BEACH ENERGY

9 July 2015

Ref: BPT/318/15

By Email

Ms Christine McDonald

The Secretary, Environment and Communications Legislation Committee

PO Box 6100

Parliament House

Canberra, ACT 2600

ec.sen@aph.gov.au

Dear Ms McDonald,

Thank you for your recent correspondence advising of references to Beach Energy (Beach) within evidence put forward as part of the *Inquiry into the Landholders' Rights to Refuse (Gas and Coal) Bill 2015.*

The information contained within the submission by the Limestone Coast Protection Alliance (the Alliance) that you have provided is well known to Beach. In South Australia, an inquiry into Fracture Simulation in the South East of the State is currently being undertaken by the South Australian Natural Resources Committee of Parliament. Many of the comments raised in the submission by the Alliance have been raised with Beach before either through our community engagement program or as part of the South Australian inquiry.

Attached is a copy of Beach's submission to the South Australian inquiry as this addresses risk management process adopted by Beach to mitigate the concerns raised by the Alliance.

Please do not hesitate to contact my office if you have any questions.

Yours sincerely,

Rob Cole

Managing Director

Beach Energy

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ATTACHMENT 1

Beach Energy Submission

SA Parliament Natural Resources Committee Inquiry into Unconventional Gas (Fracking)

30 January 2015

Mr Patrick Dupont
Executive Officer
Natural Resources Committee
GPO Box 572
ADELAIDE SA 5001

Email: patrick.dupont@parliament.sa.gov.au

Dear Mr Dupont,

Please find enclosed a submission from Beach Energy Limited (Beach) in relation to the Parliament of South Australia, Natural Resources Committee Inquiry into Unconventional Gas (Fracking) (the Inquiry).

The attached information is company specific and responds to the terms of reference set out for the Inquiry.

To address the terms of reference, information about fracture stimulation has been provided. Beach is still in the exploration stages of its operations in the Otway Basin in the South East of South Australia, and has not yet made any decision as to the suitability of fracture stimulation nor applied for approval to fracture stimulate.

As a result, the information provided in this submission is largely based on the extensive operations undertaken by Beach in the Cooper Basin, in both South Australia and Queensland, as outlined in the Environmental Impact Reports (EIR) and Statement of Environmental Objectives (SEO) developed for Beach's activities, and approved by the State Government. A regional specific EIR and SEO will be developed for the South East and submitted to the Department of State Development (Regulator) for approval, should Beach determine it feasible to progress its operations in the Otway Basin beyond exploration.

Beach welcomes any an opportunity to present the information contained within this submission, or any other aspects relating to our operations, to the Committee.

Please do not hesitate to contact my office if you require any additional information.

Yours sincerely,

Reg Nelson
Managing Director
Beach Energy Limited

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Beach Energy Limited

Beach is an Adelaide based oil and gas exploration and production company with interests in more than 300 petroleum tenements located in Australia, Romania, Egypt, Tanzania and New Zealand. The majority of Beach's operations are conducted in the Cooper Basin and overlying Eromanga Basin in central Australia. These Basins host Australia's largest onshore oil and gas resources currently under development, with Beach operating 20 oil fields on the Western Flank of the Cooper and Eromanga Basins. Beach is Australia's largest onshore oil producer, and also operates two gas and gas liquids producing fields.

Beach holds a 20.21% interest in the South Australian Cooper Basin Joint Venture (SACB JV), and between 20-40% of the South West Queensland Joint Ventures (SWQ JVs), which are operated by Santos Limited (Santos). Since 2006, Beach has participated in more than 100 oil and gas wells. Recent SACB and SWQ JVs drilling has focused on an infill program, with gas from this program expected to soon be servicing the key Australian East and South coast gas markets.

Beach has extensive first hand operational experience in fracture stimulation, having pumped more than 85 treatments in the last four years during a focused exploration program. This program has been designed to assess the potential of deep gas from shale and tight sands within the Nappamerri Trough in the Cooper Basin. Extremely robust procedures, guided by Beach's high standards, and the State's regulatory framework, have ensured that this activity was undertaken without incident to the surface environment and aquifers.

Beach is recognised as a responsible operator and has a Low Supervision Classification for its exploration and oil production operations, which was awarded by the State Government. Beach's focus on safety and sustainability is evidenced by a number of forums it organises, such as its annual contractor safety forum.

Scope of Inquiry

Pursuant to section 16(1)(a) of the *Parliamentary Committees Act 1991,* the Natural Resources Committee is inquiring into the potential risks and impacts of the use of hydraulic fracture simulation to produce gas in the South East of South Australia. The Committee has set the following points of interest for the Inquiry:

A. The risk of groundwater contamination;
B. The impacts upon landscape;
C. The effectiveness of existing legislation and regulation; and
D. The potential net economic outcomes to the region and the rest of the State.

This submission addresses the above points of interest and provides some additional background information on the Otway Basin geology, the history of exploration and production in the Otway Basin and Beach's recent exploration drilling.

Beach is in the early stages of exploration in the Otway Basin, and at this stage has not sought approval to undertake fracture stimulation in the area.

Geology of the South Australian Otway Basin

The Otway Basin is an extensional sedimentary basin which began to form about 145 million years ago, in the Late Jurassic/Early Cretaceous, as the Australian continent started to separate from Antarctica. During the rifting process, a series of topographic lows, or troughs, formed within the greater Otway Basin and these captured sediments over millions of years. The Penola Trough and the Robe Trough are two examples of these (see Figure 1).

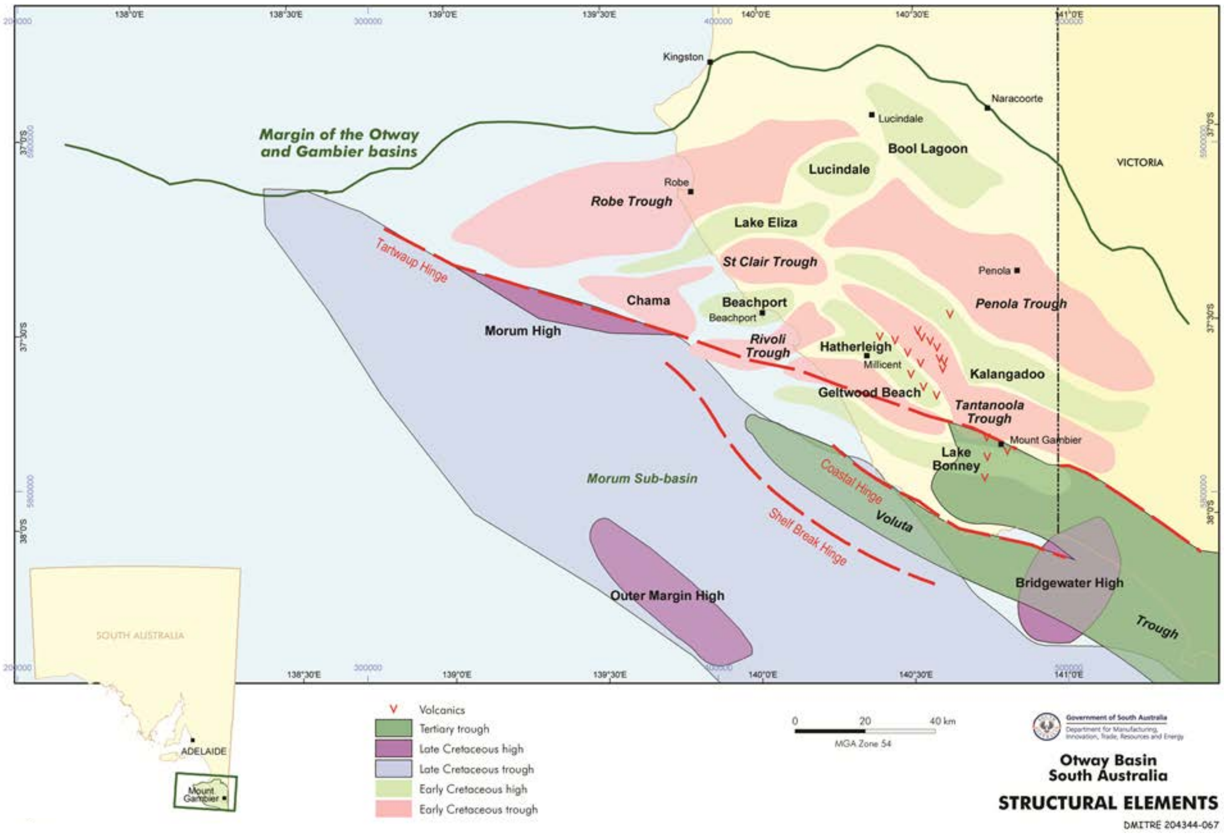


Figure 1: Structural Elements of the Otway Basin, South Australia

(Source:www.petroleum.dmitre.sa.gov.au/prospectivity/basin_and_province_information/prospectivity_otway)

The initial sediments deposited in the subsiding troughs were predominantly shale, and this interval is referred to as the Casterton Formation (see Figure 2). The shales were deposited in a low energy environment (Kopsen and Schofield, 1990) such as a lake, and the organic material contained within is interpreted to be the source of the gas, condensate and oil discoveries in the South East of South Australia.

Overlying the Casterton Formation are the Lower Sawpit Shale, Sawpit Sandstone, Upper Sawpit Shale, Pretty Hill Sandstone, Laira Formation and Katnook Sandstone (Figure 2). These formations were deposited during episodes of crustal extension and basin deepening, as Australia continued to pull apart from Antarctica. Like the Casterton Formation, the Lower Sawpit Shale was also deposited in a low energy environment and it may also be the original source rock of oil, gas and condensate discoveries.

The overlying Sawpit Sandstone and the younger Pretty Hill Sandstone and Katnook Sandstone, are interpreted to be deposited in a braided stream environment. These are reservoir rocks for hydrocarbons and have traditionally been the main target of oil and gas exploration in the South East of South Australia. All three formations have flowed gas, oil and/or condensate at commercial rates. For example, the Katnook, Haselgrove and Ladbroke Grove fields have produced gas and condensate out of the Pretty Hill Sandstone reservoir at depths 2,500 -2,800 metres below the earth's surface.

The Upper Sawpit Shale and Laira Formation are comprised of siltstone and shale and were deposited in a low energy environment such as a floodplain or lake. Both of these units are important as they act as seals to the Sawpit Sandstone and Pretty Hill Sandstone respectively thereby trapping hydrocarbons at depth.

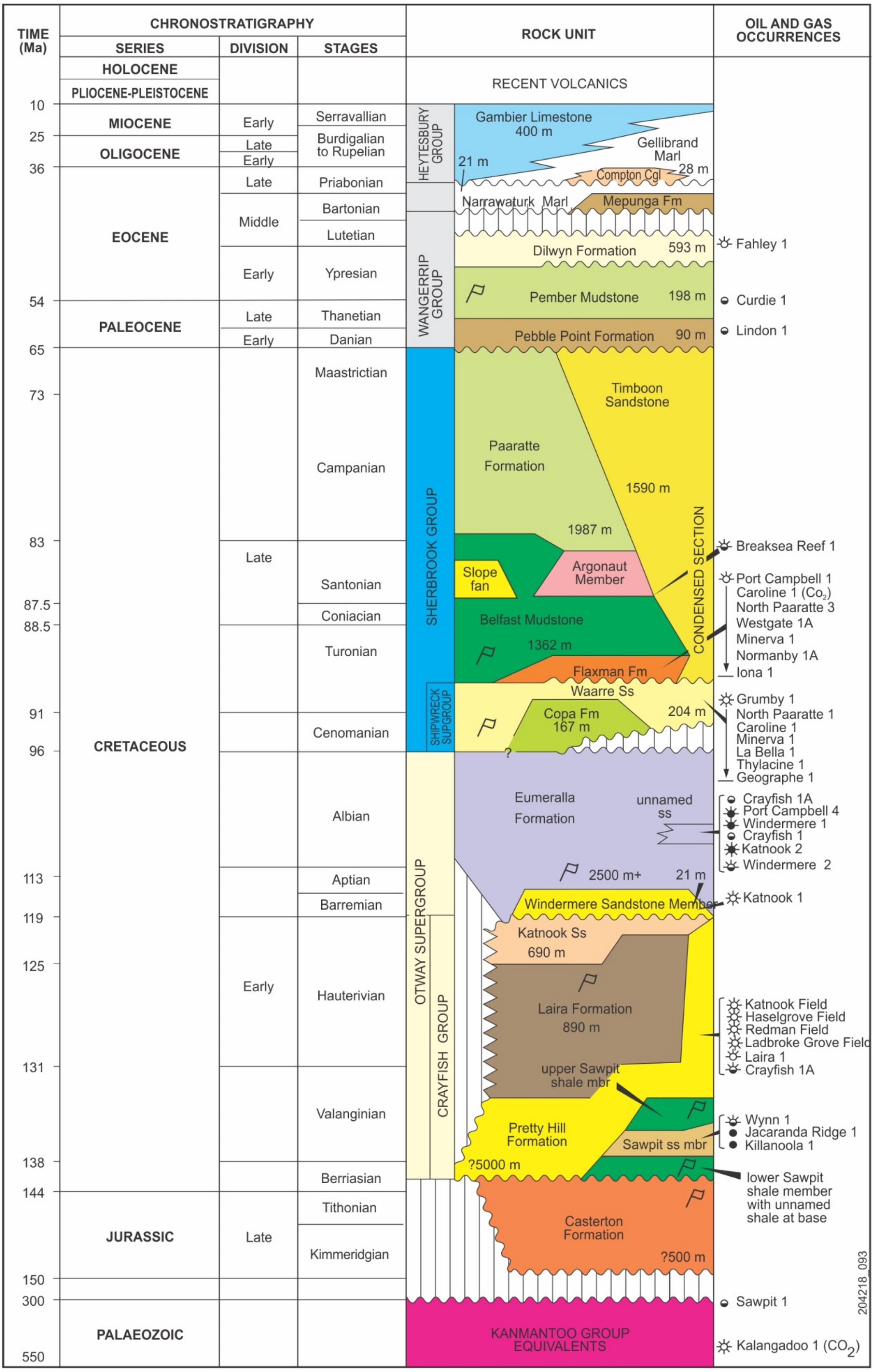


Figure 2: Lithological Rock Units of the Otway Basin, South Australia

(Source:www.petroleum.dmitre.sa.gov.au/prospectivity/basin_and_province_information/prospectivity_otway)

After the deposition of the Katnook Sandstone approximately 120 million years ago, a period of structural activity caused uplift of the sedimentary formations followed by subsequent erosion as the activity waned. A thick sequence of interbedded shales and siltstones comprising the Eumeralla Formation was deposited, possibly in an expansive system of shallow lakes, on a fairly low relief, slowly subsiding basin surface. The Eumeralla Formation is an important formation as it forms an extensive regional seal, approximately one kilometre thick in the Otway Basin in South Australia, and sits a further one kilometre above the target zone.

The overlying Sherbrook Group of Late Cretaceous age is a thin sandstone sequence in the northerly part of the South Australian Otway Basin. To the south, and particularly offshore, it thickens and can be subdivided into different lithological units representing the facies of a delta system (Moreton, 1990).

The overlying Tertiary-aged sediments are also relatively thin onshore, consisting mainly of sandstones of the Dilwyn Formation, shales of the Pember Mudstone and fossiliferous limestones of the Gambier Limestone. The Dilwyn and Pember formations were probably deposited in a fluvial-deltaic setting (Gravestock et al., 1986) and the overlying Gambier Limestone in a prograding marine sequence. All the Tertiary units thicken offshore. The Gambier Limestone and the Dilwyn Formation are important aquifers for the South East of South Australia.

Exploration and Production History of the South Australian Otway Basin

The earliest well to be drilled exploring for hydrocarbons in the South East was in 1866 near Salt Creek, north of the edge of the Otway Basin. There were many more wells drilled over the next 100 years, all of which were quite shallow and not to the depths that would be considered prospective for hydrocarbons today. Modern day exploration began in the early 1960s when seismic surveys were used to locate deeply buried structures and wells were drilled below the Eumeralla Formation addressing the deeper targets. Since that time 81 wells have been drilled in the South Australian Otway Basin including the two wells, Jolly-1ST1 and Bungaloo-1, which were drilled last year (Figure 3).

Figure 3: Map of the South East with petroleum exploration well locations shown in green

The first discovery of a commercial flow of hydrocarbons was from the Katnook-1 well in 1987. A second successful well was drilled the next year proving the Katnook gas field existed and, as a result, the Katnook gas plant was built (location shown in Figure 4) and commissioned in 1991. Several other gas discoveries were made in the Penola Trough following the success of the Katnook wells. They include Redman, Ladbroke Grove and Haselgrove gas fields. Pipelines were constructed to take the gas to the Katnook Gas Plant and the adjacent Ladbroke Grove Power Station which was subsequently built to produce peak load electricity.

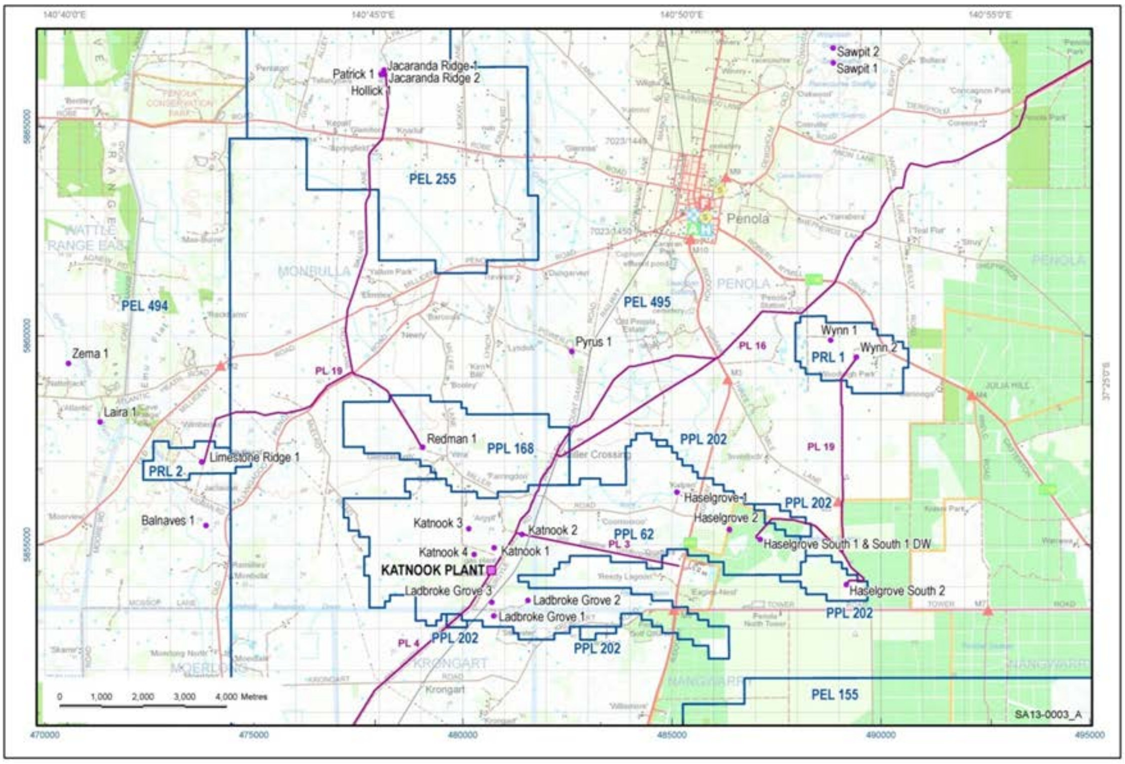


Figure 4: Map showing location of the Katnook Plant and Ladbroke Grove Power Station and nearby production wells. (Purple lines are buried gas pipelines).

The Katnook plant produced gas until 2011, and the Ladbroke Grove power station also used local gas. Pressures in the reservoirs slowly declined, with the wells shut in regularly for extended periods to allow for pressure build up before they could produce again. The SEAgas pipeline, stretching from the Victorian Otway Basin to Adelaide, became operational in 2004. An offshoot to this pipeline now provides gas to the local markets in the South East and the Ladbroke Grove power station.

Beach Activity in the South East

Beach has a long history of exploring for hydrocarbons in the Otway Basin. Early in the company's history, Reg Sprigg, the company founder, mapped a large part of the Otway Basin and undertook surveys to determine whether hydrocarbons existed below the earth's surface. Beach drilled Geltwood Beach-1 in 1963, south west of Millicent, to look for oil. Beach also explored for gas in Victoria and made the first commercial gas discovery in the Port Campbell area in 1979.

More recently in the South East of South Australia, Beach drilled the oil exploration well Cowrie-1 (2005) near Lucindale, the gas exploration well Glenaire-1 (2006) east of Penola and just across the border in Victoria, the oil exploration well Sawpit-2 (2013), north of Penola. All of these wells were searching for hydrocarbons in conventional reservoirs, i.e. reservoirs that might flow naturally, unassisted by fracture stimulation.

Early in 2014 Beach undertook a two-well exploration campaign (Jolly-1ST1 and Bungaloo-1) near Penola to determine if the organic shales of the Casterton Formation and Lower Sawpit Shale might exist in the deeper part of the Penola Tough, and if so, whether those shales may contain commercial quantities of liquids-rich gas trapped in the pore spaces at depths in the order of 3,500-4,000 metres. The targets were intersected and cores of shale were cut in both wells (181 metres). Analysis of these cores is ongoing and aims to determine whether these shale rich formations might produce gas commercially. It should be noted that the Casterton Formation and Lower Sawpit Shale are separated from shallow surface aquifers by more than two kilometres of overlying rock.

Community and Stakeholder Engagement

Beach has undertaken extensive community and stakeholder engagement as part of its exploration program, which is standard practice for the company. As part of this process, initial discussions were held with landholders of the properties on which Beach intended to drill. Once access was agreed with the landholders, and well before any drilling commenced, Beach held two public meetings in the South East (Penola and Robe) to engage with the community on its operations. Feedback from these meetings was incorporated into drafting the Statement of Environmental Objectives (SEO) for drilling activities in the region which was assessed and approved by the State Government prior to any activities commencing. Subsequent to this, Beach participated in numerous public meetings and information sessions either instigated by Beach or otherwise held at the request of either the local councils or the South East Local Government Association.

Over the last 15 months, Beach has also held numerous one-on-one briefing meetings with representatives from:

- Parliament, with those representatives being at the Federal and State levels and from both major and minor parties; local councils;
- the South East Natural Resources Management Board;
- Primary Producers SA;
- members of the community; and
- members of industries and commodities represented in the region.

Beach has established a Roundtable of Industry and Energy representatives in the South East to enable direct and ongoing dialogue with representatives from the diverse range of industries present in the region. Roundtable participants include wine and grape groups, livestock farmers, professional fishing groups, the seed industry, fruit and vegetable growers and personnel from various energy companies. The Roundtable is independently chaired, and as at the date of this submission, one meeting has been held. Participants have raised a range of important questions and issues, some of which were answered at the first meeting, with others to be addressed at future meetings. Future meetings will include certain questions being addressed by independent experts chosen by Roundtable members. The Roundtable is in addition to, and does not replace, Beach’s ongoing commitment to engage with the community in the South East.

A. The Risk of Groundwater Contamination

To understand the potential risk of groundwater contamination as a result of fracture stimulation, and how these risks can be mitigated, Beach has outlined the process of fracture stimulation in detail below. The information provided relates to the points of interest set by the Committee. Beach would be pleased to present information outside the scope set by the Committee should it be interested.

An independent study of Canadian shale oil and natural gas resource plays (ALL Consulting, June 2012) demonstrated that with the use of advanced technology, appropriate regulation and best management practices, the environmental risks associated with oil and gas developments, including hydraulic fracturing were low and able to be mitigated.

1.1 Overview

Beach is currently in the exploration stage of its work in the Otway Basin, with analysis of core samples obtained during drilling currently being assessed. As a result, at this stage, Beach has not sought approval to fracture stimulate in the Otway Basin. Should Beach's current exploration activities indicate the potential for hydrocarbon recovery from deep low permeability target intervals, the joint venture (with Cooper Energy) is likely to propose to undertake fracture stimulation to flow gas from the prospective intervals. At this stage it is more commercially viable for Beach to drill shallower conventional targets, hence Beach's next well in the area will be a conventional well targeting shallower reservoirs with greater porosity and permeability.

As it is too early to provide region specific information about fracture stimulation, the information provided below is a generalised risk assessment of fracture stimulation, which has largely been adapted from Beach's Environmental Impact Report for Fracture Stimulation of Deep Shale Gas and Tight Gas Targets in the Nappamerri Trough (Cooper Basin) South Australia (Beach 2012).

Region specific planning will always guide any issues that need to be addressed when operating in different regions, such as landscape, climate and the variation in the environment. This information will be prepared in due course in the event that Beach proceeds to seek approval to fracture stimulate wells in the Otway Basin.

1.2 Fracture Stimulation - Background

Basin centred gas and shale gas reservoirs have very low natural permeability. Permeability is defined as allowing a liquid or gas to pass through. In order to assess the potential for production of gas from these targets it is necessary to improve connection of the pore space within the rock back to the well. This is achieved by the process of fracture stimulation.

Fracture stimulation involves the injection of fluid into the target rock interval at pressures sufficient to split the rock and create high conductivity flow paths to the well, as illustrated in Figure 5. The fractures created are of the order of a few millimetres or less in width. The injected water is slightly modified with a gelling agent to enable proppant material (sand or ceramic material, similar to sand particles) to be pumped into the rock to hold the induced fractures open. Further additives are used to control corrosion and friction, remove bacteria and assist with recovering the stimulation fluids from the interval when the well is flowed back to production.

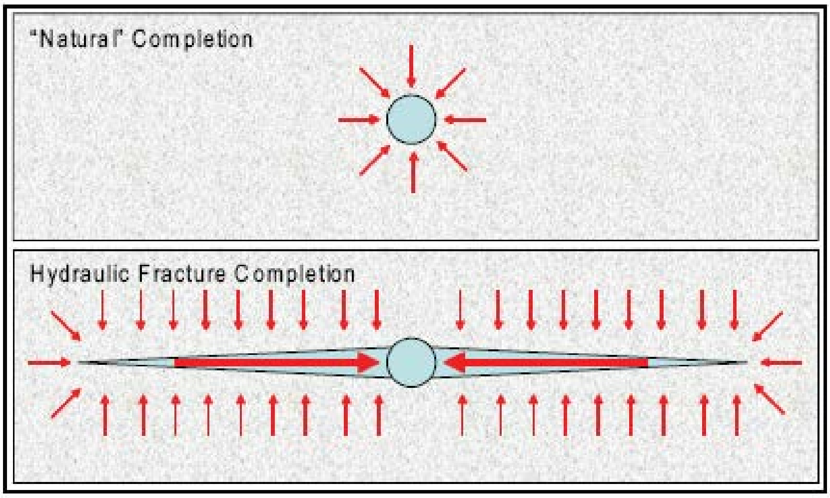


Figure 5. Illustration of flow paths in a non-fractured and a fractured well (Source: API 2009)

Fracture stimulation is not a new technique. It has been used for over forty years in onshore oil and gas production in Australia, predominantly in the mature Cooper Basin in South Australia and Queensland, where the technique has been applied to over seven hundred wells to improve the commerciality of lower permeability zones.

The following sections describe the application of fracture stimulation to the exploration and appraisal of shale and basin-centred gas. An outline is provided to demonstrate the principles of well design and construction (which ensure that injected fluid is contained in the well and injected into the target formation) and goes on to describe the fracture stimulation process, the fluids used, monitoring of stimulation, well completions, flowback and production testing, water use and other associated factors. The following sections also outline how wells are designed to mitigate any risk of groundwater contamination.

1.3 Well Design and Construction

Well design and construction is important in ensuring well integrity under the operating conditions that the well is expected to experience, and is particularly important during the high pressure fracture stimulation treatment and subsequent testing operations. Well design ensures that the wellhead, steel casing, cement and production tubing are suitable for:

- downhole temperatures;
- high pressures required to initiate fracture stimulation treatments deep underground;
- stresses induced when large volumes of cool fluids are pumped, at high pressure, into the well during stimulation;
- flow back of high temperature reservoir fluids; and
- potential flow back of sour gases (e.g. carbon dioxide).

When wells are drilled, a series of metal casing strings are installed and cemented into the ground at various depths to provide mechanical stability and isolation of the wellbore from the formations and aquifers that are penetrated during drilling. The strength of the casing and the depth at which these are set is determined through and understanding of the geological environment and the pressures that are anticipated in the formations that are drilled. The well design process also takes into account the operational conditions that are anticipated during the life of the well, including fracture stimulation, production of fluids, pressures and temperatures. These final parameters impact on the production casing, which is the last string of casing installed and cemented into the well bore. The casing string's size, strength, coupling and material must satisfy the identified operational conditions and industry standard design safety factors.

Beach's current well design for a typical vertical exploration well, suitable for fracture stimulation in the Penola Trough, is shown in Figure 6. The layers of casing shown in the diagram are as follows:

- conductor pipe, which is installed at the surface and provides the initial stable structural foundation for the well;
- surface casing string, which extends from the surface to approximately 650 metres to isolate aquifers;
- intermediate casing string, which is inside the surface casing and extends from the surface to approximately 2,400 metres; and
- production casing string, which is inside the intermediate casing and runs from the surface to the total depth of the well.

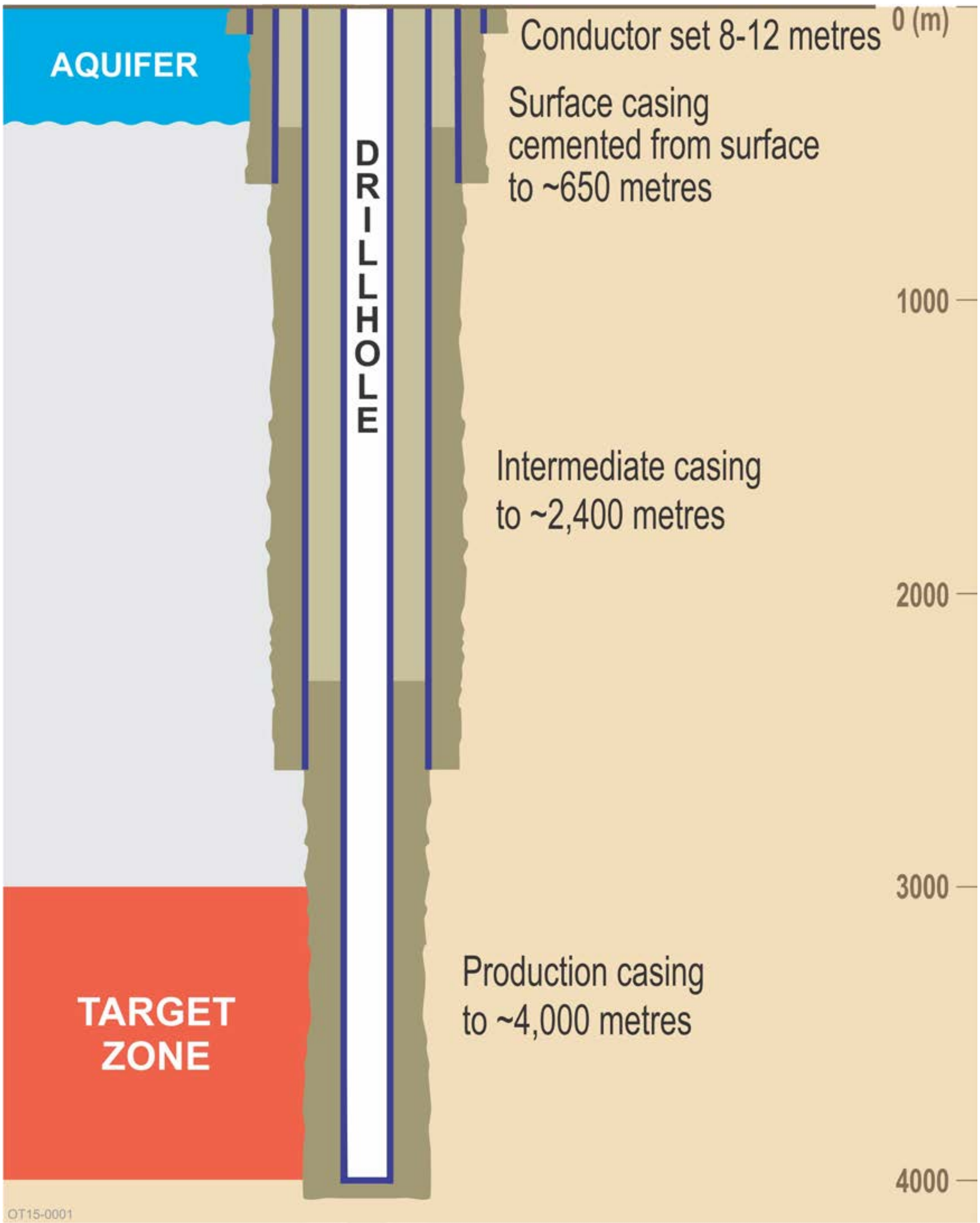


Figure 6: Indicative well design. Wells are designed to meet engineering and regulatory requirements for specific well objectives. Casing size, weight, grade, depths and cement volumes will be varied to meet engineering design specifications.

Each casing string in the well is cemented into the borehole. Cement integrity is important for isolating formations along the well bore. Cement integrity is verified by various means, including:

(a) monitoring of the cement placement during pumping to confirm it is placed as per the cement design;

(b) pressure testing of the cement; and

(c) cement bond logs of the production casing string (prior to stimulation), using an acoustic tool to detect whether spaces are present behind the casing.

Casing centralisation, cement design, volumes and pumping parameters are important in setting up the seal between the casing and the well bore. The correct cement design and implementation ensures production fluids remain within the well bore, completely isolated from aquifers.

Wells are pressure tested again prior to commencing fracture stimulation to confirm the integrity of the casing and cement.

In order to connect the inside of the casing with the target formation, a technique known as perforating is used. Shaped charges, also known as guns, are lowered into the hole and triggered to create holes through the casing and cement. These perforations are delivered with accurate precision and penetrate tens of centimetres into the rock into the target zone.

In designing a well, its integrity and the isolation of aquifers are the priority.

1.4 The fracture stimulation process

A typical fracture stimulation treatment involves pumping of several stages, which can be broadly classified as:

Pad stages

In this stage small volumes of 'friction reduced water' are injected. The initial pad volume, injected at high pressure, is used to split the rock and propagate the fractures. During the early stage, a small amount of hydrochloric acid may be pumped to clean up perforation holes. Additionally small amounts of fine grained sand may be used to further abrade the perforations and improve connection with the rock. At other times during the pad stage, additional fluid may be used to sweep proppant into the reservoir.

Proppant stages

Once the fracture has initiated, proppant is introduced. To keep proppant suspended in the fracture stimulation fluid, a gelling agent such as guar gum, an additive in food production, is used. Typically, the higher the injection rate of fluid, the less gel is required to carry the proppant. Additionally, finer grained proppants require less gel to carry them. Gel breakers, or surfactants, are added during the stage to assist in recovery of injected fluids from the fracture at a later stage.

Flush/Displace

In this stage, a final volume of water is used to push proppant from the well bore into the rock which cleans the well bore prior to the next stimulation job.

Plug/Perforate

Once the stimulation treatment is placed, a wireline unit is rigged up to run a plug that isolates the zone stimulated from subsequent stages. The wireline is also used to perforate the casing in readiness for the next stimulation treatment.

The process above outlines the activities associated with stimulating a single zone in the well. When multiple targets are identified, this process is repeated several times within a single wellbore.

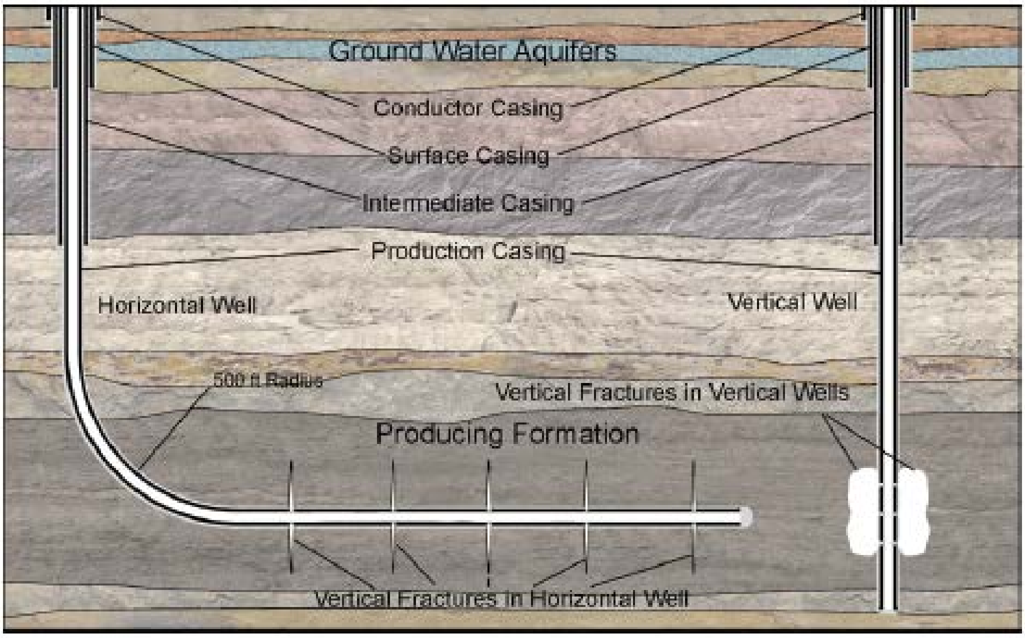


Figure 7: Example of fracturing in a horizontal and vertical well (Source: API 2009)

1.4.1 Fracture Stimulation Equipment

The fracture stimulation process requires equipment for pumping, proppant loading, blending, pipework and valves, tanks, additives and monitoring. The monitoring equipment is used to track the volume of fluids, the concentration of proppant being pumped, and most importantly the injection pressure. The injection pressure gives an indication of how the treatment is progressing.

As fracture stimulation involves injection of fluid and proppant at high pressures, mechanical integrity of pipework is integral to safe placement of each treatment. As with the well design process, stimulation equipment is designed to meet the pressures expected during the treatment process, with secondary protection to shut down equipment before design pressures are reached.

Figure 8. Fracture stimulation operations at Beach's Holdfast-1 well (Cooper Basin) in 2011

Fracture stimulation equipment is mobilised as required. At each well, operations would typically involve a two day set-up, one day per stimulation stage and two days to rig-down and demobilise to the next well.

1.5 Fracturing Fluids

Water is the main component of fracture stimulation treatments and comprises approximately 97% of the fluid injected during fracturing operations. The proppant is the next largest constituent. Proppant is a granular material, typically sand or small ceramic beads (used if additional strength is required), which is mixed in with the fracturing fluids to prop open the fractures and allow gas to flow to the well.

In addition to water and proppant, a range of other additives are necessary to ensure successful fracture stimulation. Additives, which constitute only 0.5% of the total fracture stimulation fluid, include acid, buffers, biocides, surfactants, iron control agents, corrosion and scale inhibitors, crosslinkers, friction reducers, gelling agents and gel breakers. Several of these ingredients are essential to maintaining well integrity.

The overall percentages of additives in a typical fracturing operation on a deep shale gas well in the Cooper Basin are shown in Figure 9. A similar hydraulic stimulation design is likely to be used should Beach apply to, and receive approval to fracture stimulate in the Otway Basin.

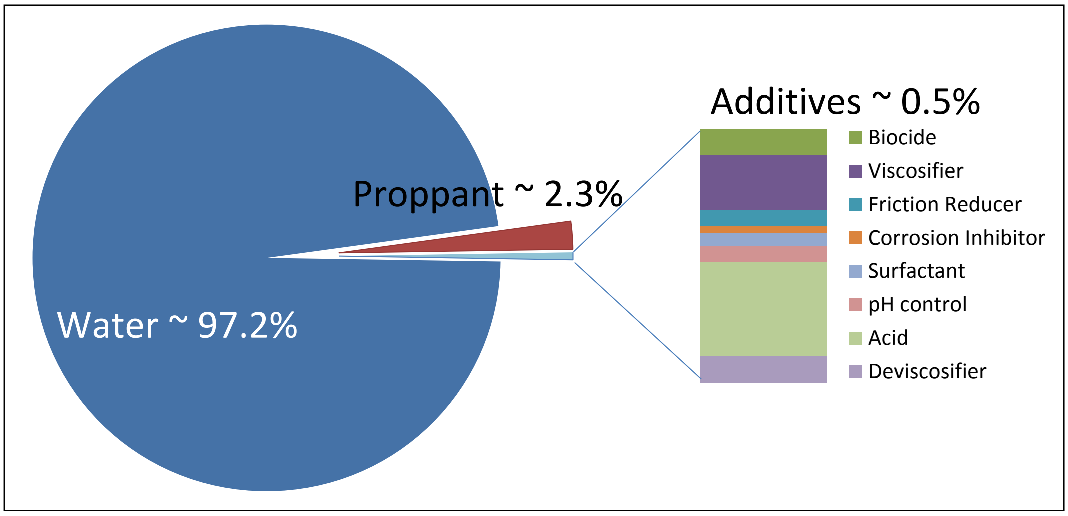


Figure 9: Example of overall percentages of additives in a deep shale gas well fracturing operation in the Cooper Basin (based on data from fracture stimulation of the Holdfast-1 well).

The fracturing fluid injected into the well is not uniform throughout the fracturing process. Each task performed during the fracturing operation will use fluid with additives specifically designed for the task. For example, acid is pumped in the initial acid injection phase to clean the well bore. In following phases, the fluid designed to propagate the fractures is injected, initially without proppant, and then proppant is added to the fluid to enter the fractures and hold them open. Gelling agents, or viscosifiers, are used during these phases to increase the viscosity of the fluid that helps suspend the proppant in solution. Gel breakers and surfactants are added to aid in recovery of the injected fluids from the formation.

Fracturing fluids are a carefully formulated product. The design of the fluid is varied based on the characteristics of the reservoir being fractured and the fracture stimulation design for the particular well. The design of the fluids must take into account depth, temperatures, pressures, reservoir geology and chemistry, scale build-up, bacteria growth, proppant transport, iron content and fluid stability, and breakdown requirements.

The types and purposes of additives expected to be used, in the event that fracture stimulation of unconventional hydrocarbon targets in the Otway Basin proceeds, are summarised in Table 1.

This information is based on the fluid makeup for fracture stimulation of Beach's Holdfast-1 well (Cooper Basin) that was undertaken in 2011 and information provided by the fracture stimulation contractor. Further detail on these additives and their constituents is provided in Appendix A. Links to Material Safety Data Sheets (MSDSs), which contain detailed information about each additive are also provided in Appendix A. The MSDS information is important for the safe handling, storage and clean-up of additives and fuels.

Table 1: Additives in typical deep fracture stimulation fluids

Additive	**Purpose**
Acid / Solvent	Removes scale and cleans wellbore prior to fracturing treatment.
Buffer / Acid Additive	Acid used to adjust the pH of the base fluid and Iron control additive in acid.
Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulphide and can physically plug flow of oil and gas into the well.
Buffer	Used to adjust the pH of the base fluid.
Crosslink Agent	A delayed crosslinker for the gelling agent.
Iron Control Agent	Helps to sequester dissolved iron in spent acid.
Friction Reducer	Allows fracture fluid to move down the wellbore with the least amount of resistance.
Corrosion Inhibitor	Prevents acid from causing damage to the wellbore and pumping equipment.
Crosslinker	A non-delayed crosslink agent.
Surfactant / Penetrating Agent	Allows for increased matrix penetration of the acid resulting in lower breakdown pressures.
Proppant	Holds open fracture to allow oil and gas to flow to well.
Scale Inhibitor	Prevents build-up of certain materials (i.e. scale) on sides of well casing and surface equipment.
Surfactant	Aids in recovery of water used during fracturing.
Gelling Agent / Viscosifier	Gelling agent for developing viscosity.
Breaker /Deviscosifier	Agent used to degrade viscosity.

The information provided in Appendix A relates to the service provider that Beach utilised for the stimulation project carried out in 2011 in the Cooper Basin. More recently, as the requirement for fracture stimulation has increased for both conventional and unconventional targets, other fracture stimulation providers now have equipment capable of meeting the requirements for unconventional resource targets and each of these companies will provide their own stimulation additives.

It is expected that the types, purpose, volume and concentrations used by other providers are likely to be similar to those outlined in Appendix A. Fracture stimulation providers may have their own proprietary stimulation compounds, which are generally from the same group of additives but with different amounts of, or slightly different, active ingredients.

Detailed additives proposed for use in fracture stimulation operations will be provided to the Regulator as required, together with details as to how the level of risk posed by these additives can be monitored and managed to maintain environmental outcomes. Chemical disclosure requirements across Australia vary from State to State. If necessary, in order to comply with applicable State requirements or where stakeholder considerations dictate, Beach will utilise additives from service providers who do not consider the additives to be proprietary and who are therefore willing to disclose the overall chemical make-up of the injected fracture stimulation fluid.

A number of other websites also provide information on fracturing fluid additives and are listed in Appendix A, including websites for the fracture stimulation service providers currently operating in Australia.

Most of the additives used in fracture fluids are found within products that are used in the home or in industry, as indicated in Appendix A. While many of the additives used in the fracturing process are hazardous in their concentrated product form, they are significantly diluted by water and are present in fracturing fluids in relatively low concentrations. Nonetheless, the fracturing fluid is always handled with care.

Beach aims to: keep utilisation of additives to the lowest level possible; safely manage the use of additives and fuels; and contain recovered stimulation fluids to minimise the environmental footprint of the stimulation activities. To meet these aims the following strategies are implemented:

- pumping as low a concentration of additives as is needed to perform the treatment;
- requiring the material handling and safety aspects of these additives, as managed by the contractor, to be in accordance with MSDSs and relevant standards and guidelines including AS 1940, EPA guidelines and the Australian Dangerous Goods Code (where relevant), which includes appropriate storage of all materials on site;
- auditing the contractor's management systems and conducting site inspections to assess the contractor's compliance;
- on-site supervision to monitor conduct of the treatments and ensure any spills are reported and remediated;
- containing recovered flow back fluids in lined ponds, above ground tanks or other appropriate holding tanks, as discussed in Section 1.9;
- monitoring and sampling of returned fluids during the exploration stage. Once the treatment is placed, it is estimated that less than 50% returns to the surface (King 2012). Much of the fracture fluid remains trapped in the rock underground and some of the additives may become adsorbed to the surface of the rock;
- managing ponds and/or tanks to ensure integrity of containment;
- removing pond liner to a licensed waste facility following evaporation/treatment/disposal; and
- rehabilitating pond and lease sites post activities.

Beach will continue to investigate methods to further reduce the use of additives as part of Beach's commitment to continuous improvement. Changes to fracture stimulation fluids that have been investigated include treatment with ultra-violet light to reduce the level of biocides that are required to control the growth of microbes. The quality of source water can affect application of UV technology.

1.6 Fracture Height Growth and Fracture Monitoring

Evaluation of many hundreds of fracture stimulation treatments in the United States across four different shale gas plays, has demonstrated that fracture height growth is restricted to (at most) approximately 200 to 300 metres (Fisher and Warpinski 2011). Due to stress changes in the rock and the finite volume of material pumped during the treatment the stimulation treatments are confined.

Due to the physical separation of the hydrocarbon target intervals and the shallow surface aquifers by approximately 2,000 metres to 3,000 metres, as described in the Beach activity overview and shown in the well construction schematic (Figure 2), it is apparent that there is very low likelihood that fractures induced during stimulation will extend into the shallow aquifer zones.

However, Beach monitors fracture stimulation treatments in a variety of ways to understand the results and the impact on production and recovery from the wells. Aside from conventional pre-stimulation and post-stimulation modelling of the proposed treatments and monitoring of treating pressures during the stimulation, some other techniques that may be applied include tracer injection and microseismic monitoring (although microseismic monitoring is applied more to appraisal and development wells as projects expand and enhanced reservoir understanding is required).

<u>Tracer monitoring</u>

Non-hazardous chemical tracers may be added in very low concentration to each of the fracture stimulation stages to assist with understanding which zones are contributing to flow back after the treatments. This information may be used to optimise future stimulation design.

Concentrations of the tracer injected into each stage are in the order of 750 parts per billion. However on flow back, as some of the tracer remains underground, total concentration of tracers recovered is expected to be less than 250 parts per billion comprised of between 0-100 parts per billion from each of the stimulation stages.

<u>Radioactive tracer monitoring</u>

Tracers have a short half-life of less than 100 days. The trained engineers responsible for handling tracer material are subjected to less radiation than a hospital worker, which is well below the regulatory limit for radiation workers.

Small amounts of these tracers may be added to each stimulation stage. Once the treatments are placed the well can be logged to estimate the fracture height growth near the well bore. The information can assist with confirming wellbore integrity during stimulation and provide information on how far a treatment may have grown adjacent to the wellbore.

Microseismic Monitoring

As discussed, during fracture stimulation water is injected into the target reservoir at sufficient pressure and rate to fracture the rock underground. When the rock moves the energy released from the slippage can be detected by monitoring equipment, provided the size of the event is sufficient and the equipment is sensitive enough. To put it in context with seismic events normally associated with earthquakes, a typical microseismic event is between -2 and 0 Mw and the smallest earthquake that can be felt is approximately 3 Mw.

There are two main types of microseismic monitoring applied in the industry, downhole microseismic and surface microseismic, which are explained below. Downhole microseismic monitoring is likely to be cost-prohibitive in the exploration and appraisal stages as it requires an adjacent wellbore to monitor the treatment.

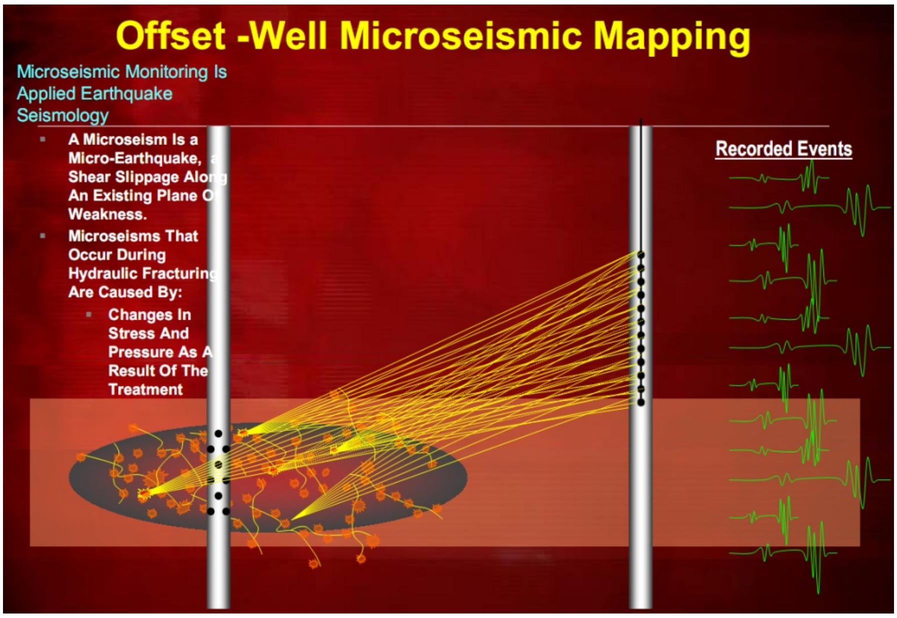
Downhole microseismic survey

The process, shown in Figure 10 involves placing a sensitive set of listening devices (geophones) in an adjacent monitoring bore (right hand well in the figure) during the stimulation of the target well (left hand well in the figure). During stimulation small movements of rocks are detected at the monitoring well and the location of those movements is determined by triangulation. The technique is accurate enough to assist geologists and engineers in understanding the height of fracture growth of a treatment and whether the fracture treatment is breaking new rock or has grown back into a previously placed fracture treatment.

Mapping the extent of the fracture treatment aids in understanding how much of the rock may be connected back to the well bore which in turn assists in assessing the potential quantity of gas that might be drained by the well. It also helps in determining the distance required between wells to maximise stimulation of the rock and increase recovery of the gas.

Understanding these key reservoir variables has resulted in application of this monitoring methodology in many shale development projects in North America where it has been used in around 5% of stimulation treatments (Maxwell 2014). As a result of this monitoring, an extensive database of fracture height growth has been built that demonstrates that fracture growth is limited (see Section 2.1.2).

This technique requires an adjacent monitoring bore to be available in close proximity to the treatment well (typically within 300-800 metres) and the monitoring tools are currently not designed for temperatures above 170 degrees Celsius (problematic in some basins). For stimulation of exploration wells this type of monitoring becomes prohibitively expensive as an additional well may need to be drilled.



From Pinnacle: Kevin Fisher, Oil and Gas Shale Developer, Houston May 2009

Figure 10: Schematic of micro-seismic monitoring of fracture stimulation treatment

Surface microseismic survey

Similar to seismic surveys, a surface array of geophones is placed in a pattern around the well with thousands of sensors to detect the small signals associated with the treatment. Beach has operated 5 surface microseismic monitoring projects in the Cooper Basin as part of the evaluation and monitoring of fracture stimulation treatments in the Nappamerri Trough.

1.7 Post-Stimulation Completion

Immediately following fracture stimulation, depending on the stimulation technique used, isolation plugs used to separate the fracture stimulation stages will be drilled out with coiled tubing or an equivalent. During this process excess well fluids will be directed to a lined interceptor pit or tank.

Prior to commencement of testing or production operations a tubing string is typically installed to isolate the final casing string from the production stream. The tubing string is another set of steel pipe installed in the well bore with an anchor arrangement at the bottom that attaches it to the production casing, sealing the space between the tubing and the production casing such that the void space between the two sets of pipe can be filled with protective brine and monitored for any breach of the tubing integrity. In the event there is a breach, the tubing string can be recovered and replaced.

The well design for the exploration activities requires that a tubing string is installed to isolate the majority of the production casing string from the production fluids. On-going monitoring of the gas composition from the well is undertaken to understand equipment design requirements for subsequent appraisal and development wells.

1.8 Flowback and Production Testing

Following installation of the tubing string the well is opened and flow commenced. As the initial flow back will be predominantly recovered stimulation fluid, production will be directed to either a lined pond or tank. Once the well begins to recover gas, the flow will be directed to the separator. The gas from the top of the separator is metered and sent to the flare where it is burnt. The water from the bottom of the separator is metered and directed to contained tankage or ponds dependent on the environmental requirements of the specific well site.

The gas stream and recovered water is sampled on a regular basis to evaluate their composition. While on production test, the gas will be flared at the well site.

During the flow back period the rate of production of the recovered fracture fluid diminishes. It is expected that approximately 40-50% of the injected fluid may be recovered, based on experience from shales in the US which indicates that a significant proportion of the injected fluid remains trapped underground with generally less than 50% of the placed fluid returning to surface (King 2012).

Prior to stimulation and testing, a site specific water management strategy will be developed to address:

- sourcing of water for stimulation;
- storage and handling of water prior to stimulation;
- treatment and disposal of recovered brine during completion, flowback and testing operations; and
- treatment and disposal, which may require trucking to a processing or disposal facility.

During testing operations typically four operators will be assigned, two covering the day shift and two covering night shift, to monitor well performance and equipment.

The production of the wells, use of separation equipment, sampling and logging activities are regular production techniques that Beach has conducted in the Cooper Basin on multiple wells.

<u>Additive Concentrations in Flowback</u>

Additives returning from a well after a fracturing treatment are usually a fraction (usually 20% or less for additives and about 40% for polymers) of what was pumped down the well (King 2012, Friedman 1986, Howard 2009). Polymers decompose quickly at temperature, biocides are spent on organic demand and degrade, surfactants are adsorbed on rock surfaces and scale inhibitors precipitate and come back at 10 to 15 ppm (parts per million) over periods of up to several months (King 2012). Hydrochloric acid used in initial clean-up is spent within a short distance of the entry point and no live acid is returned to the surface. Corrosion inhibitor is used in only the acid and is adsorbed onto the steel and then on the formation, and only about 5 to 10% total returns to the surface (King 2012). Consequently, many of the compounds that are identified as potentially hazardous on their MSDS, such as acids, corrosion inhibitors or biocides, are effectively neutralised or present at significantly reduced concentrations in the flowback fluid. The flowback fluid may also contain salts that were dissolved from the geological strata underground. Monitoring of ion concentrations in the flowback fluids will be undertaken to understand the extent to which this is occurring.

1.9 Water Management

At this stage the joint venture is yet to determine whether there is a prospective target for stimulation in the Otway Basin. As such, Beach and the joint venture have not undertaken planning for the requisite water management associated with a potential stimulation.

However, based on Beach's experience in the Cooper Basin, there are two distinct parts to water management for stimulation. The first phase is sourcing and storing water for the stimulation treatment, and the second phase is management of stimulation fluid that returns to the surface on flowback of the well during production testing.

Water sourcing and storing

In the Cooper Basin, water storage is in either lined earthen ponds or above ground open tanks. All earthen ponds are lined and fenced. The construction utilises both excavation and bunding to raise the sides of the ponds above ground level to prevent surface water runoff into the ponds. The temporary water holding ponds are constructed and filled in advance of the planned stimulation date, with water sourced, where possible, from shallow water bores on the well lease in the early exploration and appraisal stage. Beach is looking to drill a deeper alternative source of non potable water should the project proceed to production stage. Any water extracted to support the stimulation activities will occur in accordance with the relevant government regulations.

Post stimulation fluid management

A smaller lined interceptor pit, tank or solids capture mechanism may be required to receive fluids associated with post stimulation clean-out and completion activities. Initial flow back of the well, prior to diversion of the well stream to the separator, is directed to this equipment. If and as required, water from this interceptor may be transferred to appropriate tankage or storage with pumping equipment. It is expected that between 10% - 20% of the injected volume may flow back in this early clean out stage and the interceptor and transfer equipment will be designed for this load.

Once production is directed to the separator the flow back fluid will be sent (via a gauging tank or other metering device) to the appropriate tankage or storage.

At the conclusion of the production testing, the recovered fluids will require disposal. In the Cooper Basin this is achieved through evaporation, however alternative strategies are likely to be required in the Otway Basin. Should fracture stimulation be considered in the Otway Basin, an environmental assessment will be undertaken prior to stimulation to plan for water management. Some options that may be considered include the trucking of recovered fluid for disposal at a suitable facility or treatment at site to concentrate the brine for trucking and disposal at a suitable facility.

The area required to accommodate water management infrastructure results in the well lease being larger than a lease required for drilling a typical petroleum well (in the order of 200 metres by 200 metres compared to 130 metres by 100 metres).

The well sites will be rehabilitated once the wells are successfully stimulated and tested.

As part of Beach's commitment to continual improvement and prior to and future potential stimulation in the Otway Basin, Beach will investigate alternatives for water storage and produced fluid management such as free-standing lined tanks. An environmental risk assessment will be undertaken to determine the appropriate solution for water sourcing, storage and management of recovered stimulation fluid prior to undertaking stimulation, should Beach proceed to that stage.

1.10 Water Use

A typical fracture stimulation design utilised by Beach in the shale and low permeability intervals in the Cooper Basin requires 1.3 to 1.6 megalitres (ML) of water per treatment.

Assuming that the exploration well indicates positive potential for the area, in a vertical well, due to the thick target horizon in the section, there may be as few as three but potentially up to ten zones that may be fracture stimulated. In a horizontal well, with a length of 1,500 metres, stimulation treatments are likely to be placed every 100 metres requiring 15 treatments in the well.

Consequently, fracture stimulation of a vertical well would require in the order of 4 to 16 ML of water, and a horizontal well would require up to 24 ML. Recent stimulation campaigns by Beach have focussed on reducing the fluid volume pumped which has reduced this load further. Beach actively optimises stimulation treatment to improve stimulation outcomes which include minimising water use.

Water use for exploration is exempt from the water allocation planning process. However, should exploration proceed to production, Beach will have to apply for a water licence through South East Natural Resources Management Board. Beach is very aware of the importance of water to the region, and is searching for a deeper alternative source of non-potable water to use.

1.11 Other Aspects of Fracture Stimulation Operations

This section provides detail on aspects that are specifically relevant to the fracture stimulation process.

1.11.1 Waste Management

Any waste material generated from site would be managed as outlined in Table 2 below.

Table 2: Typical wastes and disposal methods

Waste	**Disposal Method**
Domestic Waste	
Sewage and grey water	Camp and sewage would be managed using a septic system. Septic systems must comply with the *Standard for the Construction, Installation and Operation of Septic Tank Systems in SA*.
Food waste and paper	Collected (may be compacted) for disposal to approved landfill.
Plastic, glass and cans	Collected at the site for disposal to approved landfill or recycling where possible.

Waste	**Disposal Method**
Industrial Waste	
Workshop waste (rags, filters)	Approved landfill.
Chemical bags and cardboard packaging materials	Compacted and collected at site for disposal to licensed facility.
Scrap metals	Collected in designated skip for recycling or to licensed facility.
Used chemical and fuel drums	Collected in designated skip for return to supplier or recycling.
Chemical wastes	Approved landfill or return to supplier.
Flowback fluids	Held in appropriate tankage for containment and management.
Timber pallets (skids)	Recycled or to licensed disposal facility.
Vehicle tyres	Shredded and disposed to approved landfill.

Waste management practices would be guided by the principles of the waste hierarchy (i.e. Avoid, reduce, reuse, recycle, recover, treat, and dispose).

Generation of domestic waste (e.g. food waste, paper, plastics, cans and glass) would be limited as most domestic waste handling would occur at the camp. The camp for fracture stimulation would be similar to the camp that is utilised during drilling operations and the same management of waste standards would be applied. Any domestic waste at the well site would be stored on site in secure bins or skips. Recyclable materials would be segregated for transport to a recycling facility where practicable. Other materials will be transported to a licensed waste disposal facility.

All industrial solid wastes at the site would be collected in designated skips for eventual recycling or disposal to an appropriately licensed facility. All wastes generated would be segregated on-site and, where feasible, reused or recycled. All waste would be transported to a licensed waste management facility in appropriate containers (e.g. drums or covered skips) by a licensed waste contractor where appropriate.

1.11.2 Material Storage

Fracturing additives and fuels required for the fracture stimulation operation (see Section 1.5) would be stored on site. Fuel and additives would be stored and handled, with appropriate secondary containment, in accordance with relevant guidelines and legislation (e.g. Australian Dangerous Goods Code, AS 1940 and EPA guideline *080/12 Bunding and Spill Management*).

1.11.3 Spills and Emergency Response

Appropriate spill containment and clean-up equipment would be maintained on site, including acid spill kits and hydrocarbon spill kits. Any spill that occurred would be contained, reported and cleaned up by treatment *in-situ* where appropriate, or removal off-site for treatment or disposal. A spill response and emergency response plan would be in place detailing actions to be taken to minimise the impacts of accidents and incidents.

1.11.4 Cleanup and Rehabilitation

Following the completion of fracture stimulation activities, all materials would be removed off site. The site would be re-profiled to match pre-existing surface contours, and the surface ripped to promote revegetation.

Site cleanup, rehabilitation and well abandonment (when required) would be carried out in accordance with the parameters established in the relevant environmental objectives document for the activity. Standard criteria have been established under the Petroleum and Geothermal Energy Act to measure the successful rehabilitation of abandoned well sites (PIRSA 2009).

Figure 11 below shows an example of a wellhead arrangement post-stimulation and flow testing in the Cooper Basin, located in the Strzelecki Desert in northern South Australia. The wellhead is approximately 3 metres tall and is standing on the lease which is shown prior to rehabilitation. The remaining footprint around the wellhead is small (approximately 3 metres across). As the Otway Basin wells are likely to have lower pressures than the Cooper Basin the well heads are expected to be smaller again.

The picture on the right shows a production lease of a gas well in the Otway following rehabilitation where vegetation is established over the original lease pad and has low visual impact on the surrounding environment.

Figure 11: Wellhead in Cooper Basin (Strzelecki Desert) after stimulation and testing (left) and production wellsite in Otway Basin (Ladbroke Grove 2) rehabilitated to reduced lease area.

2 Environmental Impact Assessment

This section discusses potential environmental impacts related to the fracture stimulation process in deep shale and tight gas reservoirs. The discussion is supported by an indicative environmental risk assessment which is summarised in Section 2.5. This risk assessment quantifies the level of risk based on an assessment of the likelihood and consequences of potential events occurring.

The indicative risk assessment is provided as a guide to the typical environmental risk areas and management practices that are considered prior to undertaking stimulation. It is intended as a guide for the purpose of the inquiry. Prior to stimulating in the Otway Basin a region specific detailed environmental risk assessment and Statement of Environmental Objectives will be developed to ensure all environmental aspects are addressed as required by the regulatory authority.

The text in sections 2.1 to 2.4 provides a detailed discussion of aspects of the environment that are potentially (or commonly perceived to be) impacted by fracture stimulation activities that related to the points of interest set by the Committee. Reference is made to the results of the indicative risk assessment where relevant throughout the discussion. The key aspects discussed are:

- aquifers, where the perceived hazards are in relation to the injection of fracture stimulation fluids into the target formations; and
- soil, shallow groundwater, surface water and fauna, where the perceived hazards are in relation to storage and handling of fuel, chemicals and flowback fluids.

The indicative risk assessment summary table (Table 3) in Section 2.5 provides a summary of the key hazards, management measures and resulting level of risk, and provides information outside the Committee's points of interest. Beach would be pleased to provide more information on additional areas should the Committee be interested. This indicative table has been adapted from a risk assessment prepared by Beach in relation to its activities in the Cooper Basin (Beach (2012)).

2.1 Aquifers

Best management practice in well design and operations is the key to protecting aquifers. The perceived hazards to aquifers resulting from fracture stimulation activities, and how these risks are mitigated are discussed below.

2.1.1 Aquifer protection through well integrity

Well integrity is the key to ensuring there is no leakage into aquifers. This is achieved through ensuring best practice in terms of well design and continuous monitoring throughout operations. In particular:

- well design and construction provides the mechanical integrity to isolate well contents from aquifers;
- pressure testing confirms that production casing meets designed pressure specification;
- cement bond logs assess the integrity of cement that fills the casing-wellbore space prior to stimulation;
- pressure safety trip out systems during fracture stimulation prevent pressure limits of the surface pipework and downhole casing equipment being exceeded;
- pressure monitoring is used as an indicator of well integrity during stimulation; and
- installation of a tubing string, after stimulation, provides further isolation of production fluids from aquifers.

These items are discussed below.

Well design

As indicated in Section 1.3, the well design and construction process provides the mechanical integrity of the well bore for the operational conditions and life of the well. The process ensures that casing, well head and production equipment are designed to meet the stresses and loads associated with the temperature, pressures and fluids that may be pumped into and produced from the well.

The required casing, production and well head equipment is purchased from suppliers that have demonstrated to Beach their ability to supply the materials that meet or exceed the design specification with appropriate supporting certification documents.

Well construction

During construction of the well the casing strings are cemented into the ground. As shown in Figure 6, the shallow aquifers are isolated behind three strings of casing. In addition to anchoring the casing string into the bore, the cement provides a barrier to fluid migration between the casing and borehole isolating aquifers and hydrocarbon bearing intervals.

Cement design, casing centralisation in the well bore and correct cement pumping procedures are important in ensuring good quality cementing and isolation of the formations. This will maximise the potential for technical success of the well and prevent migration of fluids behind casing.

Pressure testing and cement bond logs

Prior to the stimulation treatment, the wellbore is pressure tested to confirm the pressure integrity of the casing and the cement at the base of the well. Water is injected into the well and the pressure increased to the maximum design pressure.

Additionally, a cement bond log is run prior to stimulation to characterise the quality of the cement behind the casing. The log assists with understanding stimulation and production results in the event that unexpected production characteristics develop.

Should the cement bond log indicate poor cement isolation between zones within the target interval, this may result in poor separation between individual fracture stimulation treatments. If this occurred it would result in a negative impact on production but would not affect shallow aquifers. This provides a commercial driver to ensure proper isolation of intervals.

Pressure protection during stimulation

In order to ensure that the pumping equipment does not generate pressures which exceed the design pressure of the casing and wellhead equipment, controls are fitted to the pumping equipment that will shut down the pumps once a pre-set operational maximum pressure is reached.

Monitoring during fracture stimulation

Monitoring of injection pressures is carried out during fracture stimulation to ensure well casing integrity.

During the fracture stimulation treatment the injection pressure at the wellhead is constantly monitored to understand how the injection is progressing. As discussed in the well design section, the choice of casing size, weight and connection type, the use of new casing from a reputable supplier and adequate supervision while running the casing ensures well integrity is maintained.

Tubing string installation

During the production testing phase, the tubing string provides a further barrier, preventing the production string being exposed to well production fluids. The annular space between the tubing string and the production casing is monitored for pressure. A sudden unexpected change in the annular pressure would indicate that the tubing integrity has been compromised. If necessary a plug can be set in the tail pipe of the tubing until the tubing is replaced, minimising exposure of the production casing to production fluids.

Summary

The likelihood of aquifers being impacted by leakage during fracture stimulation of a properly constructed and operated well is low as tabulated in Table 3.

2.1.2 Fracture propagation

Monitoring of many fracture stimulation treatments in shale gas plays in the United States has shown that typical height growth of fractures is less than 200-300 metres (Fisher and Warpinski 2011). Figure 12 is a plot of the upper extent of the fracture treatment, the perforation depth and lower extent of the fracture treatment plotted against target zone depth (decreasing depth to the right) for more than 300 wells in the Eagle Ford shale in Texas.

The Otway Basin stratigraphic section and the location of the shallow surface aquifers are shown in Figure 12 to illustrate that a typical shale gas fracture treatment cannot reasonably be expected to have sufficient height growth to stimulate into the overlying aquifers. The Eagle Ford data shows no occurrence of height growth sufficient to intersect an aquifer located more than 400 metres above the fracture stimulation zone in at least 250 treatments. In relation to the Otway Basin and the zones to potentially be targeted, it is important to remember that the Eumeralla formation acts as a natural geological seal. In addition, the base of this section is still far removed from the much deeper target intervals by around one kilometre.

The Eagle Ford data is presented because the monitored fracture stimulation treatments were conducted over a similar depth interval to the Otway Basin target zones.

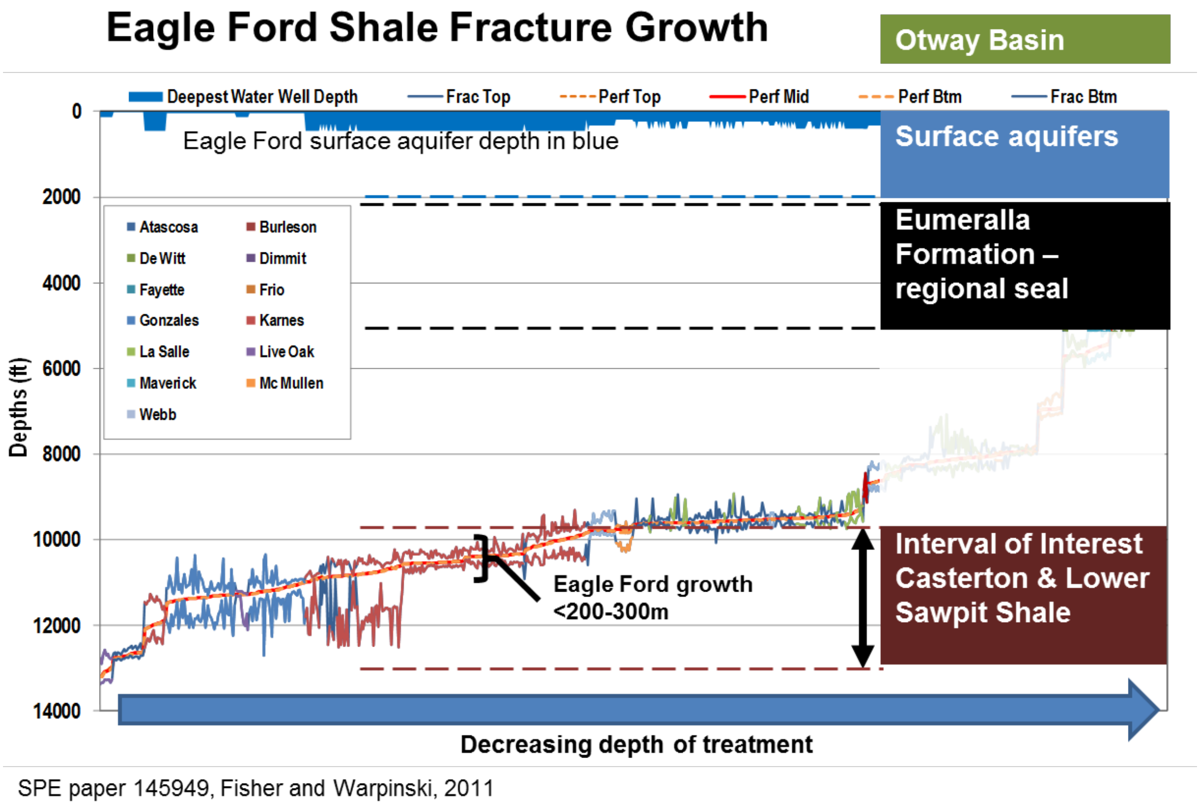


Figure 12: Typical fracture height growth measured during shale gas stimulation in the Eagle Ford (USA) with Otway Basin well section superimposed.

2.1.3 Migration of fluids through geologic media

Migration of stimulation fluids to aquifers through the overlying strata is not considered to pose a credible risk.

As discussed above, the nearest aquifers of any significance are the shallow aquifers of the Gambier Limestone and Dilwyn Formation. As indicated in the geological overview, the target intervals are separated from the shallow aquifers by at least 2,000 metres of rock.

2.1.4 Target reservoir aquifer potential

The impact of fracture stimulation operations on the aquifer potential of the target reservoirs themselves (i.e. the target formations for fracturing) is not considered to be a risk.

The Casterton Formation is considered to be an aquitard (barrier to water flow) not an aquifer. The sandier units within the Lower Sawpit Shale may be considered to be aquifers if water saturated. However, if the units are water saturated there is no hydrocarbon resource potential and the units will not be fracture stimulated.

2.1.5 Lateral migration of injected fluid within the target section

Due to the low permeability, any fracture stimulation fluid that enters the intervals is highly unlikely to migrate any significant distance beyond the stimulation treatment. Additionally, once the fracture stimulation treatment is performed the well is then flow tested. This creates a pressure sink at the wellbore. The pressure difference between the fluids in the rock pore space and the wellbore is the drive mechanism that results in gas and fluid production to the well. Once flow commences the pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or laterally away from the fracture stimulation.

2.1.6 Fracture propagation between pressure cells that are normally isolated

Fracture growth out of the immediate fracture stimulation zone and into adjacent strata within the target section may possibly occur, but would have negligible impact as it is unlikely to result in significant cross-flow within the target formations.

Should there be extension of induced fractures that connect two separate systems there would be a brief cross-flow of the higher pressured gas into the lower pressure gas system until the well is flow tested. During production testing the gas flow would be towards the wellbore as this will be lower pressure than the neighbouring strata. This is not likely to have significant environmental impact in the low permeability, gas-saturated formations in the Otway Basin, and rather than being detrimental, growth of fracture stimulation through the target interval can assist in improving recovery of gas from isolated sand pockets in the strata, maximising efficiency of drainage.

2.1.7 Groundwater impacts from water use

If the exploration and appraisal phase in the Otway Basin is successful and Beach is likely to progress to a development phase, application for use of groundwater under the Government regulations would be carried out. Beach would also investigate the option of recycling recovered fracture stimulation fluids where possible. In this case, detailed investigation and consultation regarding water sourcing would be carried out to ensure that water resources are protected and any potential impact on other water users is avoided.

Beach is considering alternative sources of non-potable water should the project move into production phase to avoid competition for water resources with existing groundwater users.

2.2 Soil and shallow groundwater

Soil and shallow groundwater in the Otway Basin would be protected by ensuring that all materials on site are stored and handled in accordance with relevant standards and guidelines. Fuel and chemicals would be stored with appropriate secondary containment as required.

As discussed in Section 1.9, there would be two parts to water management in the Otway Basin. The first part is associated with water storage prior to stimulation and the second part is to manage the storage and disposal of the recovered fracture stimulation fluids during flow back and production testing activities.

Water storage in preparation for stimulation would be in lined ponds, above ground tanks or other surface tankage as is assessed to be appropriate for the activity. The stimulation fluids recovered during flowback and testing would be captured and contained via the interceptor pit or tank and the separation process and directed to appropriate tankage as set out in the environmental assessment that would be conducted prior to stimulation.

Should earthen or surface ponds be utilised in the Otway Basin, quality control during construction of the ponds would be important in preparing a suitable base for the lining material to minimise risk of liner breaches. For earthen ponds, fencing prevents large fauna and livestock from entering the ponds and damaging the liners. Regular monitoring of the pond and fence condition, operating the ponds below maximum fill levels (allowing freeboard for rain events and wave action) and construction with above-ground bunding to prevent surface runoff into the ponds all minimise the risk of seepage or release from the pond. Above ground tanks, where used, would reduce potential environmental impacts by preventing entry of large fauna and livestock.

The water table in the Otway Basin region is close to the surface, and is predominantly fresh water. There is moderate population density and the agricultural industry is heavily reliant on the use of shallow groundwater.

Fracture stimulation requires the injection of high pressure fluids into the wellbore. Surface pipework, valving and pumping equipment required for the treatment must have a valid certification for the pressure rating. Once set up for the fracture stimulation the equipment would be pressure tested to ensure integrity and pressure trip out devices would be present to shut down pumps before equipment limitations are reached (Section 2.1.1). The design, pressure test and shut down systems ensures that the equipment can be quickly shut down from a control van should the need arise.

Storage of waste and transport to licensed disposal facilities would be undertaken in accordance with relevant legislation and guidelines. Waste generation would be minimised where practical, waste would be stored securely and licensed waste contractors would be used for waste transport.

Beach is establishing a monitoring program at well sites and water wells throughout the area to establish a baseline and monitor soil and groundwater quality on an ongoing basis. Some of this work has commenced.

Other potential impacts to soil in the Otway Basin (e.g. soil disturbance, erosion) would be localised and generally short term. These are principally a result of well lease preparation activities. Site rehabilitation, including remediation of these impacts would also be carried out.

2.3 Surface Water

Measures to ensure safe handling and storage of fuel, chemicals and flowback fluids would be implemented by Beach, as discussed in Section 2.2, including secondary containment, lining, spill response and cleanup. Similarly, secure storage and handling of waste would be implemented as discussed in Section 2.2.

To mitigate the risk of onsite fuel, fluid or chemical release due to flood inundation, well leases would not be located in areas where frequent flooding is likely. If well leases are to be located in areas where flooding may occur, measures would be undertaken to ensure that ponds are not vulnerable to flooding. For example:

- ponds may be located on higher ground out of the floodplain;
- pond walls would be constructed at these locations;
- surface tanks or trailerised tanks could be used;

- tests would not be undertaken during known flooding seasons.

Above ground tanks as shown in Figure 13 naturally prevent surface water drainage into the tank. Selection of appropriate well site and pond locations would also ensure that the consequences of a potential pond failure are minimised (e.g. ponds would not be located in close proximity to creek channels or other significant watercourses such that failure would result in direct release to these watercourses).

Ponds would be constructed with sufficient wall height to allow for rain events and wave action, would be monitored.

Figure 13: Examples of temporary water holding ponds used in the Cooper Basin

Prior to undertaking fracture stimulation operations, site-specific assessments would be prepared to demonstrate that environmental objectives can be met. The site specific assessments would indicate risks identified at individual well locations and set out management strategies required to mitigate the risks and meet the environmental objectives.

The mitigation measures discussed above, particularly in regard to the location of ponds and well sites, indicate that the likelihood of release of flowback fluid to surface water could be reduced to a very low level.

2.4 Other Issues

2.4.1 Public Safety

Fracture stimulation activities would be carried out at established well leases where public access is restricted. Lease access would also be further restricted to necessary personnel only during pressure pumping activities.

Measures such as signage and fencing would be in place at the well lease to warn of the hazards at the site and restrict access into the site, with sumps and ponds securely fenced.

Fracture stimulation activities (and drilling activities in general) would not be carried out in close proximity to places of residence.

Fracture stimulation operations may result in a short term and localised increase in traffic volumes. Measures to mitigate the risks to the public would be implemented and include signage, speed restrictions, monitoring of speeds in industry vehicles, education programs and ongoing maintenance of roads and tracks.

2.4.2 Cultural Heritage

Potential impacts to cultural heritage arise mainly from activities occurring outside designated or approved areas.

Fracture stimulation operations would be undertaken on a prepared well lease, within the area cleared for activity by the local Aboriginal group during a cultural heritage field survey, if required. Signage and fencing (where required) would be installed to delineate approved areas and any restricted areas. If sites of cultural heritage significance are present in the vicinity they may be flagged and/or fenced off where necessary to prevent disturbance. In addition, procedures would be place to deal with the incidental discovery of cultural heritage material.

2.4.3 Seismicity

With the relatively small volume of fluid pumped in a fracture stimulation stage (an injection of 1.6 ML of water per stage), the maximum release of energy in one stage equates to a 1,000 to 100,000 times smaller than the smallest perceivable earthquake.

Beach's experience with microseismic monitoring of stimulation of horizontal shale wells has been that events are typically between -2 Mw and 0 Mw. The scale is logarithmic meaning that there are two orders of magnitude (100 times) difference between the smallest events (-2 Mw) and the larger events (0 Mw). To put these into context, typically humans do not register or feel earthquakes that are below a magnitude of 3 Mw.

Data from Geoscience Australia has been referred to for information on earthquake activity in the South East corner of South Australia since 1970. The data search spans from the coastal town of Kingston across eastwards to the state border and everything south of this (area size approximately 17,000 km^2). This area is in the lowest category for seismic hazard indicated by Geoscience Australia's seismic Hazard map (Burbidge, 2012).

Prior to undertaking stimulation in the Otway Basin, a site specific risk assessment would be undertaken to determine the potential for induced seismicity. If determined that risk mitigation is required in this regard, a traffic light system could be adopted similar to the process described for stimulation of the Paralana geothermal project in South Australia (Petratherm 2010, 2011).

2.5 Environmental Risk Assessment Summary

As outlined at the beginning of this document, the information contained within this submission is a generalised environmental risk assessment of fracture stimulation of deep shale gas and tight gas reservoirs based on Beach's first-hand experience in the Cooper Basin (Beach 2012). An Otway Basin specific risk assessment would be carried out should Beach and the joint venture wish to proceed past the exploration stage. The following section summarises the process and results that would typify an assessment reflecting the risks described in the document.

Environmental risk is a measure of the likelihood and consequences of environmental harm occurring from an activity. Environmental risk assessment is used to separate the minor acceptable risks from the major risks and to provide a basis for the further evaluation and management of the major risks.

The risk assessment process involves:

- identifying the potential hazards or threats posed by the project;
- categorising the potential consequences and their likelihood of occurring; and
- using a risk matrix to characterise the level of risk[1] .

The risk assessment process applied to the Cooper Basin evaluation (Beach 2012) was based on the procedures outlined in Australian and New Zealand Standard AS/NZS ISO 31000:2009 (Risk Management) and HB 203:2006 (Environmental Risk Management – Principles and Process).

The risk assessment below uses Beach's risk matrix and definitions for consequences and likelihood, as defined in Beach Energy HSE Procedure 04 – F04. These tables are contained in Appendix B. These tables use:

- five categories of consequence (Negligible to Critical) to describe the severity, scale and duration of potential impacts;
- five categories of likelihood of potential environmental consequences occurring (Remote to Almost Certain). The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring; and
- a risk matrix to characterise the risk associated with each hazard as low, medium or high.

Risks are generally considered acceptable if they fall into the low category without any further mitigation measures, and 'tolerable' if they fall into the medium risk category and are managed to reduce the risk to a level 'as low as reasonably practicable'. Risk reduction measures must be applied to reduce high risks to tolerable levels.

A summary of the level of environmental risk for fracture stimulation activities is provided in Table 3 below. The level of risk has been assessed based on the assumption that the management measures outlined in this document will be in place.

B. The Impacts Upon landscape

Gas production and agriculture have co-existed in the Otway Basin, South Australia, since the Katnook gas facility was first commissioned by Origin Energy in 1991. Oil and gas activities are carefully located to minimise impacts to flora, fauna, visual amenity, groundwater and surface waters. The existing Katnook gas facility which is serviced by 12 wells and approximately 42 kilometres of buried pipelines provides an excellent example of a low impact production facility once all exploration activities have been completed.

During fracture stimulation phase, the existing well lease (1.5 hectares) is used to provide a safe working environment, with an additional 1-1.5 hectares of land required to manage stimulation water and flowback fluid. Once a well has been fracture stimulated and production commences, the

[1]The risk assessment process is iterative for many hazards. For example, the risk assessment may initially indicate that risks are unacceptably high, based on minimum or familiar management practices. In such cases, management practices are reviewed to identify additional management options to lower risk and/or improve environmental outcomes (e.g. elimination, substitution, reduction, engineering controls and management controls). The risk is then re-assessed based on these additional management options. This document details the final or residual risk after management options have been applied.

total working area is significantly reduced to around 0.5 hectares with the remaining area rehabilitated to its original condition.

Roads and Movement of Vehicles and Heavy Machinery

Impacts of road use are generally short term, with peak traffic movements occurring during equipment moves. Landholders, local councils, potentially affected residents and police would be informed of significant activities such as equipment mobilisation and demobilisation. Equipment movements would detour around town centres where possible. Warning signs and traffic management measures would be installed where appropriate near well sites. All necessary permits would be obtained for trucks transporting drilling and other equipment. Transport moves would be restricted to daylight hours as far as possible.

Any deterioration of property tracks or infrastructure caused by fracture stimulating-related traffic would be rectified.

Consultation with landholders is undertaken to ensure that the location and timing of activities minimises the potential for impact on any stock in the area. Measures in place to minimise impacts include speed limits, fencing of access tracks if required, positioning lighting to minimise light emanating from the site during fracture stimulation operations, avoidance of night transport moves as far as possible, and prompt removal of fracture stimulation equipment and camps from site following the completion of operations.

Water Production

Water associated with conventional and unconventional gas production is expected to be minimal compared to the large volumes associated with coal seam gas production, which require large holding ponds. Any water co-produced with gas (or oil) in the Otway Basin will need to be licensed under the Natural Resource Management Act through the local regional water allocation plan. The low volume of water co-produced with gas production is evidenced by the size of the ponds at the Katnook gas facility. Katnook is supported by two plastic lined holding ponds which have a combined holding capacity of 7 ML and cover a total area of 0.45 hectares (10-15 % of total facility area).

Landowner Benefits

Beach works closely with its landowners to ensure they are consulted regarding the location, management and timing of proposed activities, with the aim of minimising disturbance. Ongoing liaison with landholders is carried out following drilling and throughout the well’s life if it is successful. Appropriate access tracks to drill sites are chosen in consultation with landowners and any deterioration of property tracks or infrastructure as a result of drilling-related traffic is rectified. Previous experience in the Otway Basin has indicated that access tracks can generally be located so that they can be retained as all-weather access across the property and provide a long term benefit to property operations.

Furthermore, under the Petroleum and Geothermal Energy Act, landowners have rights to compensation. Compensation is payable where there is:

- deprivation or impairment of the use and enjoyment of the land;

- damage to the land (not including damage that has or will be made good by the licensee);
- damage to, or disturbance of, any business or other activity lawfully conducted on the land; and
- consequential loss.

Compensation agreements are therefore negotiated and agreed with affected landowners based on any activities undertaken.

Benefits as a result of exploration and appraisal for shale and tight gas on owners of the land, the region and other licensees are as follows:

- well access routes would be rehabilitated in the event of an unsuccessful well but may be of use to landholders and may save construction costs to the landholder;
- improved access routes, less affected by flood or heavy localised rain events, may be established and be beneficial to stakeholders;
- increased utilisation of regional food, fuel and lodgings which has direct impact to owners and potential indirect impact to users if services were to be expanded or augmented;
- increased utilisation of indigenous land owner crews to undertake clearance surveys associated with activities;
- potential enhancements to infrastructure dependent on success and on-going activity;
- potential installation of gathering systems and connection to gas lines may provide access to gas as an alternative fuel source for landowners and other licensees; and
- increased understanding of the geological zones under the ground provides information for other licensees in the area once data becomes open file.

C. The Effectiveness of Existing Legislation and Regulation

Beach recommends that the Committee hear from the Regulator with regards to the legislative framework that underpins oil and gas exploration and production.

In South Australia the oil and gas industry is a highly regulated industry by the State Government. All regulated activities such as fracture stimulation, are conducted under the *Petroleum and Geothermal Energy Act 2009* (the Act). A fundamental requirement of the Act is all regulated activities must be conducted under an SEO. The SEO is underpinned by an Environmental Impact Report (EIR) which describes the activity, identifies the actual and potential risks associated with the activity, and proposes mitigation strategies to manage those risks. The SEO is subject to consultation with stakeholders actually and potentially impacted by the activity to assist in the identification of any further risks. The draft SEO and EIR is submitted to the State Government for assessment, where the document is reviewed by the relevant government departments such as but not limited to, Department for State Development (DSD), Environment Protection Authority (EPA), and Department for Environment, Water and Natural Resources (DEWNR). Once the documents have been assessed and comments reviewed, the documents are re-submitted for approval by the Minister for Mineral Resources and Energy. Once gazetted these documents are subject to review every five years.

Once an SEO is approved, on ground activities are subject to further activity approval pursuant to the Act and Regulations through the activity notification process which is managed by DSD.

D. The Potential Net Economic Outcomes to the Region and the Rest of the State

Australia, in particular the east coast, will soon be in the midst of a gas supply shortfall, with long dated legacy gas contracts expiring. Demand for gas is anticipated to increase once LNG facilities in Gladstone come on-line over the next twelve months. Beach has invested its gas exploration activities into two key areas, the Cooper and Otway Basin, in a bid to explore and hopefully produce and supply gas to meet this demand, and supply gas to the domestic market. As mentioned in this submission already, Beach is still evaluating core samples taken from the two wells drilled in the Otway Basin earlier this year, with early indications suggesting that the potential exists to produce gas from both conventional and deeper targets.

The impact of an energy supply shortfall will not be limited to the east coast of Australia. South Australian gas supplies come from offshore in the Otway Basin. Any shortages in the east coast gas market, whether they are from supply, the impact of bushfires, or excessive heat may have flow on impacts that could result in power outages across South Australia.

Unconventional gas development, in particular shale gas, has become an important source of energy in the United States, which now produces more natural gas than any other country, and has delivered significant economic benefits to that country.

Until we have more information on what any future program in the Otway Basin could look like, it is difficult to quantify the likely scale and economic impact. Analysis of core samples taken during exploration drilling will provide some insight.

Any future program could have direct benefits to the region and the state, beyond supplying gas that is in need. Benefits will include:

- royalty payments to the State;
- direct employment benefits that are significant in the exploration and development stage, as well as indirect benefits associated with the increase in investment driven demand in related industries;
- the use of local contractors and suppliers where possible;
- local community support. Beach has already supported sporting clubs and conservation programs in the region and has been approached by others seeking support;
- a potential resurgence of industries that rely on cost effective energy, i.e. the chemicals industry, the production of fertilisers used in agriculture; and
- a clean energy supply.

Conclusion

Beach Energy has a 50 year history of successfully working with communities and landholders.

The company is committed to safety and is a responsible environmental custodian, pioneering low impact seismic and heritage clearance processes.

Beach has a long history of gas exploration in the South East of South Australia and is committed to supporting the local community through employment opportunities, using local labour where possible.

Recent drilling in the Otway Basin has identified conventional gas structural targets within existing gas fields. Drilling these will be the Company's first priority.

Beach engineers its wells to ensure that where potential gas zones are encountered, the gas does not have any chance of mixing with aquifers. Wells are triple steel and cement cased through the areas where they pass though aquifers.

Fracture stimulation has been used in South Australia for over 40 years without any negative impact on the environment. No fracture stimulation will be undertaken by Beach without Government approvals and community consultation. A successful drilling and further development program would deliver economic benefits to the State and the region.

Beach would welcome the opportunity to meet with members of the Natural Resources Committee and to appear before the Committee to expand on the matters we have raised in our submission.

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Appendix A

Listing of Fracturing Additives and Constituents

1 Introduction

This appendix provides detailed information on additives used in fracture stimulation operations. It provides data on fracturing fluid additives for a typical deep fracturing formulation in Australia, as supplied by Halliburton. Links to Material Safety Data Sheets for the additives are provided and sites where further information is available are also listed.

As discussed in Section 1 of this document, Halliburton information is used to exemplify the makeup of a typical fracturing fluid. This information is directly copied from the Beach Energy Environmental Impact Report for Fracture Stimulation of Deep Shale Gas and Tight Gas Targets in the Nappamerri Trough (Cooper Basin) South Australia (Beach 2012). The detailed chemical listing provided includes some trace chemicals that were at that stage, and may still be, confidential to Halliburton. Where necessary Beach has and will modify the fracture stimulation additives utilised in fracture stimulation treatments to enable full disclosure of the chemical components in the pumped stimulation treatment as may be required by State or stakeholder requirements.

2 Typical Deep Fracturing Formulation (Halliburton Australia)

The following information has been obtained from Halliburton[2], and is based on a typical fracture stimulation formulation for deep wells in the Cooper Basin.

Information is first provided on the additives used in fracture stimulation, then on the individual chemical constituents that make up these additives.

2.1 Fracturing Fluid Additives

The following table lists the additives for a typical fracture stimulation formulation for deep wells in the Cooper Basin. Information on actual concentrations (as a total percentage of the fracturing fluid) of additives used in the fracture stimulation of the Holdfast-1 well is also included in the table.

Table A1: Fracturing fluid additives

Product Name	Additive	Purpose	Concentration (within stage injected)	Indicative overall % in total fracturing fluid (Holdfast-1)
100 Mesh Sand, 100 Mesh Premium, 30/50 Premium, 40/70 Premium	Proppant	Holds open fracture to allow oil and gas to flow to well	0.25 - 10 lbs/gal	2.3%
15% Hydrochloric Acid (HCl)	Acid/Solvent	Removes scale and cleans wellbore prior to fracturing treatment	1000-5000 gal run ahead of frac treatment	0.19%
Acetic Acid	Buffer/Acid Additive	Acid used to adjust the pH of the base fluid and Iron control additive in acid	<0.2 gal/ 1000 gal and 5 - 20 gal/1000 gal of	0.02%

[2] See http://www.halliburton.com/public/projects/pubsdata/Hydraulic_Fracturing/fluids_disclosure.html

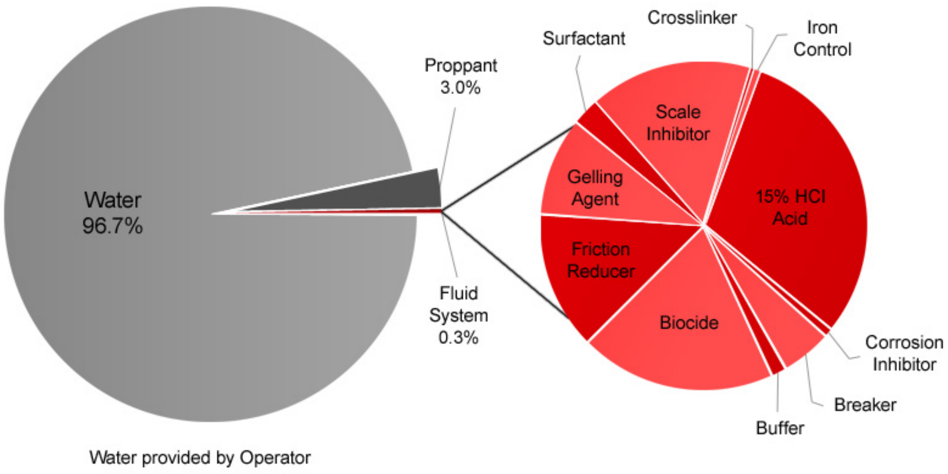
Product Name	Additive	Purpose	Concentration (within stage injected)	Indicative overall % in total fracturing fluid (Holdfast-1)
			acid	
BE-6™	Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulfide and can physically plug flow of oil and gas into the well	0.15 lbs/1000 gal	0.0001%
BE-9™	Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulfide and can physically plug flow of oil and gas into the well	0.25 - 0.75 gal/1000 gal	0.05%
Caustic Soda	Buffer	Used to adjust the pH of the base fluid	0.2 - 2 gal/1000 gal	0.01%
CL-28M™	Crosslink Agent	A delayed crosslinker for the gelling agent.	0.3 -1.1 gal/1000 gal	0.03%
FE-2™	Iron Control Agent	Helps to sequester dissolved iron in spent acid	5 - 100 lbs/1000 gal of acid	0.002%
FR-46™	Friction Reducer	Allows fracture fluid to move down the wellbore with the least amount of resistance	0.5 - 2 gal/1000 gal	0.03%
HAI-404M™	Corrosion Inhibitor	Prevents acid from causing damage to the wellbore and pumping equipment	5- 25 gals/1000 gal	0.01%
HII-500M +	*Corrosion inhibitor intensifier*	*Increases effectiveness of corrosion inhibitor*	*2 gal/1000 gal of acid*	*0.002%*
K-38™	Crosslinker	A non-delayed crosslink agent	0.25 - 5 lbs/1000 gal	0.0002%
PEN-88 HT™	Surfactant / Penetrating Agent	Allows for increased matrix penetration of the acid resulting in lower breakdown pressures.	1 - 5 gal/1000 gal of acid	0.002%
Scalecheck® LP-55	Scale Inhibitor	Prevents build up of certain materials (i.e. scale) on sides of well casing and surface equipment	0.1 - 0.5 gal/1000 gal	- *
Superflo 2000™	Surfactant	Aids in recovery of water used during frac	0.5 gal/1000 gal	0.025%
ViCon NF™	Breaker	Agent used to degrade viscosity	1 - 10 gal/1000 gal	0.053%
Water	Base Fluid	Base fluid creates fractures and carries proppant, also can be present in some additives	N/A	97.2%
WG-11™	Gelling Agent	Gelling agent for developing viscosity	20 - 60 lbs/1000 gal	0.08%

* Not used in the Holdfast-1 fracturing

+ Used in the Holdfast-1 fracturing but not listed on the Halliburton website for a typical deep well fracturing

2.2 Indicative Overall Percentage of Additives

The indicative overall percentages of additives in a typical fracturing operation on a deep shale gas well in the Cooper Basin are shown below.



Note: This is based on Halliburton typical data and differs slightly from the figures above for Holdfast-1 fracturing.

2.3 Constituents

The chemical constituents that are included in the fracturing fluid additives listed above are described in the following table.

Table A2: Halliburton listing of constituents in fracturing additives

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on MSDS
1-(Benzyl) quinolinium Chloride	Quaternary Ammonium Salt	15619-48-4	Industrial and Commercial Disinfectant	Yes
2-Bromo-2-nitro-1,3-propanediol	Bronopol	52-51-7	Anti-Bacterial Soap, Skin Cleansing (Wipes), Hand Wash and Body Shampoo	Yes
Acetic Acid	Organic Acid	64-19-7	Processed Fruit, Cheese, Meat and Poultry	Yes
Acid Red 1	Red Dye	3734-67-6	Aloe and Olive Oil Cream, Stainless Steel Polish, FDA Approved Colorant, Industrial Buffer Solution	No
Acid Red 27	Red Dye	915-67-3	Laboratory Dye, Industrial Buffer Solution	No
Acid Violet 12	Violet Dye	6625-46-3	Air Freshener, Commercial pH Indicator Solution	No
Acrylate Polymer	Acrylate Polymer	*	No Common Product Uses Identified	No
Alcohol	Alcohol	*	Commercial Defoamer	No
Alcohols, C12-C16, Ethoxylated	Alcohols, Ethoxylated	68551-12-2	Car Wash Liquid, Laundry Stain Remover, Air Freshener	No
Aldehyde	Aldehyde	*	Non-Alcoholic Beverages, Ice Cream, Candy, Baked Goods, Chewing Gum	Yes
Alkylphenols	Alkylphenols	*	Metal Soldering Flux, Commercial/Industrial Cleaners and Degreasers	No
Amines, Coco Alkyl, Ethoxylated	Ethoxylated Amine	61791-14-8	Commercial Bathroom Cleaner, Medical Rinsing Solution, Photography Printer Ink	No
Ammonium Phosphate	Inorganic salt	7722-76-1	Milk Products	No
Ammonium Sulfate	Inorganic Salt	7783-20-2	Lawn Insecticide, Fertilizer, Fire Extinguishing Agent, Insulation, Body Wash, Caramel Food Coloring Agent	Yes

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on MSDS
Borate Salt	Borate Salt	*	Agricultural Plant Food/Fertilizer, Industrial Glass Manufacturing Additive	Yes
Chlorous Acid, Sodium Salt	Inorganic Salt	7758-19-2	Food Additive	Yes
Citric Acid	Organic Acid	77-92-9	Fruit Juice, Dishwasher Cleaner, All Purpose Cleaner, Hand Soap	Yes
Crystalline Silica, Quartz	Silica	14808-60-7	Cat Litter, Tile Mortar, Arts & Crafts Ceramic Glaze	Yes
Disodium Octaborate Tetrahydrate	Inorganic Salt	12008-41-2	Wood Preservative, Agricultural Pesticide	Yes
Ether Compound	Ether Compound	*	Air Freshener, Food Flavoring Agents	No
Ethylene Glycol Monobutyl Ether	Glycol Ether	111-76-2	Paint Removal Gel, Citrus Household Cleaner, Sterilizing Wipes, Commercial Lubricating Oil	Yes
Fatty Acids, Tall Oil	Fatty Acids, Tall Oil	61790-12-3	Car Polish, Industrial Hand Cleaner	No
Glycerine	Glycerine	56-81-5	Laundry Stain Remover, Antimicrobial Soap, Toothpaste, Lipstick	No
Guar Gum Derivative	Guar Gum Derivative	*	Fabric Softener, Hair Straightening Aid, Shampoo, Body Lotion, Shaving Cream	Yes
Hydrochloric Acid	Inorganic Acid	7647-01-0	Table Olives, Unripened Cheese, Cottage Cheese	Yes
Isopropanol	Alcohol	67-63-0	Tape Head Cleaner, Hops Extract used for Beer, Air Freshener	Yes
Methanol	Alcohol	67-56-1	Furniture Refinisher, Liquid Hand Soap, Windshield Washer Concentrate, Hops Extract	Yes
Naphthenic Acid Ethoxylated	Cyclo Alkyl Acid Ethoxylate	68410-62-8	No Common Product Uses Identified	No
Polyacrylamide Copolymer	Polyacrylamid e Copolymer	*	Mulch Binder/Dust Control Agent, Moisture Control Agent for Gardens, Emulsion Agent in Industrial Water Treatment	No
Polyacrylate	Polyacrylate	*	Laundry Detergent, Glass Cleaning Solution, Dishwashing Detergent	Yes
Polyacrylate	Polyacrylate	*	Paint Hardener, Detergent, Children's Bathwater Additive, Food Defoaming Agent	No
Polyethoxylated Fatty Amine Salt	Ethoxylated Amine	61791-26-2	Toilet Bowl Cleaner, Car Glass Polish	No
Proprietary	Proprietary	*	Hair Colorant, After Shave, Fabric Softener, Deodorant, Air Freshener	No
Proprietary	Proprietary	*	Floor Soap, Shampoo, Car Shampoo, Nail Polish Remover, Insect Repellent	No
Proprietary	Proprietary	*	Air Freshener, Fragrance, Scent for Soap and Household Cleaning Products	No
Proprietary	Proprietary	*	Medical Disinfectant, Automotive Rust Remover, Commercial Floor Cleaner	No
Proprietary	Proprietary	*	All-Purpose Household Cleaner, Fabric Softener, Pool Algae Control, Disinfecting First Aid Wipes	No
Proprietary	Proprietary	*	Laundry Detergent, Dishwashing Liquid, Toothpaste, Pool pH Adjustment Liquid	No

Constituent Name	Generic Name	CAS Number	Common Use	Hazardous as Appears on MSDS
Proprietary	Proprietary	*	Air Freshener, Perfume Oil, Flea Repellant, Insect Repelling Candle	No
Proprietary	Proprietary	*	Deodorant, Body Hair Bleach, Leather Cleaner, First Aid Burn Treatment	No
Proprietary	Proprietary	*	Hydraulic Clutch Fluid, Brake Fluid	No
Quaternary Ammonium Salt	Quaternary Ammonium Salt	*	Industrial and Commercial Water Acidity Neutralizing Solution	Yes
Silicate	Silicate	*	Industrial Joint Compound, Industrial Construction Thickening Agent	No
Silica Gel	Silica	112926-00-8	Mouthwash, Toothpaste, Powdered Sugars	No
Sodium Carbonate	Carbonate	497-19-8	Laundry Detergent, Dishwashing Liquid, Toothpaste, Pool pH Additive	No
Sodium Chloride	Inorganic Salt	7647-14-5	Concentrations greater than 1%: Food Grade Salt, Laundry Detergent, Aquarium Fish Medication, Ice Melting Product	Yes
Sodium Hydroxide	Caustic Soda	1310-73-2	Laundry Detergent, Toothpaste, Cocoa, Milk Products , Chocolate	Yes
Sodium Iodide	Inorganic Salt	7681-82-5	Light Bulbs, Infant Food	No
Sodium Sulfate	Sulfate	7757-82-6	Dishwasher Detergent, Laundry Detergent, Liquid Hand Soap, Toothpaste	No
Terpene	Terpene	*	Laundry Soap, Furniture Oil, Thickened Stripper for Grease, Paint, Ink, and Gum Removal	Yes
Tributyltetradecylphos-phonium Chloride	Organic Phosphonium Salt	81741-28-8	Industrial Water Treatment Agent	Yes
Water	Water	7732-18-5	Water Present in Additives (Not Water Used as Carrier Fluid)	No

Notes:

*In certain cases, a small percentage of constituents may be protected under existing agreements between Halliburton and suppliers and customers. In these situations, CAS numbers are not provided by Halliburton – but the constituent's listing as hazardous on the MSDS is, as well as other common uses when identified.

**Items identified in the "common uses" column were chosen in part because the constituents found in these products exist in roughly the same concentrations as would be found in fracturing materials at the wellhead. In some cases, however, concentrations present in consumer products are either not publicly available or in higher percentages than would be found at the well site.

2.4 Material Safety Data Sheets

Material Safety Data Sheets for the fracturing fluid additives listed above are available at the following website, by following the links to Australia and 'Typical Deep Frac Formulation':
http://www.halliburton.com/public/projects/pubsdata/Hydraulic_Fracturing/fluids_disclosure.html

2.5 Further Information

Additional information on fracture stimulation additives is available from the following sources:

Fracture stimulation providers:

Halliburton	http://www.halliburton.com/public/projects/pubsdata/Hydraulic_Fracturing/fluids_disclosure.html
Schlumberger	http://www.slb.com/services/completions/stimulation/unconventional_gas_stimulation/openfrac_hydraulic_fracturing_fluids.aspx
BJ Services	http://www.bakerhughes.com

Industry bodies:

APPEA	http://www.appea.com.au
API	http://www.api.org

Appendix B

Environmental Risk Assessment Tables

Environmental Risk Assessment Tables

The risk assessment that is summarised in this document uses Beach Energy's risk matrix and definitions for consequences and likelihood, as defined in Beach Energy HSE Procedure 04 – F04. The risk matrix and the consequence and likelihood definitions are outlined below.

Definition of Consequences

To describe the severity, scale and duration of potential impacts, the five categories of consequence listed in the following table are used.

Consequence definition

		Health and Safety	Natural Environment	Reputation Community/Media	Financial A$
Critical	**5**	Fatality of employees, contractors, or the public	Critical ecological or cultural impact and/or regulatory intervention	Critical impact on business reputation /or international media exposure	Financial loss in Excess of $20 Million
Major	**4**	Extensive injury or Hospitalisation of employees, contractors, or the public	Significant ecological or cultural impact and/or regulatory intervention	Significant impact on business reputation and/or national media exposure	Financial loss $2 Million to $20 Million
Moderate	**3**	Medical treatment of employees, contractors, or the public	Significant local environmental impact and/or regulatory intervention	Moderate to small impact on business reputation	Financial loss from $0.5 Million to $2 Million
Minor	**2**	First-aid treatment of an employee, contractor, or a member of the public	Minor local environmental impact and/or regulatory notification is required	Some impact on business reputation	Financial loss from $0 to $0.5 Million
Negligible	**1**	Minimal impact to any issue	Minimal impact to any issue	Minimal impact to any issue	Minimal impact to any issue

Definition of Likelihood

The likelihood of potential environmental consequences occurring is defined using the five categories shown in the following table. The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring.

Likelihood definition

Likelihood of the Consequences selected occurring

A	**Almost Certain**	Is expected to occur in most circumstances (happens several times a year)
B	**Likely**	Will probably occur in most circumstances (happens several times a year)
C	**Possible**	Possible that it might occur at some time (has occurred previously at Beach)
D	**Unlikely**	Unlikely, but could occur at some time (has occurred previously in the Industry)
E	**Remote**	Highly unlikely, may occur in exceptional circumstances (never heard of in Industry)

Characterisation of Risk

The risk associated with each hazard was characterised as low, medium or high, using the matrix below.

Environmental risk matrix

RISK MATRIX			Consequence				
			Negligible	**Minor**	**Moderate**	**Major**	**Critical**
			1	**2**	**3**	**4**	**5**
Likelihood	**Almost Certain**	**A**	**M**	**M**	**H**	**H**	**H**
	Likely	**B**	**M**	**M**	**M**	**H**	**H**
	Possible	**C**	**L**	**M**	**M**	**H**	**H**
	Unlikely	**D**	**L**	**L**	**M**	**M**	**H**
	Remote	**E**	**L**	**L**	**L**	**M**	**M**

High Risk - Immediate Action Required. **Medium Risk** - Management Attention Needed
Low Risk - Managed by Standard Operating Procedures

Risk Assessment Summary Table

A summary of the level of environmental risk for fracture stimulation activities is provided in Table 3 of this document. The level of risk has been assessed based on the assumption that the management measures outlined will be in place.

Appendix C

Table 3: Risk assessment for fracture stimulation of deep shale gas and tight gas targets

Table 3: Indicative risk assessment for fracture stimulation of deep shale gas and tight gas targets (adapted from Beach (2012)). As Beach has not yet applied to fracture stimulate in the Otway Basin, a detailed regional assessment has not been developed. Where possible Beach has included information that relates to the Otway Basin.

Risk assessment for fracture stimulation of deep shale gas and tight gas targets

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Injection of fracture stimulation fluid					
Loss of well integrity	Leakage to aquifers Contamination of soil, groundwater and surface water Emissions to the atmosphere	Aquifers isolated behind multiple casing strings, cemented to surface. New casing and wellhead installed. Casing and wellhead designed to meet pressure, temperature, operational stresses and loads. Design reviewed by independent engineering firm where necessary. Cement bond logs run on production casing to confirm quality of cement. Well pressure tested prior to stimulation. High pressure stimulation equipment has valid certifications, is properly secured and is pressure tested once set-up, prior to commencement of stimulation. Stimulation pumping pressures do not exceed design safety factors. Trip systems to shut off pumping units during stimulation. Injection pressures are monitored and compared to expected fracture initiation pressure. If significantly lower initiation pressure, stop job and assess for potential casing integrity failure. Well control equipment used during coiled tubing, wireline and workover activities. Installation of tubing string for production testing. Ongoing well integrity monitoring. Emergency response plan in place and drills conducted.	Moderate	Remote	Low
	Injury / danger to health and safety of employees, contractors and possibly the public		Major	Remote	Medium
Fracture propagation into overlying aquifers	Contamination of aquifers Indirect adverse impacts to groundwater users	Significant physical separation between targets and shallow overlying aquifers (~2,000m to 3,000m thick). Fracture height growth in shales at similar depths in US is not more than 200-300 m. Microseismic monitoring may be used to monitor height growth, if required, due to thinning of geological strata or evidence of unsuitable geomechanical conditions.	Minor	Remote	Low
Leakage to aquifers through geologic media	Contamination of aquifers Indirect adverse impacts to groundwater users	Target intervals separated from overlying shallow aquifers by 2,000-3,000 m.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Injection of fluid into target reservoir section	Impact on target formation aquifer potential	Source rocks are aquitards and do not conduct water. Sandstone units of the Lower Sawpit Shale thought to be gas saturated (i.e. can't be considered 'aquifers' as they may be in other parts of the Basin where they are filled with water). If source rocks are considered to be aquifers and are away from the hydrocarbon well, they are not suitable for water extraction for the following reasons: • if water is present, it is expected that the salinity will be sufficient to preclude use of the water • low permeability of the rocks results in insufficient yield for commercial use • depth of the zones requires expensive drilling and pumping equipment, which is not commercially viable.	Minor	Unlikely	Low
Lateral migration of injected fluid in the target section	Impact on target formation aquifer potential	Due to low permeability in the intervals, fracture stimulation fluid is highly unlikely to migrate any significant distance beyond the stimulation treatment. Once on production, pressure gradient underground will result in fluids moving towards the well rather than migrating either upwards or laterally away from the fracture stimulation.	Minor	Unlikely	Low
Fracture propagation between pressure cells that are normally isolated	Crossflow between aquifers resulting in contamination / loss of quality Pressure depletion in hydrogeological cells	If induced fractures connect these two systems there will be a brief cross flow of the higher pressured gas into the lower pressure gas system until the well is flow tested. During production testing flow will be towards the wellbore. This can assist in improving recovery of gas but is not likely to have a detrimental impact.	Negligible	Possible	Low
Water supply / use	Drawdown of local aquifers Adverse impact on groundwater users Impact on groundwater dependent ecosystems	Water extraction is in compliance with licensing and water allocations where applicable. Water supply wells are reviewed to ensure that their use does not impact adversely on existing users of groundwater or groundwater dependent ecosystems Options for alternative water supplies to be investigated / used where possible.	Minor	Unlikely	Low
Storage and handling of fuel, chemicals and fracturing / flowback fluids					
Leak of brackish or saline pre-stimulation water from holding ponds or tanks	Localised salinisation of soil, surface water and groundwater Indirect impacts to flora and vegetation	Quality control on pond or above ground tank construction and liner installation to minimise risk of compromised liner integrity. Pond liners prevent pond wall erosion. Maximum pond fill level not exceeded (allow for rain events and wave effects). Ponds with above-ground walls / bunds to prevent surface runoff into ponds. Pond operation monitored (e.g. pond wall integrity) and repair undertaken if required. No chemicals added to pre-stimulation water in ponds.	Minor	Unlikely	Low

<table>
<tr><th>Risk Event / Hazard</th><th>Potential Environmental Impacts</th><th>Key Management Measures / Comment</th><th>Consequence</th><th>Likelihood</th><th>Residual Risk</th></tr>
<tr><td>Minor spill / leak from hazardous material storage and handling (e.g. several litres)</td><td>Localised contamination of soil, surface water and groundwater
Access to contaminants by stock and wildlife
Indirect impacts to flora and vegetation</td><td rowspan="2">Handling and storage in accordance with relevant International Standards Organisation standards, relevant MSDS and State regulatory requirements, as recommended by APPEA Code of Practice Guideline 4(2011).
Fracturing additives contained in units with appropriate secondary containment.
Emergency/spill response procedures in place with immediate clean up and remediation of spills.
Personnel trained in correct procedures for use of materials, including refuelling and clean-up procedures.
Bulk fuel storage with appropriate secondary containment system.
Refuelling undertaken with appropriate drip capture systems.
Suitable facilities present to contain potential spills when handling fuel and chemicals.
Clean-up materials and wastes appropriately contained for off-site disposal to a licensed waste management facility.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Major spill / leak from hazardous material storage and handling (e.g. entire contents of refuelling tank)</td><td>Contamination of soil, surface water and groundwater
Access to contaminants by stock and wildlife
Indirect impacts to flora and vegetation</td><td>Moderate</td><td>Unlikely</td><td>Medium</td></tr>
</table>

<table>
<tr><th>Risk Event / Hazard</th><th>Potential Environmental Impacts</th><th>Key Management Measures / Comment</th><th>Consequence</th><th>Likelihood</th><th>Residual Risk</th></tr>
<tr><td>Minor leak or spill to ground from surface handling / storage of flowback fluids</td><td>Localised contamination of soil and/or groundwater
Access to spilt contaminants by stock and wildlife
Indirect impacts to flora and vegetation</td><td rowspan="2">Routine inspections of flowback storage area and pipelines.
High pressure stimulation equipment has valid certifications, is pressure tested once set-up (prior to commencement of stimulation) and trip systems prevent operation above design pressure limits.
Flowback lines from the wellhead rated and pressure tested to appropriate pressure.
Emergency shut-down system installed on well-head.
Flowback fluids securely contained in ponds / interceptor pit lined with UV stabilised material or other tankage as appropriate.
Quality control on pond construction and liner installation to minimise risk of compromised liner integrity.
Where ponds assessed as suitable for flowback containment, pond liners to be capable of withstanding expected operating conditions, ponds to be constructed with above-ground walls / bunds to prevent surface runoff into ponds (liners prevent pond wall erosion) and maximum pond fill level not exceeded (allow for rain events and wave effects).
On flowback ponds/tankage will be filled to significantly less than capacity as flowback is expected to be 30-40% of initial clean water storage volume.
Pond / tank operation monitored (e.g. pond wall / tank integrity) and repair / remediation / decommissioning undertaken where appropriate (e.g. if leak evident, create drainage channel, recover fluid, repair or decommission pond).
Spills / leaks cleaned up and remediated.
Additional fencing installed where necessary to prevent stock access.
Chemical utilisation during stimulation kept to the lowest possible to achieve necessary stimulation outcome.
Lower toxicity chemicals investigated and used where practicable and suited to the stimulation design required.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Major leak or spill to ground from surface handling / storage of flowback fluids (e.g. pond wall or tank failure)</td><td>Contamination of soil and/or groundwater
Access to spilt contaminants by stock and wildlife
Indirect impacts to flora and vegetation</td><td>Moderate</td><td>Unlikely</td><td>Medium</td></tr>
</table>

<table>
<tr><th>Risk Event / Hazard</th><th>Potential Environmental Impacts</th><th>Key Management Measures / Comment</th><th>Consequence</th><th>Likelihood</th><th>Residual Risk</th></tr>
<tr><td>Minor leak or spill of flowback fluids to surface water</td><td>Localised contamination of surface water
Localised death or injury to aquatic fauna</td><td rowspan="2">Chemical utilisation during stimulation kept to the lowest possible to achieve necessary stimulation outcome.
Lower toxicity chemical additives used where practicable and suited to the stimulation design required.
Many of the fracturing fluid additives are used or degraded in the reservoir and at surface in the flowback pond.
Flowback fluid securely contained in lined ponds, above ground ponds or other tankage, as discussed above.
Ponds (earthen and above ground) lined with UV stabilised material
Quality control during construction to minimise risk of compromise to integrity of liner
Monitoring of pond operation (freeboard) to maintain pond integrity
Spills / leaks cleaned up and remediated
Ponds with above-ground walls / bunds to prevent surface runoff into ponds
Pond liners prevent pond wall erosion
Other tanks utilised as may be required by site specific assessment
Well sites and pond locations selected to ensure that the consequences of a potential pond failure are minimised (e.g. ponds would not be located in close proximity to creek channel or other significant watercourses such that failure would result in direct release to these watercourses).
Well leases located on higher ground as far as practicable.
Implementation of additional management measures as identified by site-specific assessments against the stated environmental objective to avoid surface water impacts.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Major leak or spill of flowback fluids to surface water
(e.g. if pond fails and contents reach surface water)</td><td>Contamination of surface water
Death or injury to aquatic fauna</td><td>Major</td><td>Unlikely</td><td>Medium</td></tr>
<tr><td>Interaction of stock or native fauna with storage ponds/tanks</td><td>Death or injury of fauna or stock</td><td>Ponds securely fenced to exclude stock and large native fauna.
Pond construction to minimise attractiveness to birds i.e. relatively steep sides and lined with suitable polyethylene material, with no ‘beaches’ or vegetation.
Many of the fracturing fluid additives are biodegradable.
Routine surveillance monitoring will be undertaken to detect incursions.
Ongoing inspection and monitoring of ponds would detect fauna mortality (if it occurred).
Bird deterrent measures will be introduced if bird mortality incidents are observed.
Ponds/tanks will be temporary and will be rehabilitated following removal of liner.</td><td>Minor</td><td>Unlikely</td><td>Low</td></tr>
<tr><td>Personnel and third party access to storage ponds</td><td>Injury / danger to health and safety of employees, contractors and possibly the public</td><td>Ponds securely fenced.
Signage in place to warn of access restrictions.
Access to sites restricted during operations.
Sites will be attended by an operator during and after fracturing operations.</td><td>Moderate</td><td>Remote</td><td>Low</td></tr>
</table>

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Separator upset resulting in small volumes of flowback fluid going to flare	Contamination of soil and/or groundwater Access to spilt contaminants by stock and wildlife	Regular inspection and maintenance of equipment. Ongoing monitoring during flaring. Remediated as required.	Minor	Unlikely	Low
General issues					
Activity outside designated / approved areas	Damage to significant vegetation Degradation of fauna habitat Damage to cultural heritage sites	Activities confined to existing cleared areas (e.g. access roads, prepared well lease) within area subject to environmental assessment and cultural heritage clearance. Approved work areas and restricted areas clearly delineated on site. Training and induction for all personnel to educate them on the importance of remaining within designated / approved areas. If flora with significant conservation value is present in the vicinity of the well site it will be flagged and/or fenced off where necessary to prevent disturbance. Cultural heritage sites or exclusion zones in the vicinity of the well site will be flagged and / or fenced off to prevent disturbance where necessary.	Minor	Unlikely	Low
Air emissions	Reduction in local air quality Generation of greenhouse gas emissions	Equipment operated and maintained in accordance with manufacturer specifications. Well flowback diverted to separator as soon as practicable to minimise gas not being captured and sent to flare. Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters (consistent with APPEA Guideline 6 (2011)). Uncertainty in production rates and gas composition prevents construction of pipeline and processing facilities to enable connection of exploration and appraisal market. Fracturing would not be carried out in close proximity to local residences. Note: Greenhouse gas emissions recorded and reported in accordance with NGER requirements. Monitoring of well parameters during testing operations to check for potential for fugitive emissions at the wellbore.	Minor	Unlikely	Low
Noise emissions	Disturbance to native fauna Disturbance to local community	Equipment operated and maintained in accordance with manufacturer specifications. Fracturing would not be carried out in close proximity to local residences. Landowners notified of location of operations and appropriate consultation and mitigation measures implemented, if required, to ensure that no reasonable complaints are received.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Bushfire (resulting from activities)	Loss of vegetation and habitat Disturbance, injury or death of fauna Atmospheric pollution Damage to infrastructure Disruption to land use Danger to health and safety of employees, contractors and possibly the public	Activities undertaken on cleared well lease. Combustible materials cleared from area surrounding flare. Firefighting equipment available as appropriate for location and use. Fire and Emergency Services Act requirements will be complied with (e.g. permits for 'hot work' on total fire ban days).	Moderate	Remote	Low
Seismicity	Ground disturbance	Low background seismic hazard Known faults in area. Undertake site specific assessment and determine requirement for monitoring with accelerometers and adoption of traffic light system. Release of energy associated with injection of 1.6 ML of water in a single event estimated to be 3 Mw which is barely detectable by humans.	Negligible	Possible	Low
Light emissions	Disturbance to local community Disturbance to native fauna	Minimise lighting where possible. Flaring during production testing kept to minimum length of time necessary to establish resource and production parameters.	Minor	Unlikely	Low
Use of roads; movement of heavy machinery and vehicles along roads and access tracks	Injury or death of stock or fauna Dust generation Noise generation Damage to third party infrastructure Degradation of public roads and tracks Disturbance to cultural heritage sites	Existing access roads, cleared well lease and turn-arounds used. Dust control measures (e.g. water spraying) implemented if dust generation becomes a problem e.g. near sensitive sites. Equipment that has been operating in areas of known weed infestation will be cleaned before arrival at the site. Speed restrictions and appropriate signage to reduce speed and increase awareness of hazards. Driver awareness training for all personnel. Traffic and journey management procedures followed. Liaise with road authorities regarding arrangements and responsibilities for road maintenance and undertake maintenance where required.	Minor	Unlikely	Low
	Introduction and/or spread of weeds		Moderate	Remote	Low
	Road hazard / disturbance to local road users		Major	Unlikely	Medium
Storage of waste and transport to landfill	Localised contamination of soil, surface water and groundwater Damage to vegetation and habitat Attraction of scavenging	Waste generation minimised (e.g. reduce, reuse and recycle). Waste removed off-site and disposed of at appropriately licensed waste handling facility. High standards of 'housekeeping' implemented. Secure systems used for storage and transport of waste (e.g. covered bins in designated area for waste collection and storage prior to transport).	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
	animals (native / pest species) and access to contaminants by stock and wildlife Litter / loss of visual amenity	Hazardous wastes handled in accordance with relevant legislation and standards. Licensed contractors used for waste transport.			