under section 4.1. The risk that waste from operations may enter the surrounding environment

Risks which have been assessed in accordance with section 4.2 of the Code of Practice	Document which assessed the risk and summary
	was assessed as low. HHERA: Table 6 Note The flowback water will be captured into open tanks at each well and then piped via gathering lines to the temporary above ground water storage. Flowback water will be characterised before being lawfully disposed of to an appropriate facility. Produced water is natural groundwater suitable for re-use (once salinity aspects are addressed through blending or other treatment). Produced water will be taken to Tiedman's and stored then potentially irrigated provided the irrigation water achieves prescribed the water quality criteria as outlined in the existing approval for the irrigation program.
Well Control and Integrity Assessment	REF: includes section 2.8.7 EMP: section 3.6 Safety Management Plan Risk Assessment Report: item ix in table under section 4.1. This report concluded that the risk to well integrity due to issues such as failure of pressure containment devices, casing, master valve or lubricator is low.

4.4 Safety Management Plan

[Code of Practice, Sections 5.1, 5.2]

The Gloucester Gas Project Health and Safety Management Plan, which is part of AGL's Health Safety and Environment Management System, complies with the mandatory requirements of the Code of Practice [section 5.2 of the Code of Practice].

Prior to commencing any activities relating to the Waukivory Pilot, AGL will ensure that operators and contractors prepare, implement and review a Safety Management Plan to address any safety risks that may arise from the fracture stimulation activity, and to ensure that the design and operation of the site and its equipment are safe.

Personnel from both AGL and the contracted fracture stimulation service provider actively contributed to the fracture stimulation risk workshops. This ensured that likely interactions between safety management systems, and specific risks that may arise as a result of likely interaction between safety management systems, were addressed.

AGL will hold control of all activities at the site except during fracture stimulation activities. During fracture stimulation activities, the operation (including safety management of the site) will be handed over to the fracture stimulation contractor.

Permit to Work rev3 will be issued each morning prior to start of work activities to identify work to be conducted that day, any simultaneous operations for that day, AGL/contractor interactions, any risks and mitigations to be implemented.

Pre-job safety meetings will be held prior to any fracture stimulation activity to identify specific risks and controls in place, and confirm line of reporting for each person present on site, their specific role and location during the activity.

A copy of the Safety Management Plan is attached as Appendix E to the REF.

5 Emergency Response Plan

[Code of Practice, Sections 11.1, 11.2]

Incidents and emergencies will be prepared for and managed appropriately to ensure that risks to health, safety and the environment are minimised.

The Gloucester Gas Project Emergency Response Plan, which has been prepared in accordance with cl 43 of the *Work Health and Safety Regulation 2011,* complies with the mandatory requirements of the Code of Practice [section 11.2], as well as the *NSW Code of Practice for Coal Seam Gas Well Integrity.*

A copy of the Emergency Response Plan is attached to the REF as Appendix D.

6 Environmental Incident Response Plan

[Code of Practice, Section 11.3]

An Environmental Incident Response Plan has been prepared for the GGP, which sets out procedure to be followed and actions to be taken in the event of:

a) Well blow out or loss of integrity;
b) Chemical spill or other pollution incident;
c) Damage to an overlying water source;
d) Breach of regulatory requirements, including significant non-compliance with the FSMP;
e) Any other significant environmental incident associated with the fracture stimulation activity.

A copy of the Environmental Incident Response Plan is Appendix F to the REF.

7 Design

[Code of Practice, Sections 3.1, 3.2 and Section 3.3 *Leading Practice*]

The fracture stimulation activity will be designed to:

- avoid impacts on water resources;
- contain fractures within the targeted area; and
- minimise additive use.

Successful hydraulic fracture stimulations require comprehensive planning and design phases. The fundamental principles of the fracture stimulation design will be to ensure:

- Safe pressure and pump rates;
- the fracture is contained within the target formation;
- Well integrity is maintained at all times;
- the minimal use of water;
- the minimal use of additives; and
- the safe handling of fracture stimulation fluid flowback and disposal.

The table below indicates the relevant sections of this FSMP which discusses the description of the design of the fracture stimulation activity required under section 3.2 of the Code of Practice.

Information required to be incorporated under section 3.2 of the Code of Practice	**FSMP**
a) characteristics of geological formations, including the identification of rock types and conditions, aquifers and hydrocarbon-bearing zones	sections 2.1 and 2.2
b) definition of distances to these aquifers from the target coal beds	section 2.3
c) identification of the characteristics of intervening strata, including porosity/permeability and the extent of natural fracturing	section 2.4
d) determination of geological stress fields and areas of faulting	section 2.4
e) determination of maximum pressures to be used for fracture stimulation, based on the characteristics of surrounding geology	section 2.5
f) modelling of the likely fracture propagation field, including extent and orientation	section 2.6
g) discussion of any potential for the fracture propagation field to exceed that modelled in (f)	sections 2.6 and 2.7

7.1 Well Construction

The construction of a well is often influenced by whether or not hydraulic fracture stimulation is going to be performed. If a well is to be fracture stimulated then it needs to be designed and completed to accommodate for the requirements of the fracture. Treatment pressures, zonal isolation, flow rates, monitoring and flowback requirements can greatly influence a well's construction.

The *Code of Practice for Coal Seam Gas: Well Integrity* has been adopted and complies with the API standards and best practice for wells that will be fracture stimulated. All gas production wells have been or will be completed with multiple casings (and pressure cemented in place) to ensure that aquifers remain isolated. Cement Bond Logs (CBLs) are conducted on wells proposed for fracture stimulation to confirm that cement quality and bond are acceptable for the fracture stimulation of these wells.

7.2 Historical Review of Activities

A valuable tool in the design process is reviewing past activities in the area and other areas of a similar nature. Reviewing past activities promotes a culture of continuous improvement and optimises future activities. As designs are optimised and tailored to an area the amount of materials (water, proppant and additives) used in a treatment can be minimised reducing the impact of the fracture stimulation activity.

Numerous technical reports have been reviewed and investigations conducted to better understand key parameters that influence the impacts of fracturing to ensure the designs are fit for purpose.

7.3 Core Analysis

[Code of Practice, Section 3.3 *Leading Practice*]

By analysing cores prior to treatment many key characteristics can be identified about the formation. These characteristics include:

- Mineralogy – Evaluate the mineral content of the rock to help determine fluid sensitivity, anisotropy and potential for clay swelling/migration.
- Water Saturation – To determine potential for water production and fluid cleanup issues.
- Permeability – Both vertical and horizontal
- Porosity
- Presence of Natural Fractures
- Rock Mechanics – Determine elastic properties, embedment potential, and the stress contrast for zonal isolation.

When working in a new formation, it is important to conduct core analyses to gather information required for building accurate models and selecting the correct additives and proppants.

To date, AGL has cored and analysed 25 coreholes in Gloucester which includes Pontilands 03 (cored in April - May 2013) from which core analyses are being used to build a geomechanical earth model which can be calibrated for each pilot well in the region.

7.4 Fluid Selection

[Code of Practice, Sections 6.1, 6.2]

Fracture stimulation fluids were designed with guiding principles to:

- minimise volumes of water and additives;
- minimise potential impact to the environment and human health;
- ensure that all additives are certified as BTEX free;

- ability to transport proppant into the fracture;
- act as friction reducer to pressure, thus requiring less horsepower on site;
- induce a fracture geometry suitable to reservoir characteristics; and
- the fluid breaks back to water in a predetermined time and leaves minimal formation damage to the coal seam.

There are three main fluid types that are most commonly used.

- Treated Water – A treated water fluid recipe is a basic fluid for performing hydraulic fracture stimulations. The fluid is usually treated with a bactericide to minimise the risk of introducing foreign bacteria into the formation.
- Linear Gel – Linear gel fluid is a viscosified treated water. Linear gels are able to carry higher concentrations of proppant (sand) than water, thereby reducing the required volumes of water. They also reduce pumping friction and can reduce the required hydraulic horsepower required.
- Cross-linked Gel – Cross-linked gel is based on a linear gel. The cross-linked fluid has additional additives that crosslink the gel which further increases the viscosity of the gel. Cross-linked gels are used when high proppant (sand) concentrations are required or when low viscosity fluids are unable to maintain the desired fracture geometry.

The fluid’s main purpose is to create the fracture geometry and to transport the natural fracture sand (proppant). After fracture treatment, the fluids viscosity breaks or reduces (with the aid of a “breaker”) back to water so that it can easily flow back to the wellbore and hence to surface.

Water-based linear gel is proposed to be used for the Wauikivory Pilot, with a cross-linked gel to be used as an alternative.

This FSMP identifies:

Mandatory requirements for use of chemicals in fracture stimulation (section 6.2 of the Code of Practice)	**Document**
All chemicals to be injected as part of the fracture stimulation process	Section 7.5; and HHERA (Appendix C to the REF)
The Chemical Abstract Service (CAS) registry number for those chemicals	HHERA Appendix C to the REF
The volumes and concentrations of those chemicals	Section 7.5; and HHERA (Appendix C to the REF)
Potential risks to human health arising from exposure to those chemicals	HHERA section 3.4, section 4 (Appendix C to the REF)
The risk, likelihood and consequences of surface spills of these chemicals	HHERA section 3.4.3 and Table 9
Whether chemical concentrations at the point of injection will exceed: ANZECC 2000 guidelines for overlying groundwater and	HHERA section 3.4.3 and Table 8 and HHERA appendices

surface water uses that may be affected; ADWG 2004 if a drinking water supply may be affected natural background concentrations if the water source is not effectively described by ANZECC or ADWG guidelines; or if the chemical is not specified in ANZECC or ADWG guidelines and may have a toxic effect, then assess whether the toxic[1] effect is likely to exceed a trigger toxicity level determined in accordance with a suitable methodology such as those described in section 2: OECD Guidelines for the Testing of Chemicals	
The risk, likelihood and consequence of the injected chemicals affecting the beneficial use class of the target aquifer or any other aquifer	Risk Assessment Report (Appendix L of the REF), including Groundwater risk assessment
Storage and management of chemicals	REF EMP EIRP Risk Assessment Report (Appendix L of the REF)

[1] As defined in Approved Criteria for Classifying Hazardous Substances (National Occupational Health and Safety Commission 2004).

7.5 Fracture Stimulation Additives

[Code of Practice, Sections 6.1, 6.2]

A list of additives (concentrations and volumes) that may be used in fracture stimulation of these pilot wells is provided in the table below. While linear gel has been selected for the Waukivory Pilot, all additives that may be needed have been listed for completeness, and risk assessed in the HHERA. The number of additives has been minimised as far as possible.

The recipe used for hydraulic fracturing fluid were selected to represent the most basic, low risk recipe with the least number of additives, to ensure potential impacts to subsurface coal seams are negligible to minor, while at the same time providing adequate physical properties to achieve the hydraulic fracturing design objectives.

Volumes and Constituents in Proposed Fracture Stimulation Fluid

(Based on information provided by AGL's contracted service provider)

Purpose	Compound Present	Well Pre-Treatment[1]	Treated Water	Linear Gel	Cross-Linked Gel	Indicative Quantity[2]
		% volume of compound in fluid				(litres)
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[3]**	-	<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
Total		100.00%	100.00%	100.00%	100.00%	4,039,000

Indicative Volume of Fluid[2]	Well Pre-Treatment[1]	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:

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

(2)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.

(3)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.

7.6 Water Usage and Resources

[Code of Practice, Section 7.1, 7.2]

Water for the activities covered in this FSMP will be sourced from licensed water supply works located on either of AGL's Pontilands and Tiedman's properties off Fairbairns Road. AGL (in advance of the REF evaluation and approval process) has submitted an application to NOW to licence a large dam on the Pontilands property and to take water for 'stock, irrigation and industrial' purposes.

The estimated volume of water to be used in these fracture stimulation activities is approximately 4 ML for the Waukivory Pilot site (equivalent to the volume of approximately 1.6 Olympic sized swimming pools). The expected licence allocation for industrial/stock/irrigation purposes for the Pontilands Dam is 20 ML per annum (from the total volume available in dam of approximately 50ML) so there will be sufficient water available to take this source water for industrial purposes. For further information see the Surface water and Groundwater Management Plan, which is Appendix G to the REF.

7.7 Hydraulic Fracture Stimulation Fluid Pump Schedules

[Code of Practice, Sections 3.1, 3.2, 10.2]

Pumping schedules will depend primarily on three factors; proppant (sand) mass, proppant concentration, and fracture extension pressure. The fluid selected for the pumping schedule will be decided either from fluid compatibility tests or through historical information.

Proppant mass required for a hydraulic fracture stimulation is based on a factor of mass of proppant per net height of coal to be stimulated. A typical range for this factor is 3000 to 8200 kg of proppant /net metres of coal height.

Depending on the fluid selected, the proppant concentration will vary. Typical values for the maximum sand concentration able to be supported for the three main types of fluids are:

- Treated water: up to 200kg proppant /m3 of fluid
- Linear Gel: up to 500kg proppant/m3 of fluid
- Crosslinked Gel: up to 1000kg proppant /m3 of fluid

Maximum proppant concentrations are generally only a guideline for planning material quantities (water, proppant and additives) required to execute stimulation. Often the maximum proppant concentration is decided during the treatment by observing the treating pressures. The onsite engineer will often make changes to the pumping schedule during the operation based on observed treating pressures and rates and other diagnostic data that is able to be analysed in real time. Should a significant event occur that is outside of the expected operating parameters, the TARP will be implemented.

7.8 Fracture Geometry Modelling

[Code of Practice, Sections 3.1, 3.2, 10.2 and Sections 3.3, 10.3 *Leading Practice*]

Several simulators are available for modelling the idealised geometry of hydraulic fractures. To ensure that these models are reliable, they will be calibrated using direct diagnostic tools to accurately predict fracture geometry. AGL has developed a mechanical earth model to incorporate measured stress (both core and *in-situ*) in target zones and bounding layers into the fracture stimulation model (see section 2.6).

Numerical simulators require a great deal of input data in order to accurately represent the rock mechanics, fluids, pressures, and temperatures. Modelling is strengthened by performing diagnostic injection tests prior to the main fracture stimulation. The diagnostic injection test includes pumping a predetermined volume of the selected fracture fluid into the coal seam without any proppant. The pressure decline post injection is monitored and the information obtained by this test can be entered into the fracture simulator and a higher degree of confidence is then obtained. During the fracture stimulation at Waukivory 13, real time monitoring will occur using geophones in a neighbouring monitoring well. This will enable the fracture geometry to be monitored whilst the fracture propagates, and afterwards fracture stimulation model will be further refined with this measured data.

7.9 Equipment Selection

[Code of Practice, Sections 5.2, 10.2, 14.2]

The equipment that comprises a hydraulic fracture stimulation fleet generally consists of High Pressure Pumps, Treating Iron, Blending Equipment, Dry Gel Blender, Well Head Equipment Monitoring Instrumentations and a Data Monitoring Van. Other pieces of equipment may include mobile fluids laboratories, additive trailers, and additive pumps.

High Pressure Pumps

High pressure pumps should be evaluated for both their hydraulic horsepower (hhp) and their maximum working pressure. It is general practice to have at least 50% more hhp on location than the job design specifies to compensate for unforeseen equipment failures and/or treating conditions. Pump combinations should be able to deliver both high and low flow rates to allow sensitive adjustment of flow rate as required for hydraulic fracture stimulation in exploration wells.

The pumping equipment will be rated high enough to carry out the required pressure test. The pressure test will be at least 10% higher than maximum allowable treating pressure during the job. Therefore the pumping equipment will be pressure rated to greater than the pressure required for the pressure test.

Treating Iron

The treating iron is the high pressure steel pipe which carries fluids from the pump to the wellhead.

The treating iron on location will have annual inspections. Inspection of treating iron will include hydrostatic pressure testing and wall thickness measurements. The pressure rating of the treating iron will be at least, if not greater than, the required test pressure.

The treating iron will be arranged so that maximum fluid flow rates are not exceeded in any of the treating iron components. Tables of maximum flow rates will be kept, and made available by the service company for their respective equipment.

Blending Equipment

The blending equipment on location should be able to add the required number and quantities of additives. The additive rates required is cross checked against the additive rates available from the blending equipment.

Dry Gel Blending Equipment

AGL will use a dry gel blender, allowing an environmentally sensitive option compared to batch mixing of fracture fluid. When using a dry gel blender, additives are mixed with water as it is pumped to create the fracture stimulation fluid. The advantages of this technology are significantly less volume of leftover fluids which would then have to be disposed of, less additive usage and better environmental control. Less handling and mixing of additives will result in a lower exposure to safety risks and greatly reduced risk of spillage of made-up fracture stimulation fluid.

Data Monitoring Van

The data monitoring van is generally the central point of communications during a treatment. It is important that the supervisors in the Data Monitoring Van have a clear line of site of the well site, and that all data acquisition equipment is properly recording. Prior to a treatment, all data equipment and sensors are calibrated and tested to ensure proper operation and reliable recordings.

8 Fracture Geometry Diagnostics

[Code of Practice, Sections 3.1, 3.2, 10.2, 13.2, 14.2 and Section 10.3 *Leading Practice*]

Fracture geometry is complex and can take many shapes and orientations. Over 6,000 mapped fractures have shown fracture geometries with multiple parallel planes, geometries in multiple directions, and "T-Shaped" fracture geometries having both a vertical and a horizontal component (Barree, 2002).

However by implementing proper diagnostics, fracture geometry can be properly characterised. Table 1 lists the various diagnostic tools available for monitoring fracture geometry along with their associated limitations and degrees of certainty.

Table 1. Fracture Geometry Diagnostic Tools, Limitations, and Degree of Certainty

Will Determine	**Y**
May Determine	M
Can Not Determine	N

Group	Diagnostic	Main Limitation	Length	Height	Width	Azimuth	Dip	Volume	Conductivity
Indirect, Direct, Near Wellbore	Net Pressure Analysis	Modelling assumptions from reservoir description	M	M	M	N	N	M	M
	Well Testing	Need accurate permeability and pressure	M	N	M	N	N	N	M
	Production Analysis	Need accurate permeability and pressure	M	N	M	N	N	N	M
	Radioactive Tracers	Depth of Investigation	N	M	M	M	M	N	N
	Temperature Logging	Thermal conductivity of rock layers skews results	N	M	N	N	N	N	N
	Production Logging	Only determines which zones contribute to	N	M	N	N	N	N	N

		production							
	Borehole Imaging Tool	Run only in open hole and only provides near wellbore information	N	N	N	M	M	N	N
Direct **Far Field**	Surface Tilt Mapping	Resolution decreases with depth	M	M	N	Y	Y	Y	N
	Downhole Offset Tilt Mapping	Resolution decreases with offset well distance	Y	Y	M	M	M	M	M
	Geophone Mapping	May not work in all formations	Y	Y	N	Y	M	N	N
	Treatment Well Tiltmeters	Fracture length must be calculated from height and width	M	Y	Y	N	N	N	N

To determine fracture geometry with a high degree of confidence the methods that must be employed are a Surface Tilt Mapping, Downhole Offset Tilt Mapping, and/or Geophone Mapping. These diagnostic tools directly measure the geometry of the fracture. The results from using this new technology will assist in understanding the response of fracturing in a known geographical area.

8.1 Diagnostic Tools

There are many diagnostic tools used in the oil and gas industry in conjunction with hydraulic fracture stimulation.

The suite of diagnostic tools proposed for diagnosing fracture geometry at the Waukivory Pilot will be Temperature Logging, Geophone monitoring, Nolte-Smith plots (Diagnostic Plots), and Pressure Confirmation Test.

Geophone Monitoring Technology

Geophone monitoring is based on detecting the small reservoir movements that take place as a result of the fracture stimulation process. These movements are caused by changes in stress (fracture opening) and fluid pressure (leakoff), and they occur along natural fractures, bedding planes, and other weakness zones in the rocks with which the fracture makes contact. Therefore, it is an acceptable and widely used technology for monitoring fracture growth by tracking the distribution of the microseismic events. The geophones are so sensitive, they are picking up movements of fracture growth which are typically 1-millionth the size of a movement that could be detected by a human. Geophone fracture mapping services enable real-time monitoring of key fracture parameters, fracture height and length, fracture azimuth, fracture asymmetry, fracture growth versus time and formation containment.

Geophone monitoring is usually performed by placing long arrays of sensitive receivers in offset wells at a depth that is close to the zone to be fractured. The microseisms are characterized by the emission of both compression (P) waves and shear (S) waves, and these are detected by the receivers in the monitoring well. Robust grid-search and migration methods are used to determine where the events originated based on wave arrival times and polarizations. It is important to have an accurate velocity model, therefore significant effort is placed on characterizing and calibrating the model.

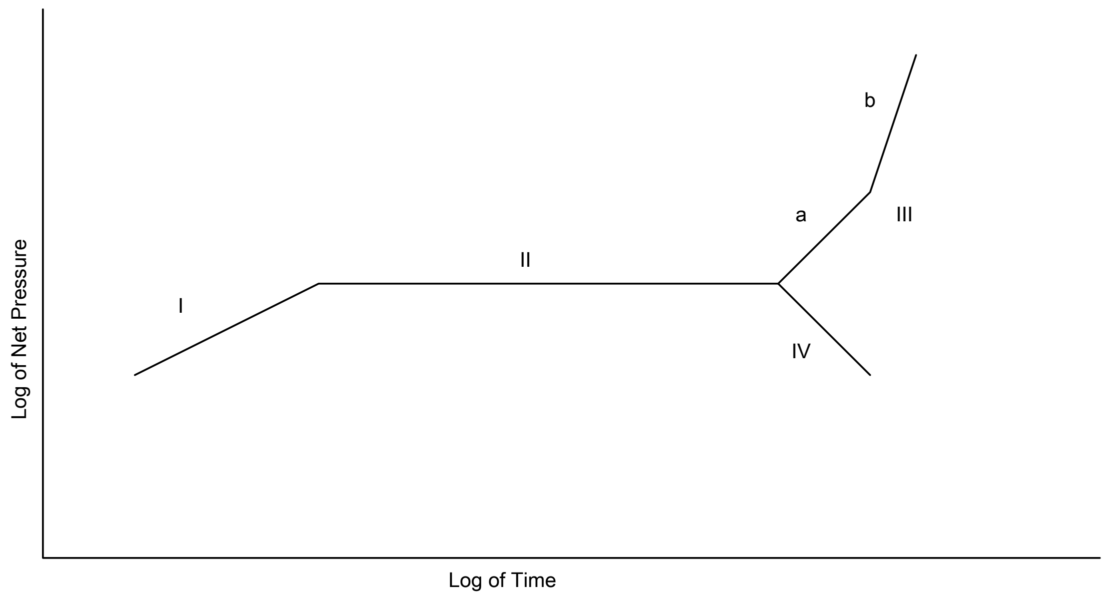
The distance that microseisms can be observed depends primarily on the size of the microseism and noise levels. In shale reservoirs, microseisms can often be detected at distances up to 1,500 m, whereas many other reservoirs such as coal have much shorter observation distances. In shale and tight gas sand formations, the large detection distance allows vertical height to be monitored even if there is significant height growth. Although the microseisms in coal are less pronounced, they can be accurately measured by having the geophone monitoring well closer to the offset well that is being fracture stimulated. Depending on the coal, the distance may be between 60 to 250 metres.

For the Wauikivory Pilot project, the geophone monitoring well will be 160 metres from the selected well to be fractured.

Geophone monitoring technology is typically deployed in the exploration phase to better understand fracture geometry, optimize the fracture treatment, provide information on geometry which will compliment groundwater testing and optimize well spacing and density.

Diagnostic Plots (Nolte Smith Plot)

A Nolte-Smith Plot can be used to analyse net pressure real-time responses during a fracture treatment to interpret the fracture geometry being created (Economides, 2007).



- Mode I: Propagation of fracture geometry.
- Mode II: Represents height growth in addition to length growth, or increased fluid loss, or both.
- Mode IIIa: Indicates that there is width growth. Good indication that a tip screenout is occurring.
- Mode IIIb: Indicates that a screenout is occurring
- Mode IV: This behaviour is indicative of uncontrolled height growth.

By using a Nolte-Smith plot during activities it is possible to predict if a fracture is starting to grow out of the targeted formation. If this behaviour is observed the treatment can be stopped prematurely or slowed to avoid excessive height growth. In this way, AGL and its contractor will carefully control the extent of fracture propagation during the hydraulic fracturing activity.

Pressure Confirmation Test

Fracture treatments commence from the deepest target seam, progressing up the well targeting the next upper interval. When a zone has been fracture stimulated, the zone is isolated by deploying a wireline set bridge plug. This plug provides a pressure seal and isolates the fractured zone which still contains pressure from the treatment. When the next upper zone is perforated, the pressure in the well is monitored. If there is an increase in pressure or the well starts to flows then it can be determined that the pervious fracture has grown and intersected the coal above. If no change in pressure is measured, then it can be determined that the lower fracture did not intersect the zone above. This test is repeated as the intervals are treated in the well.

Temperature Logs

A geophysical logging unit is used to lower temperature instruments into a well after the fracture execution. The temperature profile when compared to the base temperature gradient provides information such as fracture height growth. Although the well is cased and cemented, the temperature probes used can measure the influence of temperature behind pipe.

9 Execution

[Code of Practice, Sections 5.1, 5.2, 13.1, 13.2, 14.2]

The execution of a hydraulic fracture stimulation usually involves several parties (i.e., AGL personnel, hydraulic fracture stimulation company operators, perforation company operators and crane company operators). It is important when conducting fracture stimulation activities that a clear line of communication and reporting is established between all parties.

Each service company will have their own safety standards and standard operating procedures to abide by. However, outlined below are the guidelines for the practices adopted to execute a safe and successful hydraulic fracture stimulation activity.

[see also Risk Assessment, HHERA and Gloucester Gas Project Emergency Management Plan.]

The Principal Contractor (Fracturing Services Company) is an integral participant in the safety management plan and emergency response plan as regards fracturing stimulation activities. These plans are conducted to minimise risk to health and safety of employees of AGL, principal contractor, and other contractors, official visitors to the fracture stimulation operation site, and general public that may be affected by the activities.

The safety management plans and standard operating procedures of contractors and AGL are assessed to ensure that interaction between parties is managed safely and safety responsibilities are identified for each party.

9.1 Pre Job Planning

[Code of Practice, Section 5.2]

The service company will ensure the following before mobilising to location:

- Review loadout sheet and verify all equipment and additives required for the operation are loaded.
- Ensure that all MSDS sheets are available for the additives to be used.
- Ensure that adequate pressure and rate monitoring equipment is loaded with the data monitoring van.
- Supervisor reviews the projects pumping requirements and ensure that sufficient treating iron and pumps are available.

9.2 Location Preparation

[Code of Practice, Sections 5.2, 13.1, 13.2]

The following should be read in conjunction with the Health and Safety Management Plan and Environmental Management Plan location preparation requirements:

- Conduct Operator specific site induction for the area.

- Conduct a safety meeting upon arriving at location.
- Assign roles and responsibilities to all crew members involved on location.
- Review the location and assess for safety hazards.
- Designate a muster area in case of emergency.
- Spot the equipment on location. A guide should be used when spotting equipment. The guide should be wearing high visibility vest.
- Verify that all tanks on location are equipped with sites so that fluid volumes can be gauged and recorded.
- Verify proppant quantities on location.
- Verify wellhead for connection and pressure rating.
- Check there is adequate communication equipment on location so that all personnel operating critical machinery are in direct communication with the site supervisor.
- Prime pumps and treating lines.
- Follow the service company's standard operating procedures to conduct pressure tests.
- Set and test pressure relief valves according to the service company's standards.
- Set and test the overpressure shutdown system according to the service company's standards.

9.3 Fluids Quality Assurance

[Code of Practice, Section 10.2(e)]

Prior to execution of the operation, the fluids are tested for quality assurance. Upon arrival at the location the service company will:

- Treat water with bactericide if batch mixing the gel. If using a dry add gel blender, bactericide will be added in measured dose as the fluid is pumped.
- If using a gelled system, perform a gel test with water on location and the gelled system to be used. The water and gel additives should yield the desired viscosity. If the system does not gel, then remediation should be undertaken until desired gel system is obtained.
- Once a good gel is obtained, a gel breaker test is performed. The breaker is tailored to give the desired break time.

9.4 Mitigating Health, Safety and Environment Risks

[Code of Practice, Sections 4.2, 5.2, 13.1, 13.2]

A number of documents are relevant to mitigating health, safety and environmental risks.

The Risk Assessment Report (Appendix L of the REF) identifies how activities will be conducted in a manner that mitigates health, safety and environment risks (including additive use, impact on water resources, land contamination, air pollution, noise and vibration, induced seismicity, induced subsidence or other induced ground movements, and waste management).

The Gloucester Gas Project Emergency Response Plan (Appendix D to the REF) identifies how activities will be conducted in a manner that mitigates risk due to loss of well integrity, workplace health and safety and public safety.

The Gloucester Gas Project Environmental Management Plan (see Appendix I in the REF) forms the basis of the environmental management for the GGP's exploration activities. The Environmental Management Plan:

- provides that all activities will be undertake in accordance with the AGL Energy HSE Policy, which outlines AGL's commitment to ongoing sound management of environmental aspects and performance;
- sets out AGL's Environmental Principles, which include a commitment to minimise our impact on the environment;
- describes AGL's Environmental System Management Framework for the GGP;
- sets out key legislative and regulatory requirements;
- describes GGP activities;
- sets out processes for implementation, monitoring and review; and
- incorporates the environmental management requirements of Life Guard, the AGL Health, Safety and Environment (HSE) Management System which is based on the requirements of ISO: 14001:2004. The Life Guard system is implemented across all AGL Energy operated businesses.

The Gloucester Gas Project Environmental Incident Response Plan (see section 6 above and REF) sets out procedures to be followed and actions to be taken in the event of environmental incidents.

The Gloucester Gas Project Health and Safety Management Plan (as referenced in section 4.4 above and see Appendix E to the REF) addresses the specific safety risks that might arise from a fracture stimulation activity, including ensuring that the design and operation of the site and equipment are safe, and including mitigating risks due to noise and spills.

For mitigating conflicts with existing land uses see section 4.2 (Stakeholder Consultation) and Section 13 (Coal Mining).

For further information on potential for impact on water resources see section 2.3, as well as the Surface Water and Groundwater Management Plan.

AGL has carried out a comprehensive assessment of all risks associated with the activity and how each of the identified risks will be avoided, managed or mitigated by adopting best practice safety and environmental risk management practices.

Given AGL's controls, the risk of a "worst case" operational scenario, being a loss of well integrity or if natural gas is found to be leaking out of the ground from unidentified well bores, is low.

However in the unlikely event that AGL experiences one of these events, then AGL would immediately take steps to contain the situation by shutting down hydraulic fracturing activities or flow testing operations to identify the cause of the incident, and rectify the issue. This would be considered a reportable incident to the OCSG and the EPA.

In the highly unlikely event that the cause of the incident cannot be immediately identified or the steps taken to rectify the situation are unsuccessful, then a management plan would be initiated to identify and rectify the issue. This would be done in consultation with relevant regulators.

As a last resort, then a protective measure can be taken to stop any and all leakage by injecting cement into the entire well and plugging the well and sealing all perforations (plugging and abandoning). This means that the well bore is sealed and isolated from the surrounding rock and coal layers.

The process of plugging and abandoning a well is a common practice that is carried out at the end of life of a natural gas well but it is also a practice that can be applied at any time when there is a risk that well control or well integrity has been compromised. Once a well has been plugged and abandoned, the well is completely inert and isolated from the external environment.

The small and highly diluted concentration and choice of additives being used in the hydraulic fracture stimulation activity when compared to the gross rock and water volume of the earth stratum located in the area of the pilot well project, means that there is likely to be negligible long term impact on the natural environment in the highly unlikely event of a worst case operational scenario.

9.5 Job Execution

[Code of Practice, Sections 5.2, 10.2(e), 13.1, 13.2]

Following the completion of rig up all personnel involved in the operation will conduct a safety meeting. This meeting will be lead by the supervisor of the service company.

- Discuss the details of the operation from start to finish.
- Assign roles and responsibilities and line of communication.
- Review expected treating pressures and maximum allowable pressures.
- Point out the location of the muster area.
- Designate emergency response and first aid personnel and an emergency vehicle.
- Ensure that the pump operator, supervisor, and blender operator have Operating Procedures for the pump and additives schedule.
- Outside supervisor should walk the treating lines and ensure that valves are in the correct configuration.
- Conduct a final pressure test before starting the job.
- Acquire approval from AGL representative before beginning the treatment.
- Open the wellhead.
- Begin the treatment as per designed pump schedule.
- If changes are made to the schedule they should be communicated through the service company supervisor.
- The engineer should monitor and record the pressure and rate data.
- Nolte-Smith plot should be used to interpret net pressure and make informed decisions about fracture geometry.
- Following the treatment, the well should be shut-in and wellhead pressure is to continue being monitored.
- Monitor the pressure until fracture closure is determined to have occurred.
- Once closure is determined, begin flowing back the well and recovering fracture stimulation fluid as per AGL's standards (See section 10 of this FSMP for details).
- While the well is flowing back, the service company can begin rigging down equipment.
- The principal fracture stimulation contractor is responsible for removal and disposal of any garbage, waste and additives on site at the completion of the fracture stimulation activity, in accordance with fracture stimulation contractor's environmental management procedures.

This will be monitored by AGL's Environment Officer ensuring disposal is managed with strict adherence to its environmental conditions.

10 Flowback, Dewatering and Disposal

[Code of Practice Sections 8.1, 8.2 and Section 8.3 *Leading Practice*]

AGL will manage flowback water in a way that ensures risks to health, safety and the environment are appropriately managed.

It is a commonly accepted practice in hydraulic fracture stimulation to flow back a well as soon as possible following a treatment. However in coal seams it is recommended to allow the reservoir to fully close before flowing back the well to minimise the amount of proppant that flows back. Closure of the fracture can be determined using diagnostic techniques such as Nolte-G Plot or Square Root of Time plot.

Specific flowback procedures will be followed to mitigate safety and environmental risks. [Gloucester AGL Risk Assessments, Appendix L of the REF].

The fracture stimulation fluid will be flowed back to an open – top tank fitted with a diffuser to diffuse the energy of the flowback stream directly from each individual well. A spare tank will be available to take on flowback water from the flowback tank to ensure sufficient holding capacity is available on site. Water quality sampling will be undertaken in accordance with the Surface Water and Groundwater Management Plan. Flowback water will then be lawfully disposed of to an appropriate facility.

Flowback water will be monitored until it has a salinity of 5000 µS/cm (expected composition of natural formation (coal seam) groundwater). Salinity readings will be used as the primary determinant to assess the recovery of flow back water. Pumped volumes will also be tracked and recorded. At this stage the fracture stimulation fluid flowback will be deemed complete when 100% of the injected volume is recovered and salinity reaches 5000 µS/cm. Subsequent water flow is known as produced water. Reuse of produced water (such as mixing with fresh water to a suitable quality for crop irrigation) is described in the REF (i.e., reuse for purposes of irrigation is subject of a separate approval).

For the fracture stimulation program, tracking water quality and any changes is important. The following water quality sampling program is proposed for all gas well locations:

- raw (source) waters to be used for fracture stimulation;
- fracture stimulation fluid mixture (i.e. the raw waters plus the sand and any additives) to be injected into each gas well (if there are multiple fracture stimulation zones per well and all are the same recipe then just one event will be sampled);
- flowback water (i.e., return water still exhibiting composition of fracture stimulation fluid); and
- produced water (natural groundwater from the coal seam/s) when sufficient fracture stimulation fluid volume is pumped back to surface so that the water exhibits the same composition as natural formation water. This is different for every fracture stimulation activity, but is expected to be after around 8 - 12 weeks of flowback.

Further details of this water monitoring program (including analytical suites) are provided in the Surface Water and Groundwater Management Sub-plan (see REF).

This FSMP is being submitted as part of an overarching REF, and as such any consent conditions will be incorporated into the storage requirements, methods for disposal and other surface water management methods in addition to those described in this FMSP.

11 Monitoring

[Code of Practice, Sections 10.1, 10.2 and Section 8.3 *Leading Practice*]

Fracture stimulation activities will be effectively monitored to allow the prompt identification and mitigation of any health, safety or environmental risks.

The FSMP describes the monitoring program to ensure that any risks have been identified, quantified and avoided or appropriately managed so that residual risks are within acceptable limits before, during and after the fracture stimulation activity.

11.1 Pre-Job Water Monitoring

Prior to fracture stimulation activities, overlying beneficial aquifers and surface water sourcesare monitored to assess water level/pressure trends and to characterise the water quality. Details are provided in the Surface Water and Groundwater Management Sub-plan for this program.

As well as the four dedicated monitoring bores (three AGL sites and one GRL site)(plus the deeper piezometers at WKmb05) close to the pilot testing sites, property surveys to assess baseline water levels and water quality in private bores will be conducted on neighbouring properties within a 2km radius (if access is allowed). Two kilometres is more than sufficient to encompass the predicted fracture length plus a very large margin to provide for any uncertainty.

11.2 Job Monitoring

During a fracture treatment the following will be monitored and recorded:

- Raw water quality of the source water to be used for fracture stimulation
- Bottom hole pressure
- Surface injection pressure
- Fracture fluid mixture water quality
- Fracture fluid injection rates and volumes (including viscosity and pumping rate)
- Additive rates and volumes
- Proppant rates and volumes

11.3 Post-Job Monitoring

Flowback fluids can be monitored so as to determine when all the flowing fluid has transitioned from injected fracture stimulation fluid to produced water. Monitoring will:

a) Determine the volume and water quality of flowback and produced water;
b) Quantify any change in surrounding water sources;
c) Pressure test casing to verify that the integrity of the well and well equipment has been maintained.

AGL will monitor salinity and composition of the flowback fluid, along with flowback water volumes to identify transition from flowback water to produced water. Details are provided in the Surface Water and Groundwater Management Sub-Plan.

12 Post Job Analysis

An integral part of the continuous improvement process in the hydraulic fracture stimulation process is post job analysis and reporting. The service company will provide AGL with a detailed analysis of treatment including:

- Designed Pump Schedule
- Actual Pump Schedule
- Summary of all additives used and their quantities
- Plot of the treatment pressures, rates, and proppant concentrations over time
- Plot of the additive rates over time
- Pressure decline analysis selecting closure:
- Nolte G Plot
- Square Root of Time Plot
- History Pressure Match
- Fracture geometry prediction
- A table summarising the following details;
    - Average Treating Pump Rate
    - Average Treating Pump Pressure
    - Formation Breakdown Pressure
    - Instantaneous Shut In Pressure (ISIP)
    - Fracturing Gradient
    - Closure Pressure
    - Closure Gradient
    - Tubular Friction (@ISIP)
    - Perforation Friction Pressure (@ISIP)
    - Total Near Wellbore Friction
    - Treatment Pad Fluid and Volume
    - Treatment Main Fluid and Volume
    - Treatment Flush Fluid and Volume
    - Treatment Total Water Volume
    - Proppant Type and Mass

- Maximum Proppant Concentration Placed
- Total Proppant Placed In Formation
- Total Proppant Pumped

13 Coal Mining

[Code of Practice, Sections 9.1, 9.2]

The FSMP aims to ensure that fracture stimulation activities do not adversely impact on current and future (approved) coal mining activities.

The Waukivory Pilot is located to the north of the Stratford Coal mine owned by Yancoal Australia Ltd. The mine currently conducts open cut mining across several small pits covering the stratigraphic interval from the Avon up to the Roseville coals.

The Waukivory Pilot is located within EL 6523 operated by Gloucester Resources Ltd which currently proposes to conduct open cut mining adjacent to the Waukivory Pilot. Gloucester Resources was consulted during the planning of the Waukivory Pilot to ensure the placement of wells would not impact on their proposal.

AGL is currently in discussions with both Yancoal Australia Ltd and Gloucester Resources Ltd regarding cooperation agreements.

AGL commissioned Orica to carry out a study of potential mine blasting and vibration impacts on its infrastructure.

Taking into account the maximum blasts proposed by the Stratford Mine Extension Project, Orica recommends that a minimum distance of 180 metres should be kept between mine blasts and well heads, pipelines and other infrastructure, to avoid blasting and vibration impacts.

The Stratford Mine open cut area is over 5km from the Waukivory Pilot. Therefore no impact from blasting is expected.

14 Notification and Reporting

[Code of Practice, Sections 14.1, 14.2]

In addition to notification requirements under the Environment Incident Response Plan, Safety Management Plan, EPL and PEL 285, AGL will notify the OCSG immediately as is practical in the event of:

- an incident resulting in threatened or actual loss of well integrity;
- a fracture stimulation being prematurely terminated in the event of a sudden and apparent loss of pressure (indicating possible uncontrolled vertical growth out of the target coal seam) where diagnostic monitoring indicates unusual vertical height growth, or an abnormal fracture treating pressure response which cannot be rectified by changes to the pumping schedule;
- in the event that gas is found to be leaking out of the ground from an unidentified bore.

A completed Fracture Stimulation Completion Report will be submitted to the Department's Mine Safety Operations and Environmental Sustainability Unit in the approved form within 30 days of completing hydraulic fracture stimulation activities on a well.

The Fracture Stimulation Completion Report will comply with the requirements of section 14.2 of the Code of Practice.

[Code of Practice Section 15.2(d)]

Following plug and abandonment of a well, AGL will provide the department with a copy of the records referred to in section 15 below.

15 Record Keeping

[Code of Practice, Section 15.1, 15.2]

Records of fracture stimulation activities must be kept in accordance with the Code of Practice. Records are to be made available to the Department for inspection on request.

The following records will be kept for each fracture stimulation:

- The FSMP
- Fracture stimulation design inclusive of fluids, treating rates and pressures, and designed pressure test requirements
- Laboratory tests conducted on fluids used in the fracture treatment
- Pressure tests
- Any leak off tests and/or formation integrity test report
- Additives used in the fracture stimulation fluid (name, type and volumes)
- Site specific risk assessments
- Source of water used in the fracture stimulation
- Service company operation reports
- Environmental monitoring results
- Completion report

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Glossary

Aquiclude	An impermeable body of rock or stratum of sediment that acts as a barrier to the flow of groundwater (also aquitard)
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 Connectivity	Exchange of flow of water from one aquifer to another
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.
Australian Height Datum (AHD)	The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores.

Barrier	Any means of preventing an uncontrolled release or flow of well bore fluids to surface.
BOP	Blowout Preventer: one of several valves installed in a wellhead to prevent the escape of pressure either in the annular space between the casing and the drill pipe or in the open hole during drilling, completion and workover activities
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Breaker	An additive that reduces the viscosity of a fluid by breaking long-chain molecules into shorter segments.
Casing	A pipe placed in a well to prevent the wall of the hole from caving in and to prevent movement of fluids from one formation to another
Casing Head	A heavy flanged steel fitting connected to the first string of casing. It provides a housing for slips and pack-off assemblies that surface seal additional casing/tubing strings
Cement	Powder consisting of alumina, silica, lime and other substances that hardens when mixed with water. Extensively used to bond casing to the walls of the wellbore
Centipoise (CP)	The symbol for centipoise is cP or cps, depending on the source. It is a unit of measurement for the viscosity of a fluid. The viscosity of a fluid is described as the measure of a fluid's resistance to flow e.g. water flows easier than honey, therefore honey has the higher viscosity.
Claystone	A non-fissile rock of sedimentary origin composed primarily of clay-sized particles (less than 0.004 mm).
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.
Completion (Or Workover) Program	A document that describes the detailed well procedures and risk mitigation for activities including completions, testing, intervention, well repair and/or abandonment
Contractors	Third parties contracted by AGL to provide well engineering equipment including drilling rigs, materials, equipment and

	services
Coring	Process of cutting a vertical, cylindrical sample of the formations.
Crosslink Gel	A fluid that has a very high viscosity typically in the range of 200-1000 cP
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.
Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
Drilling Fluid/Mud	Circulating fluid that can lift cuttings from the wellbore to the surface and cool the drill bit.
Drilling Program	A document that describes the detailed well procedures and risk mitigation for activities including drilling, testing and/or well suspension
Electrical Conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved in water. It is often used as a measure of water salinity.
Evaluation	Includes mud logging, wire line logging, formation evaluation while drilling, coring and well testing
Flowback	The process of allowing fluids to flow from the well following a treatment, either in preparation for a subsequent phase of treatment or in preparation for cleanup and returning the well to production.
Flowback Water	In relation to this document, flowback water is the return to surface of fracture stimulation fluids before transition to natural formation water, after which fluid flowing from the well is termed produced water.
Fracture Pad	The initial part of the fracture fluid that creates the fracture width and controls the initial fluid loss but contains no proppant.
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.

Hydraulic Conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).
Injection Well	Well through which fluids are injected into an underground stratum which may increase reservoir pressure.
Leak Off Test	Progressive wellbore formation pressure test: fluid is pumped fluid is pumped into the wellbore to gradually increase the pressure that the formation experiences. At some pressure, fluid will enter the formation (or leaks off) to provide well integrity information
LFL	Lower Flammable Limit: lowest concentration (percentage) of a gas or vapour in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). Concentrations lower than LFL are ‘too lean’ to burn. Also called lower explosive limit (LEL). CSG is flammable at a concentration of between 5% and 15% of gas in air.
Linear Gel	A fluid that has a higher viscosity than water but a lower viscosity than crosslink gel. Typically they have a viscosity between 12 – 20 cP.

Microsiemens/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.
Operations / Activities	Any work conducted including rig moves, drilling, running and cementing casing, evaluation, completion, workover and abandonment
Perforations	The communication tunnel created from the casing or liner into the reservoir formation, through which oil or gas is produced. The most common method uses jet perforating guns equipped with shaped explosive charges. However, other perforating methods include bullet perforating, abrasive jetting or high-pressure fluid jetting
Permeability	The ability, or measurement of a rock's ability, to transmit fluids, typically measured in darcies or millidarcies. The term was basically defined by Henry Darcy, who showed that the common mathematics of heat transfer could be modified to adequately describe fluid flow in porous media.
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).
Porosity	The percentage of pore volume or void space, or that volume within rock that can contain fluids. Porosity can be a relic of deposition (primary porosity, such as space between grains that were not compacted together completely) or can develop through alteration of the rock (secondary porosity, such as when feldspar grains or fossils are preferentially dissolved from sandstones).
Primary Well Control	Precautions taken to avoid an influx of formation fluid to the wellbore, including monitoring for increases in pore pressure, maintaining sufficient hydrostatic head and avoiding swabbing and surging
Produced Water	Natural groundwater generated from coal seams during flow testing and production dewatering. It does not include the other water streams (drill, fracture

	stimulation/flowback/workover water and brine water) that require separate water management.
Production Casing	A casing string that is set across the reservoir interval and within which the primary completion components are installed
Production Zone	Hydrocarbon producing zone of the formation
Proppant	Natural sand or synthetic high strength particles used with fracturing to fill the fracture space and hold the fracture open during the production life of a well.
Reservoir	A subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum system.
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
Sandstone Aquifer	Permeable sandstone that allows percolation of water and other fluids, and is porous enough to store large quantities.
Screenout	Occurs during a hydraulic fracture stimulation treatment when the maximum allowable treating pressure is reached before all the planned proppant is placed in the formation.
Secondary Well Control	Secondary Well Control is implemented when Primary Well Control has failed to prevent the influx of formation fluid or pressure into the wellbore. This involves the controlled circulation or the influx out of the well bore and, if necessary, increasing the mud gradient
Shale	A laminated sediment in which the constituent particles are predominantly of clay size.
Siltstone	A fine-grained rock of sedimentary origin composed mainly of silt-sized particles (0.004 to 0.06 mm).
Slickwater	A fluid with a very low viscosity (slightly higher viscosity than water) or water.
Slurry	A mixture of suspended solids and liquids. Muds in general are slurries, but are seldom called that. Cement is a slurry and

	is often referred to as such.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Surface Casing	A drilled and cemented pipe used to provide blow-out protection, to seal off water/hydrocarbon sands, and prevent loss of circulation. Often used to seal off water sands, weak formations and/or lost circulation zones. In some cases surface and intermediate casing requirements are provided by the same string
Surfactant	An additive that preferentially adsorbs at an interface, lowering the surface tension or interfacial tension between fluids or between a fluid and a solid. This term encompasses a multitude of materials that function as emulsifiers, dispersants, oil-wetters, water-wetters, foamers and defoamers. The type of surfactant behavior depends on the structural groups on the molecule (or mixture of molecules). Hydrophile-lipophile balance (HLB) number helps define the function that a molecular group will perform.
Unconventional Resource	An umbrella term for oil and natural gas that is produced by means that do not meet the criteria for conventional production. What has qualified as unconventional at any particular time is a complex function of resource characteristics, the available exploration and production technologies, the economic environment, and the scale, frequency and duration of production from the resource. Perceptions of these factors inevitably change over time and often differ among users of the term. At present, the term is used in reference to oil and gas resources whose porosity, permeability fluid trapping mechanism, or other characteristics differ from conventional sandstone and carbonate reservoirs. Coalbed methane or CSG, gas hydrates, shale gas, fractured reservoirs, and tight gas sands are considered unconventional resources.
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
	Includes the BOP stack, BOP control system, full open safety valves, circulating hose (and circulating head), drill string

Well Control Equipment	safety valves (inside BOPs), mud and cement pumps, the choke and kill lines and manifold, and all associated pipe work and valves.
Well Head Reportable Leak	An emission due to an unplanned release from a well site facility that, at a measurement distance of 150mm immediately above (and downwind) and surrounding the leak source in an open air environment above ground position; gives a sustained LFL reading greater than 10% of LFL for a 15 second duration.
Well Heads	The system of spools, valves and assorted adapters that provide pressure control of a production well.
Well Intervention	An operation carried out by re-entering an existing well
Well Program	A CSG Operator document that describes the detailed well procedures and risk mitigation for activities including Drilling, Completions, Testing, Intervention / Workover and/or Abandonment
Wellbore	A wellbore is a hole that is drilled to aid in the exploration and recovery of natural resources including oil, gas or water. A wellbore is the actual hole that forms the well. A wellbore can be encased by materials such as steel and cement, or it may be uncased.
Workover	Well procedure to perform one or more remedial activities on a producing well to attempt production increase. Examples of workover activities are pump repairs, well deepening, plugging back, pulling and resetting liners, squeeze cementing, re-perforating, etc
Zonal	An interval or unit of rock differentiated from surrounding rocks on the basis of its fossil content or other features, such as faults or fractures. For example, a fracture zone contains numerous fractures.

Appendix A – Code of Practice Table of Compliance

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
1 Fracture Stimulation Management Plan		
A Fracture Stimulation Management Plan (FSMP) must be in place prior to the commencement of a fracture stimulation activity.	✓	Section 1 - Introduction Section 1.1 - Operations
· The FSMP is a non-technical document which is designed to demonstrate to the NSW Government and other stakeholders that the titleholder will appropriately manage the risks associated with the fracture stimulation activity and comply with the mandatory requirements of this Code.	✓	"
· The FSMP may summarise relevant information from other regulatory documentation requirements and the titleholder's management systems, provided that the source of this information is identified.	✓	"
· For most exploration activities, the FSMP would normally be submitted with a Review of Environmental Factors (REF) as part of an activity approval application to the department. The FSMP may partially fulfil the content requirements for a REF as set out in ESG2: Environmental Impact Assessment Guidelines (NSW Trade & Investment - Mineral Resources Branch, 2012).	✓	"
1.1 Principles	✓	Section 1 - Introduction
· All fracture stimulation activities should be subject to a Fracture Stimulation Management Plan	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
(FSMP) approved by the NSW Government.		
· The FSMP should identify all relevant issues associated with the fracture stimulation activity and demonstrate how these will be managed to ensure that residual risks to the environment, community and workforce are reduced to acceptable levels.	✓	"
· The form of the FSMP should be flexible enough to accommodate and avoid duplication of existing titleholder management systems and regulatory requirements.	✓	"
· The detail provided in the FSMP should be appropriate to the nature, scale, intensity and potential impacts of the proposed fracture stimulation activity.	✓	"
· The FSMP should be freely available to the public.	✓	"
1.2 Mandatory requirements	✓	Section 1 - Introduction Section 1.1 - Operations
a) Fracture stimulation activities must not be conducted except in accordance with a FSMP approved by the department.	✓	"
b) The FSMP must describe the nature, location, scale, timing, duration, hours of operation and	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
other relevant features of the fracture stimulation activity.		
c) The 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.	✓	"
d) The FSMP must identify how the titleholder will address and comply with the requirements of this Code.	✓	"
e) The FSMP must be reviewed and as necessary revised by the titleholder:	✓	Section 3 - Compliance
i. before making a significant change to the design or operation of the fracture stimulation activity	✓	"
ii. if the sensitivity of potentially affected environmental, land use or community features significantly increases	✓	"
iii. in the event that monitoring indicates that the consequences of the fracture stimulation activity exceed those identified in the FSMP, or that a risk control measure does not adequately control the risk	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
f) The detail provided in the FSMP must be appropriate to the nature, scale, intensity and potential impacts of the proposed fracture stimulation activity.	✓	Section 1 - Introduction
g) The FSMP is a public document and may be published by the department on its website or by other means. Commercially sensitive or personal information should not be included within a FSMP unless specifically required by this Code.	✓	"
1.3 Leading practice	✓	Section 1 - Introduction
a) The FSMP may summarise relevant information from other regulatory documentation requirements and the titleholder's management systems, provided that the source of this information is identified and made available to the department.	✓	"
b) Examples of source documents referred to in (a) may include:	✓	"
· consultation plans	✓	Section 4.2 - Stakeholder Consultation
· risk assessments	✓	REF Appendix L REF Appendix C

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
· well design	✓	Submitted to regulator (DTIRIS)
· fracture stimulation design	✓	To be issued in Fracture Stimulation Program
· environmental impact assessments	✓	REF Appendix C
· operational plans	✓	To be issued in Fracture Stimulation Program
· environmental management plans	✓	REF EMP
· waste management plans	✓	REF EMP
· safety management plans	✓	REF Appendix E
· monitoring plans	✓	REF SWGMP
· incident response plans	✓	REF Appendix F
· emergency response plans	✓	REF Appendix D

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
· completion/workover programs	✓	Submitted to regulator (DTIRIS)
· notifications	✓	Section 4.1 - Notification
· fracture stimulation completion reports	✓	to be issued upon completion
2 Stakeholder consultation		
2.1 Principles	✓	Section 4.2 - Stakeholder Consultation
Titleholders should undertake appropriate consultation with stakeholders to:	✓	"
· ensure that affected stakeholders are fully informed about fracture stimulation activities	✓	"
· inform the risk assessment and development of management plans	✓	"
2.2 Mandatory requirements	✓	Section 4.2 - Stakeholder Consultation
a) Titleholders must consult with affected stakeholders prior to undertaking a fracture stimulation activity.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
b) The FSMP must summarise any stakeholder consultation undertaken, or proposed to be undertaken, prior to, during and after the fracture stimulation activity.	✓	"
2.3 Leading practice	✓	Section 4.2 - Stakeholder Consultation
Titleholders should engage in full and open communication with stakeholders, including providing stakeholders with an explanation of:	✓	"
a) the nature, location, scale, timing, duration, hours of operation and other relevant features of the fracture stimulation activity	✓	"
b) the risks associated with the fracture stimulation activity	✓	"
c) how these risks are being managed	✓	"
3 Fracture stimulation design		
3.1 Principles	✓	Section 7 - Design Section 7.7 - Hydraulic Fracture Stimulation Fluid Pump Schedules

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
		Section 7.8 - Fracture Geometry Modelling Section 8 - Fracture Geometry Diagnostics
The fracture stimulation activity should be designed to:	✓	"
· avoid impacts on water resources	✓	"
· contain fractures within the targeted area	✓	"
· minimise chemical use	✓	"
3.2 Mandatory requirements	✓	Section 7 - Design Section 7.7 - Hydraulic Fracture Stimulation Fluid Pump Schedules Section 7.8 - Fracture Geometry Modelling Section 8 - Fracture Geometry Diagnostics

Table of Compliance

Code of Practice Clause	**Comply**	**FSMP Reference**
The design of the fracture stimulation activity must be described in the FSMP. This description must incorporate the following:	✓	"
a) characterisation of geological formations, including the identification of rock types and conditions, aquifers and hydrocarbon-bearing zones	✓	Section 2.1 - Geology
b) definition of distances to these aquifers from the target coal beds	✓	Section 2.2 - Hydrology and Hydrogeology Section 2.3 - Target Formations
c) identification of the characteristics of intervening strata, including porosity/permeability and the extent of natural fracturing	✓	Section 2.3 - Target Formations
d) determination of geological stress fields and areas of faulting	✓	Section 2.4 - Rock Mechanics: Stress Fields
e) determination of maximum pressures to be used for fracture stimulation, based on the characteristics of the surrounding geology	✓	Section 2.5 - Pressures of Fracture Stimulation
f) modelling of the likely fracture propagation field, including extent and orientation	✓	Section 2.6 - Modelling

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
g) discussion of any potential for the fracture propagation field to exceed that modelled in (vi).	✓	Section 2.6 - Modelling
3.3 Leading practice	✓	Section 2.4 - Rock Mechanics: Stress Field Section 2.6 - Modelling Section 7 - Design Section 7.3 - Core Analysis Section 7.8 - Fracture Geometry Modelling
· Fracture stimulation modelling software can be used to assist in better understanding and controlling fracture growth.	✓	"
· Cores from formations of interest and bounding layers should be tested for rock mechanical properties and used in fracture stimulation simulations.	✓	"
4 Risk assessment		

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
4.1 Principles	✓	Section 4.3 - Risk Assessments
The FSMP should incorporate a risk assessment conducted in accordance with relevant Australian or international standards to identify the risks posed by the fracture stimulation activity and to ensure that the likelihood and consequence of these risks is properly understood.	✓	"
4.2 Mandatory requirements	✓	Section 4.3 - Risk Assessments Section 9.4 - Mitigating Health, Safety and Environment Risks
a) The FSMP must include a risk assessment complying with AS/NZS ISO 31000:2009 Risk management - Principles and Guidelines.	✓	"
b) The risk assessment must identify risks associated with the fracture stimulation activity, the likelihood of each risk and the consequence of each risk.	✓	"
c) The risk assessment must define appropriate management controls to ensure identified risks are constrained to acceptable levels.	✓	"
d) At a minimum, the risk assessment must address risks associated with:	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
i. workplace health and safety (see heading 5 of this Code)	✓	"
ii. public safety (see heading 5 of this Code)	✓	"
iii. chemical use (see heading 6 of this Code)	✓	"
iv. impacts on water resources (see headings 7 and 8 of this Code)	✓	"
v. land contamination	✓	"
vi. air pollution	✓	"
vii. noise & vibration	✓	"
viii. waste management	✓	"
ix. loss of well integrity	✓	"
x. induced seismicity	✓	"
xi. induced subsidence or other induced ground movements	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
xii. conflicts with existing land uses	✓	"
5 Safety		
5.1 Principles	✓	Section 4.4 - Safety Management Plan Section 9 - Execution
Fracture stimulation activities should be carried out safely and with minimal risks to the health of employees, visitors and members of the public:	✓	"
· The titleholder is responsible for the safety of not only workers and visitors to the site of a fracture stimulation activity, but also members of the general public who might be affected by the activity.	✓	"
· A rigorous, risk-based approach should be applied to managing the safety risks associated with a fracture stimulation activity.	✓	"
5.2 Mandatory requirements	✓	Section 4.4 - Safety Management Plan Section 7.9 - Equipment Selection

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
		Section 9 - Execution Section 9.1 - Pre Job Planning Section 9.2 - Location Preparation Section 9.4 - Mitigating Health, Safety and Environment Risks Section 9.5 - Job Execution
a) Prior to commencing a fracture stimulation activity, titleholders must ensure that operators and contractors prepare, implement and review as necessary, a Safety Management Plan2 to address the specific safety risks that might arise from a fracture stimulation activity, and to ensure that the design and operation of the site and its equipment are safe.	✓	"
b) The Safety Management Plan must provide the basis for:	✓	"
i. the identification of hazards	✓	"
ii. the assessment of risks arising from those hazards	✓	"
iii. the development of controls for those risks	✓	"

Table of Compliance		
Code of Practice Clause	**Comply**	**FSMP Reference**
iv. the reliable implementation of those controls through a formal safety assessment process.	✓	"
c) The Safety Management Plan must include:	✓	"
i. a short description of the activity and site location	✓	"
ii. the management structure of the major contractor for the activity	✓	"
iii. any systems, policies, programs, plans and procedures in place relating to the work undertaken at the site	✓	"
iv. the Emergency Plan (see heading 11)	✓	"
v. communication systems (such as emergency communication systems)	✓	"
vi. a work health and safety policy that includes the work health and safety objectives for the activity	✓	"
vii. the arrangements for appropriate instruction, training, including certification requirements, and provision of information for workers	✓	"
viii. the arrangements for the safe use of plant as per the Work Health and Safety Act 2011,	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
including the acquisition of fit-for-purpose plant and its commissioning, operation and maintenance		
ix. appropriate control systems such as:	✓	"
· alarm systems, pressure and flow detection system as part of well control, pressure control systems, emergency shutdown systems, a fluid monitoring system, a fire fighting system, a gas monitoring system	✓	"
· a process for managing change including a process for managing any changes to plant, operating procedures, organisational structure, workers and the Safety Management Plan	✓	"
· the mechanisms for implementing, monitoring and reviewing and auditing safety policies and the Safety Management Plan – for example, the plans must be reviewed if a relevant safety code, safety requirement or standard is introduced or amended, or in the event of a reasonably foreseeable incident	✓	"
· key performance indicators to be used to monitor compliance with the plan	✓	"
· mechanisms for recording, investigating and reviewing incidents at the fracture stimulation site and implementing recommendations from an investigation or review of an incident	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
· any site safety rules, with the detail of arrangements for ensuring that all persons at the site, whether workers, contractors, suppliers or visitors, are informed of the rules	✓	"
· the arrangements for document control and record keeping.	✓	"
d) Titleholders are responsible for ensuring that if a contractor is commissioned to undertake well operations, the contractor has a Safety Management Plan encompassing the scope of their work, which includes the following matters to ensure Safety Management Plans are consistent:	✓	"
ii. an identification of the specific risks that may arise as a result of the proposed or likely interactions between safety management systems, and how the risks will be controlled	✓	"
iii. an identification of the safety responsibilities of each party.	✓	"
6 Use of chemicals in fracture stimulation		
6.1 Principles	✓	Section 7.4 - Fluid Selection Section 7.5 - Fracture Stimulation Chemicals
The use of chemical additives in fracture stimulation activities should be minimised as far as	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
reasonably practicable		
Chemical additives should be selected and managed to minimise potential impacts on the environment	✓	"
The use of additives containing BTEX compounds (benzene, toluene, ethyl benzene and xylenes) is banned in NSW	✓	"
6.2 Mandatory requirements	✓	Section 7.4 - Fluid Selection Section 7.5 - Fracture Stimulation Chemicals REF Appendix C
The FSMP must identify:		
a) All chemicals to be injected as part of the fracture stimulation process	✓	"
b) The Chemical Abstract Service (CAS) registry number for those chemicals	✓	"
c) The volumes and concentrations of those chemicals	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
d) Potential risks to human health arising from exposure to those chemicals	✓	"
e) The risk, likelihood and consequence of surface spills of these chemicals	✓	"
f) Whether chemical concentrations at the point of injection will exceed:	✓	"
i. ANZECC 2000 guidelines4 for overlying groundwater and surface water uses that may be affected	✓	"
ii. ADWG 20045 if a drinking water supply may be affected	✓	"
iii. natural background concentrations if the water source is not effectively described by ANZECC or ADWG guidelines; or	✓	"
iv. if the chemical is not specified in ANZECC or ADWG guidelines and may have a toxic6 effect, then assess whether the toxic effect is likely to exceed a trigger toxicity level determined in accordance with a suitable methodology such as those described in Section 2: OECD Guidelines for the Testing of Chemicals7.	✓	"
g) The risk, likelihood and consequence of the injected chemicals affecting the beneficial use class of the target aquifer or any other aquifer	✓	"
h) How those chemicals will be stored and managed.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
7 Water resources		
7.1 Principles	✓	Section 4.3 - Risk Assessments: Groundwater and Surface Water Assessment
Protection of water resources should be a primary consideration in both the design and execution of a fracture stimulation activity.	✓	"
7.2 Mandatory requirements	✓	Section 4.3 - Risk Assessments: Groundwater and Surface Water Assessment
The FSMP must, at a minimum:	✓	"
a) Identify the location, extent, pre-existing water quality and use of water sources which have the potential to be impacted by the fracture stimulation activity.	✓	"
b) Identify sources of fracture stimulation injection water, the estimated quality and volume to be injected and any licensing/approval requirements under the Water Management Act 2000 or Water Act 1912.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
c) Include a qualitative risk assessment for risks associated with the fracture stimulation activity, including:	✓	"
i. cross-contamination between coal bed waters and shallower water sources	✓	"
ii. changes to groundwater pressure and levels	✓	"
iii. changes to surface water levels	✓	"
iv. changes to water quality characteristics.	✓	"
d) If the risk of establishing a connection between the target coal bed and other water sources as a result of the fracture stimulation activity is assessed to be moderate or higher, then a fate and transport model study must be undertaken to quantify the impacts on water sources and the likelihood of any changes to the beneficial use8 category applicable to any affected aquifer.	✓	"
e) If there is a moderate or greater risk of significant changes to pressure or levels as referred to in c) (ii) or (iii), the impacts on all affected aquifers must be quantitatively assessed.	✓	"
f) Describe consultation undertaken with the NSW Office of Water in developing the water resources component of the risk assessment.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
8 Management of flowback water		
8.1 Principles	✓	Section 4.3 - Risk Assessments Section 4.3 - Risk Assessment: Flowback and Waste Management Section 10 - Flowback, Dewatering and Disposal
That flowback water is managed in a way that ensures that risks to health, safety and the environment are appropriately managed.	✓	"
8.2 Mandatory requirements	✓	Section 4.3 - Risk Assessments Section 4.3 - Risk Assessment: Flowback and Waste Management Section 10 - Flowback, Dewatering and Disposal
The FSMP must:	✓	"
a) Identify how flowback water is to be managed to ensure that risks to health, safety and the	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
environment are maintained at acceptable levels		
b) Reflect consent conditions regarding storage requirements, methods for disposal and other surface water management methods	✓	"
c) Describe the reuse, recycling or disposal methods for the flowback water	✓	"
d) Describe if and how flowback water will be stored and treated on site	✓	"
e) Describe if and how flowback water will be characterised and disposed of in accordance with the relevant OEH waste classification guidelines9.	✓	"
8.3 Leading practice	✓	Section 4.3 - Risk Assessments Section 4.3 - Risk Assessment: Flowback and Waste Management Section 10 - Flowback, Dewatering and Disposal Section 11 - Monitoring

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
· Flowback water should be promptly pumped from the well to maximise the recovery of fluids injected as part of the fracture stimulation activity. This pumping should be continued until background water quality parameters for the target formation are reached.	✓	"
· The volume and quality of the flowback water with time should be recorded in order to establish the fate of any additives injected as part of the fracture stimulation fluid.	✓	"
· Tracer elements may be used to assist in identifying the fate of the fracture stimulation fluid.		
9 Impacts on coal mining		
9.1 Principles	✓	Section 13 - Coal Mining
To ensure that fracture stimulation activities do not adversely impact on current and future coal mining activities.	✓	"
9.2 Mandatory requirements	✓	Section 13 - Coal Mining
a) The FSMP must identify whether the fracture stimulation activity is adjacent to a mining lease, and if so, whether a cooperation agreement has been entered into with the adjacent authorisation holder regarding the potential impacts of their activities on, or arising from, the proposed fracture stimulation activity.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
b) Titleholders must refer to conditions of title for additional requirements.	✓	"
10 Monitoring		
10.1 Principles	✓	Section 11 - Monitoring
That fracture stimulation activities are effectively monitored to allow the prompt identification and mitigation of any health, safety or environmental risks.	✓	"
10.2 Mandatory requirements	✓	Section 7.7 - Hydraulic Fracture Stimulation Fluid Pump Schedules Section 7.8 - Fracture Geometry Modelling Section 7.9 - Equipment Selection Section 8 - Fracture Geometry Diagnostics Section 11 - Monitoring
a) The FSMP must describe any monitoring arrangements, including monitoring before, during and after the fracture stimulation activity.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
b) The titleholder must carry out sufficient monitoring to establish that significant risks have been:	✓	"
i. identified	✓	"
ii. quantified	✓	"
iii. avoided, or appropriately managed so that residual risks are within acceptable limits before, during and after the fracture stimulation activity.	✓	"
c) Monitoring of overlying water sources must be undertaken over an area sufficient to encompass the predicted fracture length plus a sufficient margin to provide for any uncertainty.	✓	"
d) Prior to fracture stimulation, monitoring must be undertaken to characterise water source level, pressure and quality. This monitoring should include existing wells and water bores at a minimum.	✓	"
e) During fracture stimulation, monitoring must be undertaken to:	✓	Section 9.3 - Fluids Quality Assurance Section 9.5 - Job Execution
i. record key parameters such as bottom hole pressure and surface injection pressure	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
ii. establish the volume, composition, viscosity and pumping rate of fracture fluids and proppants	✓	"
f) Post-stimulation monitoring must be undertaken to ensure that induced inter-aquifer connectivity has been prevented by:	✓	"
i. determining the volume and quality of flowback and produced water	✓	"
ii. quantifying any changes in surrounding water sources	✓	"
iii. pressure testing of casing to verify that the integrity of the well and well equipment has been maintained.	✓	"
10.3 Leading practice	✓	Section 2.5 - Pressures for Fracture Stimulation Section 7.8 - Fracture Geometry Modelling Section 8 - Fracture Geometry Diagnostics
Fracture stimulation simulations should be validated by monitoring fracture growth in real time to determine actual fracture geometry and extent.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
11 Incident and emergency response		
11.1 Principles	✓	Section 5 - Emergency Response Plan
Incidents and emergencies must be prepared for and managed appropriately to ensure that risks to health, safety and the environment are minimised.		"
11.2 Mandatory requirements – general emergencies	✓	Section 5 - Emergency Response Plan
a) The titleholder must prepare an Emergency Plan10 for the fracture stimulation activity addressing emergency procedures, including:	✓	"
i. evacuation procedures	✓	"
ii. medical treatment and assistance	✓	"
iii. notifying emergency service organisations at the earliest opportunity	✓	"
iv. effective communication to coordinate the emergency response and all persons at the workplace	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
v. testing of the emergency procedures, including the frequency of testing	✓	‘
vi. regular mandatory information, training and instruction to workers	✓	“
b) The Emergency Plan must include:	✓	“
i. the name of the project	✓	“
ii. the title ID	✓	“
iii. GPS coordinates and location on a roadmap indicating directions to the nearest hospital or emergency air evacuation site	✓	“
iv. contact details for the operating company and contractors at the site.	✓	“
c) The Emergency Plan must specify actions to be taken and identify persons responsible in the event of an emergency arising as a result of:	✓	“
i. serious injury or fatality to a person at the site	✓	“
ii. well blow-out or loss of well integrity causing an uncontrolled release of fluid	✓	“

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
iii. unplanned ignition of methane	✓	"
iv. chemical spill or other pollution incident	✓	"
v. any other serious event associated with the operations	✓	"
d) Workers must be trained in emergency response procedures.	✓	"
e) The Emergency Plan must in place and adequately resourced during the conduct of the fracture stimulation activity.	✓	"
f) Serious workplace incidents including injuries and fatalities must be reported to the department (Mine Safety) as required under Part 3 of the Work Health and Safety Act 2011.	✓	"
g) The Emergency Plan must be reviewed and tested as soon as reasonably practicable after any emergency has occurred at the site and whenever the Safety Management Plan is reviewed.	✓	"
11.3 Mandatory requirements – environmental incidents	✓	Section 6 - Environmental Incident Response Plan
a) The titleholder must prepare and maintain an Environmental Incident Response Plan11,12 setting out in detail the procedures to be followed and actions to be taken in the event of:	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
i. well blowout or loss of integrity	✓	"
ii. chemical spill or other pollution incident	✓	"
iii. damage to an overlying water source	✓	"
iv. breach of regulatory requirements, including significant non-compliance with the FSMP	✓	"
v. any other significant environmental incident associated with the fracture stimulation activity.	✓	"
b) The matters required to be included in an Environmental Incident Response Plan are:	✓	"
i. a description of the hazards to human health or the environment associated with the fracture stimulation activity	✓	"
ii. the likelihood of any such hazards occurring, including details of any conditions or events that could, or would, increase that likelihood,	✓	"
iii. details of the pre-emptive action to be taken to minimise or prevent any risk of harm to human health or the environment arising out of the activity	✓	"
iv. an inventory of potential pollutants on the premises or used in carrying out the activity, 11 Part	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
5.7A of the Protection of the Environment Operations Act 1997 (POEO Act) requires environment protection licensees to		
v. the maximum quantity of any pollutant that is likely to be stored or held at the location of the fracture stimulation activity	✓	"
vi. a description of the safety equipment or other devices that are used to minimise the risks to human health or the environment and to contain or control a pollution incident	✓	"
vii. the names, positions and 24-hour contact details of those key individuals who:	✓	"
· are responsible for activating the plan, and	✓	"
· are authorised to notify relevant authorities under paragraph (e) and (f), and	✓	"
· are responsible for managing the response to a pollution incident	✓	"
viii. the contact details of each relevant authority referred to in paragraph (e) and (f)	✓	"
ix. details of the mechanisms for providing early warnings and regular updates to the owners and occupiers of premises in the vicinity of the fracture stimulation activity	✓	"

Table of Compliance		
Code of Practice Clause	**Comply**	**FSMP Reference**
x. the arrangements for minimising the risk of harm to any persons who are present where the fracture stimulation activity is being carried out	✓	"
xi. a detailed map (or set of maps) showing the location of the fracture stimulation activity, the surrounding area that is likely to be affected by a pollution incident, the location of potential pollutants on the activity site and the location of any stormwater drains on the activity site	✓	"
xii. a detailed description of how any identified risk of harm to human health will be reduced, including (as a minimum) by means of early warnings, updates and the action to be taken during or immediately after a pollution incident to reduce that risk	✓	"
xiii. the nature and objectives of any staff training program in relation to the plan	✓	"
xiv. the dates on which the plan has been tested and the name of the person who carried out the test,	✓	"
xv. the dates on which the plan is updated,	✓	"
xvi. the manner in which the plan is to be tested and maintained.	✓	"
c) The Environmental Incident Response Plan must be made readily available:	✓	"

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Code of Practice Clause	Comply	FSMP Reference
i. to an authorised officer representing an authority listed in paragraph (e) and (f) on request	✓	"
ii. at the site of the fracture stimulation activity, to any person who is responsible for implementing the plan.	✓	"
d) The Environmental Incident Response Plan must be tested prior to the commencement of the fracture stimulation activity to ensure that the information included in the plan is accurate and up to date and the plan is capable of being implemented in a workable and effective manner.	✓	"
e) Pollution incidents that cause or threaten material harm to the environment must be immediately notified to each of the following authorities in the following order:	✓	"
i. the appropriate regulatory authority (ARA)	✓	"
ii. the Environment Protection Authority (EPA) if they are not the ARA	✓	"
iii. the Ministry of Health	✓	"
iv. the department (Mine Safety – as the WorkCover Authority)	✓	"
v. the local authority, e.g. the local council, if this is not the ARA	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
vi. Fire and Rescue NSW	✓	"
vii. the department (Environmental Sustainability Unit)	✓	"
f) The titleholder must also immediately notify the NSW Office of Water (NOW) if a water source is harmed.	✓	"
12 Notification requirements		
12.1 Principles	✓	Section 4.1 - Notification
That the department is made aware that a fracture stimulation activity is to be undertaken and has the opportunity to observe the activity.	✓	"
12.2 Mandatory requirements	✓	Section 4.1 - Notification
At least 10 business days before starting hydraulic fracturing activities, the titleholder must complete and lodge a Notice of Intention to Carry out Fracture Stimulation on the department's approved form.	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
13 Undertaking the fracture stimulation activity		
13.1 Principles	✓	Section 9 - Execution Section 9.2 - Location Preparation Section 9.4 - Mitigating Health, Safety and Environment Risks Section 9.5 - Job Execution
Fracture stimulation activities must be undertaken in accordance with all relevant approvals. The activity should be undertaken in a manner that ensures that risks to health, safety and the environment are appropriately managed.	✓	”
13.2 Mandatory requirements	✓	Section 8 - Fracture Geometry Diagnostics Section 9 - Execution Section 9.2 - Location Preparation Section 9.4 - Mitigating Health, Safety and Environment Risks

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
		Section 9.5 - Job Execution
a) The titleholder must ensure that well construction, cement and casing integrity meet the standards set out in the NSW Code of Practice for Coal Seam Gas Well Integrity before fracture stimulation operations commence to ensure that cement and casing integrity is sufficient for the planned activity.	✓	"
b) The titleholder must ensure that fracture stimulation activities are conducted in a manner which:	✓	"
i. complies with this Code, relevant Government policies, approval conditions, title conditions and legislative requirements	✓	"
ii. manages all health, safety and environmental risks associated with the fracture stimulation process	✓	"
iii. uses all reasonable endeavours to ensure the fracture stimulation is contained within the targeted area	✓	"
iv. uses all reasonable endeavours to ensure that fractures do not induce connections with water sources	✓	"
v. uses all reasonable endeavours to avoid pollution of water sources	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
vi. puts in place appropriate monitoring, response plans and reporting regimes to ensure that any risk to health, safety or the environment can be promptly addressed or mitigated	✓	”
14 Completion report		
14.1 Principles	✓	Section 14 - Reporting
Key parameters of the conduct and impacts of fracture stimulation operations must be reported to the department to ensure that health safety and environmental risks have been appropriately managed and that regulatory requirements have been met.	✓	”
14.2 Mandatory requirements	✓	Section 8 - Fracture Geometry Diagnostics Section 9 - Execution Section 14 - Reporting Section 7.9 - Equipment Selection
a) A completed Fracture Stimulation Completion Report must be submitted to the department (Mine Safety Operations + Environmental Sustainability Unit) in the approved form within 30 days of the cessation of the fracture stimulation activity.	✓	”

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
b) The report must include:	✓	”
i. identifying information concerning the title, the contractor, and the location of the well	✓	”
ii. commencement and completion dates of fracturing for each well	✓	”
iii. details of each interval fractured	✓	”
iv. summary of operations (including volume and type of chemicals used in each stage)	✓	”
v. assessment of the fracture stimulation including:	✓	”
· casing and bottom hole pressure with time	✓	”
· bottom hole calculated proppant concentration	✓	”
· rate that fracturing fluid was pumped over time and the total volume pumped at each stage	✓	”
· composition of the fracturing fluid and any other chemicals introduced into the well (quantity of each component; concentration of each component; name of chemical compounds contained in fluid)	✓	”

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
· concentration of proppant over time	✓	”
· maximum surface pressure at each stage	✓	”
· estimated frac gradient for the target interval	✓	”
· details of equipment and diagnostic techniques used	✓	”
· if fracturing has been undertaken on a coal seam – any other details to assist future assessment of the impact on the seam, and any increased risk to safe and efficient mining of coal	✓	”
· if a known event related to the fracturing activities has caused material environmental harm, details of each step taken to mitigate the harm.	✓	”
vi. a hydraulic fluid fracturing statement	✓	”
The department may publish the completion report on its website.	✓	”
Fracture Stimulation Activities 15	✓	”
15 Record keeping		

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
15.1 Principles	✓	Section 15 - Record Keeping
That appropriate records are kept of fracture stimulation activities to facilitate resolution of any future issues.	✓	"
15.2 Mandatory requirements	✓	Section 15 - Record Keeping
a) The titleholder must maintain a record of all fracture stimulation activities (refer also to the NSW Code of Practice for Coal Seam Gas Well Integrity).	✓	"
b) The records referred to in (a) must be made available to the department for inspection on request.	✓	"
c) The titleholder must maintain the following records of all fracture stimulation activities (as per (a)):	✓	"
i. the FSMP	✓	"
ii. engineering design (including design safety factors used for casing and estimated load calculations)	✓	"
iii. laboratory results for any tests conducted in conjunction with the activity	✓	"

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
iv. pressure tests	✓	"
v. leak off test and/or formation integrity test reports	✓	"
vi. details of all chemicals used (name, type and volume of each chemical)	✓	"
vii. risk assessments	✓	"
viii. sources of water used for fracture stimulation operations	✓	"
ix. service company reports	✓	"
x. environmental monitoring results	✓	"
xi. completion report	✓	"
d) Following plug and abandonment of a well, the titleholder must provide the department with a copy of the records referred to in (a).	✓	"
16 Application of Australian and international standards		
16.1 Principles	✓	Section 1 - CSG Specific Industry

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
		CoP or Guidelines Section 4.3 - Risk Assessments
Relevant Australian and international standards should be complied with where these are of an equal or higher standard than those set out in this Code and do not conflict with the NSW regulatory framework.	✓	”
16.2 Mandatory requirements	✓	Section 1 - CSG Specific Industry CoP or Guidelines Section 4.3 - Risk Assessments
Titleholders must comply with the following standards in so far as these standards are of an equal or higher standard than those identified elsewhere in this Code and do not conflict with the NSW regulatory framework:	✓	”
a) AS/NZS ISO 31000:2009 Risk management - Principles and guidelines	✓	”
b) NSW Code of Practice for Coal Seam Gas Well Integrity 2012	✓	”
16.3 Leading practice	✓	Section 1 - CSG Specific Industry CoP or Guidelines

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
a) Titleholders should comply with the following guidelines in so far as these guidelines set an equal or higher standard than those identified elsewhere in this Code and do not conflict with the NSW regulatory framework:	✓	”
i. American Petroleum Institute Guidance Document HF 1 Hydraulic Fracturing Operations - Well Construction and Integrity Guidelines October 2009	✓	”
ii. American Petroleum Institute Guidance Document HF 2 Water Management Associated with Hydraulic Fracturing June 2010	✓	”
iii. American Petroleum Institute Guidance Document HF 3 Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing January 2011	✓	”
iv. American Petroleum Institute Recommended Practice 51R Environmental Protection for Onshore Oil and Gas Production Operations and Leases July 2009	✓	”
and Gas Production Operations and Leases July 2009 b) Relevant Australian and international standards and guidelines not identified in this Code should be complied	✓	”
b) Relevant Australian and international standards and guidelines not identified in this Code should be complied with in so far as they set requirements of an equal or higher standard than those	✓	”

Table of Compliance

Code of Practice Clause	Comply	FSMP Reference
identified elsewhere in this		