BEACH ENERGY

7 July 2014

Dr Allan Hawke
Commissioner
Northern Territory Inquiry into Hydraulic Fracturing
GPO Box 4204, Darwin
NORTHERN TERRITORY 0801

Dear Commissioner,

Beach Energy welcomes the opportunity to provide comment into the Northern Territory Government's inquiry into hydraulic fracture stimulation.

Beach Energy is a member of the Australian Petroleum Production and Exploration Association (APPEA) and has provided feedback on APPEA's submission to the Inquiry.

The attached information is company specific and responds to the terms of reference set out for the Inquiry. The information is based on extensive operations undertaken by Beach Energy in the Cooper Basin in both South Australia and Queensland as outlined in Environmental Impact Reports and Statement of Environmental Objectives developed for our activities, and approved by respective State Government Regulators.

Please find our comments attached. Please do not hesitate to contact me if you require more information.

Yours Sincerely

Reg Nelson
Managing Director
Beach Energy

25 Conyngham St, Glenside South Australia 5065
GPO Box 175 Adelaide 5001
Telephone (618) 8338 2833
Facsimile (618) 8338 2336
Beach Energy Limited
ABN 20 007 617 969
www.beachenergy.com.au

Beach Energy

Beach Energy is an Adelaide-based oil and gas exploration and production company which has interests in more than 300 petroleum tenements located in Australia, Romania, Egypt, Tanzania and New Zealand. The majority of Beach operations are conducted in the Cooper Basin and overlying Eromanga Basin. These Basins host Australia's largest onshore oil and gas development. Beach currently operates 20 oil fields on the Western Flank of the Cooper/ Eromanga Basin, as well as six gas discoveries, two of which are producing

The Company owns a 20.21% interest in the South Australian Cooper Basin Joint Venture (SACBJV) and between 20-40% of the South West Queensland Joint Ventures (SWQJV) operated by Santos Limited. Since 2006, Beach has participated in more than 100 oil and gas wells operated by Santos, with the infill drilling program targeting annual resource to reserve conversion of approximately 10 million barrels of oil equivalent net to Beach over the coming years. This production has earned Beach the position as Australia's largest net oil producer.

Beach has extensive first hand operational experience of fracture stimulation having pumped more than 85 treatments in the last three to four years during a focussed exploration campaign to assess the potential of deep gas from shale and tight sands in the Cooper Basin's Nappamerri Trough.

Beach Energy operations in the Northern Territory

Beach is currently undertaking drilling operations in the Northern Territory in the Bonaparte Basin in EP 126 under a farmin agreement with Territory Oil and Gas. Beach, the operator for the permits EP-126, EP-135, EP-138 and NTC/P10 shown in Figure 1, holds 25% and through a series of farm-in stages can earn up to 85%. The joint venture is currently drilling the Cullen-1 well in the northern part of EP-126.

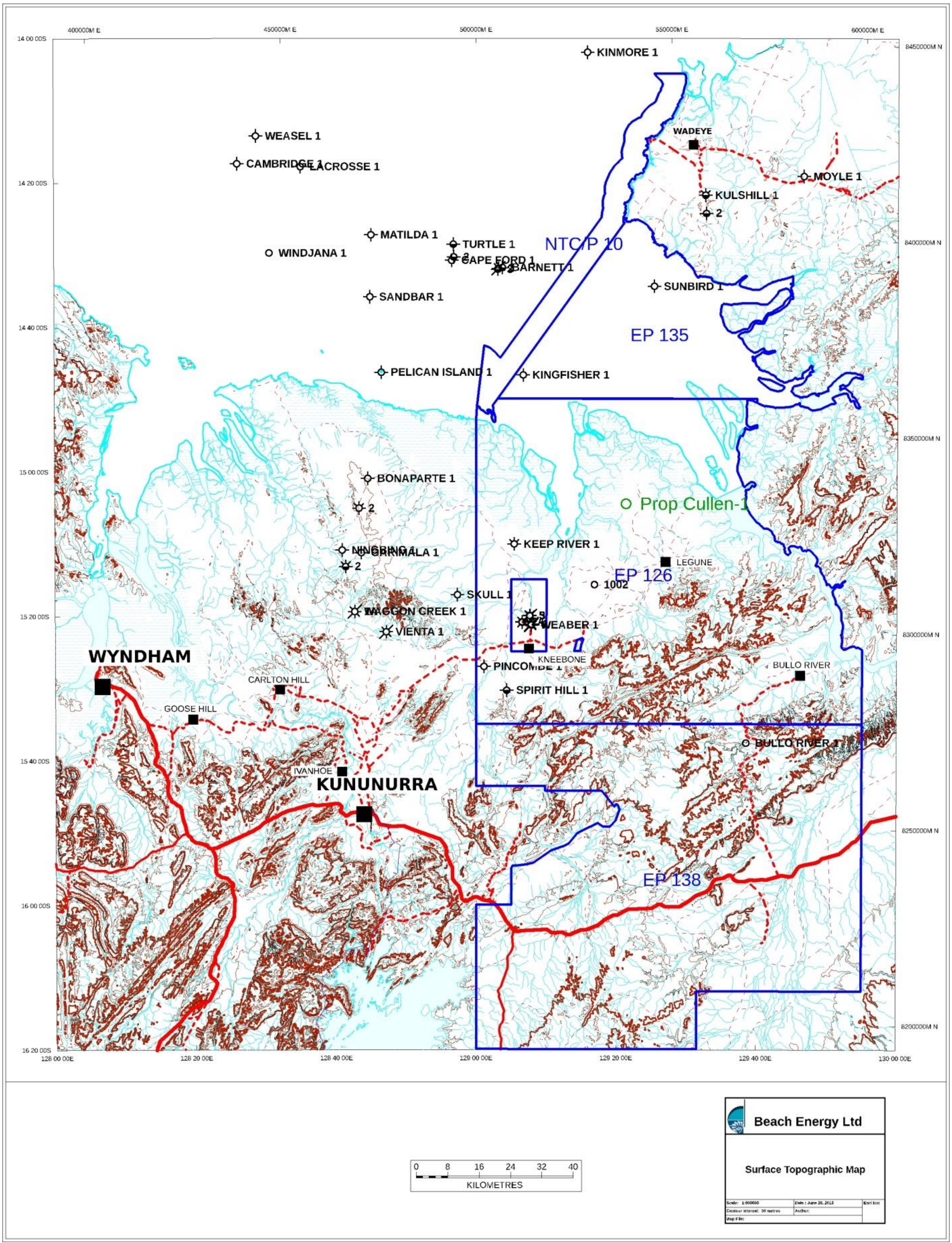


Figure 1: Surface Topographic Map, Beach Energy exploration permits in the Bonaparte Basin

Brief outline of onshore petroleum in the Bonaparte Basin

There has been little recent exploration activity in the onshore Bonaparte Basin and there is good evidence of natural petroleum seeps in the area. In 1839 the crew of HMS Beagle found bitumen in water wells sunk on the banks of the Victoria River, in the vicinity of the EP 126 permit.

Seismic operations have been hard to acquire due to the swampy nature of the black soil plains during the wet season, with deep surface cracks forming during the dry. Drilling the area has been occurring since the 1960s, but it has been sparse with very few wells. The Weaber gas field was discovered in the 1980s, but has not yet been commercially produced.

The joint venture obtained high resolution aeromagnetic and gravity surveys between January and March 2013. Aeromagnetic and gravity surveys have provided information on the geological architecture of the Basin, and helped locate the current exploration well, Cullen-1 that Beach is drilling in mid-2014.

The hydrocarbons source is from organic rich shales of Devonian to Carboniferous age, in the Milligans Formation and Langfield Group. This is the source of the gas discovered in the Weaber Gas Field, as well as Advent Energy's Waggon Creek and Vienta gas discoveries in the onshore Bonaparte on the WA side of the border. These source rocks are also thought to be the source for the sub-commercial Turtle and Barnett Oil Fields in the adjacent offshore Bonaparte.

Of the 15 wells drilled in the onshore Bonaparte to date, nine have flowed gas or have had good gas shows from this target sequence.

There is more off-shore activity in the Bonaparte Basin than onshore activity, with notable gas discoveries within the Petrel Sub-Basin including the GDF Suez/Santos potential floating LNG project from the Petrel, Tern and Frigate Fields, and also domestic gas production into Darwin from Eni's Blacktip Gas Field commencing in 2009 .

Sourcing oil or gas from the Basin could support oil and gas requirements in the Northern Territory.

Geology of the area of operation

Figure 2 shows a stratigraphic column for the formations in the Bonaparte Basin.

The shallow aquifers for much of the Keep Inlet sub-basin consist of the Permo-Carboniferous Border Creek Formation and Keep Inlet Formation of the Kulshill Group, and the Point Spring Sandstone of the Wadeye Group. This succession gets up to 500m thick, and although it has shaly interbeds there are unlikely any regional intraformational seals within this succession. Beneath this are the limestones and sandstones of the Tanmurra Formation of the Weaber Group which get up to around 250m thick, followed by the Kingfisher Shale.

The Kingfisher Shale is regionally extensive, gets up to 220m thick, and is likely an effective seal within the sub-basin. Beneath the Kingfisher Shale is the Milligans Formation, with interbedded thin tight sands near the top, becoming progressively more shaly in the middle, and then more thin tight sandy interbeds (likely deep water turbidite fans) near the bottom. The Milligans is mature for gas generation due to its burial history, and also appears to be overpressured. The section gets up to 1800m thick within the Keep Inlet sub-basin. The lower Milligans Formation and the sandy interbeds are a primary target.

Beneath the Weaber Group in an Early Carboniferous unconformity – the stratigraphy within this section depends on the structural history of the area. Beneath the unconformity is significantly more faulted, resulting in structural traps such as the Weaber Gas Field. There are permeable sands within the Langfield Group (Early Carboniferous) and the Cockatoo Group (Late Devonian), whilst the Ningbing Group between the two predominantly consists of tight limestones and deeper water shales. At the basin margin the complex uplift history results in significant amounts of missing section, with the Cockatoo Group close to the surface. Because of the highly faulted nature of parts of the sub-basin, the aquifers within the Late Devonian are discontinuous, and depending upon the location, contain salt water, are gas charged in structural traps, or are flushed by fresh water near the basin margin. Deeper into the centre of the sub-basin, the sandstones are predicted to grade to deeper water shales of the Bonaparte Formation; this forms the other primary target.

The prolonged and complex structural history of the Bonaparte Basin results in a very variable distribution of hydrocarbons. In the Carlton sub-basin on the WA side of the border, the upper Milligans Formation has structural and stratigraphically trapped gas as shallow as 400m. The Keep Inlet sub-basin has a different structural history; the only evidence for shallow hydrocarbons come from the basin margins, where bitumens have been found in shallow mineral boreholes, and in 1839 the crew of HMS Beagle found bitumen in water wells sunk on the banks of the Victoria River, in the vicinity of Beach's EP 126 permit.

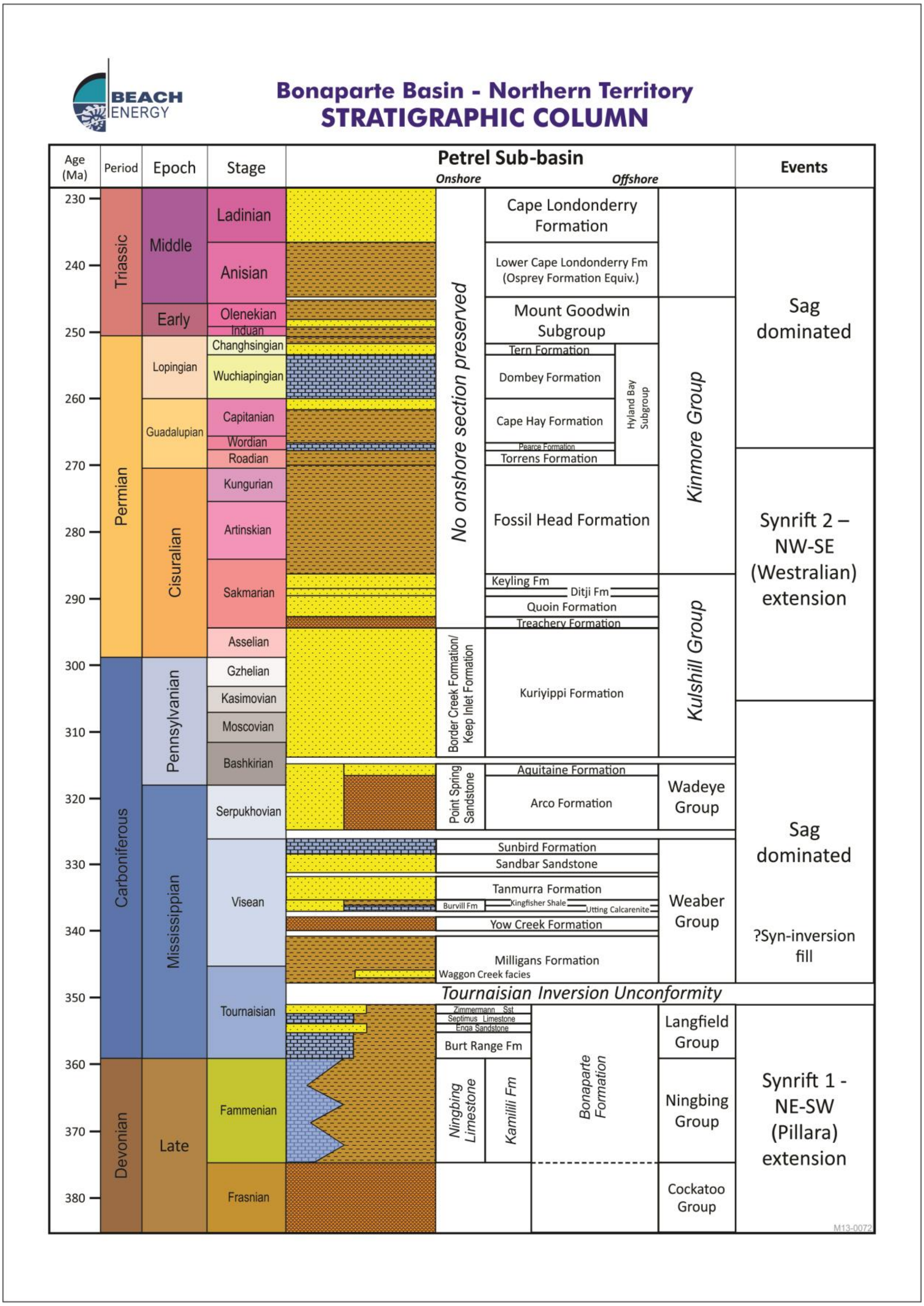


Figure 2: Stratigraphic column for the Bonaparte Basin

1 Description of Activities

1.1 Context

Beach is currently in the very early stages of exploration in the Bonaparte Basin and does not yet conduct stimulation operations in the area. Should the current exploration activities indicate the potential for hydrocarbon recovery from low permeability target intervals, the joint venture is likely to propose to undertake fracture stimulation to enhance drainage from the prospective intervals. As the first well is currently drilling and is yet to be tested it is premature to provide an environmental assessment for the activity.

Rather, the following sections outline a generalised risk assessment for fracture stimulation with information largely extracted 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).

The principle difference between the Bonaparte Basin and the Cooper Basin is the high annual rainfall and the surface water management aspects required for this will be more fully developed if and when it is established that fracture stimulation is required to further assess the potential of the Bonaparte Basin.

1.2 Overview

Basin centred gas and shale gas reservoirs have very low natural permeability. 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 3. 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, friction, remove bacteria and assist with recovering the stimulation fluids from the interval when the well is flowed back to production.

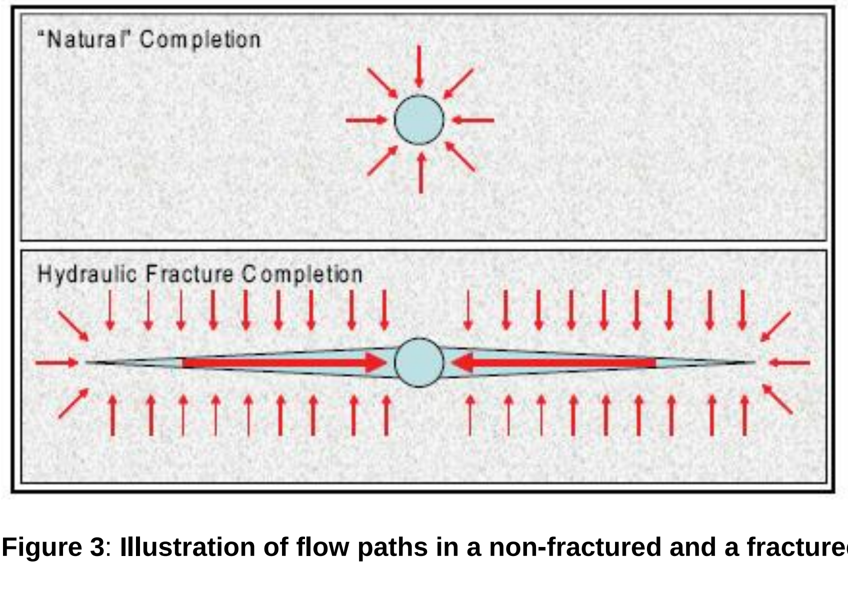


Figure 3: **Illustration of flow paths in a non-fractured and a fractured well (Source: API 2009)**

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 several hundred wells to improve the commerciality of lower permeability zones. In the Northern Territory, stimulation has predominantly been applied in the Mereenie Field. However, fracture stimulation has historically been undertaken in development wells rather than during the exploration stage of evaluating resource potential.

This section describes the application of fracture stimulation to the exploration and appraisal of shale and basin-centred gas. It outlines 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 issues.

1.3 Well Design and Construction

Well design and construction is described here as it is important in ensuring well integrity under all 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
- the stresses induced when large volumes of cool fluids are pumped, at high pressure, into the well during stimulation
- the flow back of high temperature reservoir fluids
- the potential flow back of sour gases.

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 it is set is determined through understanding of the geological environment and the pressures that are anticipated in the formations that are drilled through. The well design process also accounts for the operational conditions that are anticipated during the life of the well including fracture stimulation and production fluids, pressures and temperatures. These final parameters impact on the production casing, the last string of casing that is installed and cemented into the well bore. This casing string's size, strength, coupling and material must satisfy the identified operational conditions and industry standard design safety factors.

Beach Energy's current well design for the vertical exploration wells is shown in Figure 4. The layers of casing shown in the diagram are:

- the conductor pipe, which is installed at the surface and provides the initial stable structural foundation for the well.
- the surface casing string, which extends from the surface to approximately 600 m.
- the intermediate casing string, which is inside the surface casing and extends from the surface to approximately 1,800 m.
- the production casing string, which is inside the intermediate casing and runs from the surface to the total depth of the well.

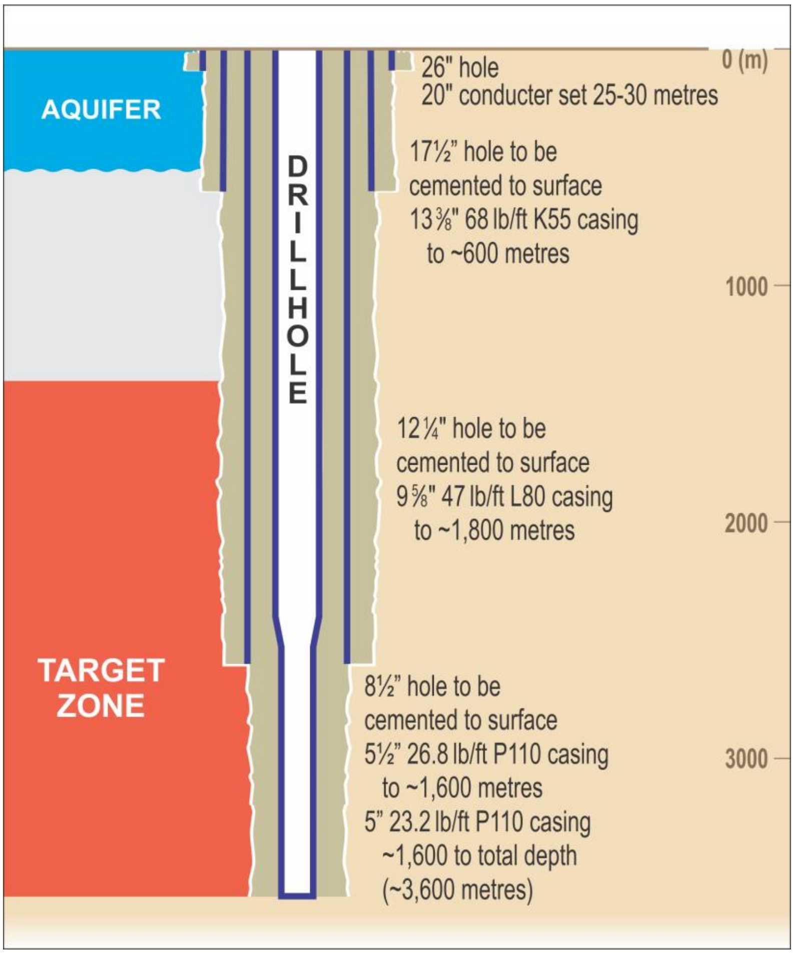


Figure 4: Indicative well design

The production casing design shown in Figure 4 is known as a tapered casing string, as it has larger diameter casing in the upper part of the well, a reducing coupling, then a smaller diameter casing to the bottom of the well.

In more developed unconventional resource plays around the globe, it is normal to utilise horizontal wells that target specific units within the stratigraphy. It is likely that a horizontal well in the Bonaparte Basin will have the same well construction as shown in Figure except that approximately 300 m above the target zone (roughly 100-200 m into the 8 ½" production hole drilling) the well trajectory will be steered from vertical around an approximate 300 m radius bend to become horizontal in the target layer. Once in the target zone the well will be drilled a further 1,500 m giving a total measured length of the well of almost 5,000 m. 5" casing will be run back to the 5 ½" transition at 1,600 m as shown in Figure 4.

As indicated, 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 observation of the cement back to surface as per the cement design and cement bond logs of the production casing string, which use 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 a good seal between the casing and the well bore. The correct cement design and implementation prevents production fluids from migrating up the hole via the well bore - casing annulus eliminating potential cross flow into aquifers.

Wells are pressure tested 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, normally a technique known as perforating is used. Shaped charges, also known as guns, are lowered into the hole and detonated to create holes in the casing, cement and penetrate tens of centimetres into the rock.

With continual refinement of downhole equipment, the way that zones in the target formation are accessed is changing. Sliding sleeves and packers can be run on casing to provide an alternative to perforating. A ball is dropped from the surface into the bore hole to engage with the sleeve. When the ball lands in the sleeve, pressure is applied to slide open a door in the casing revealing ports that now allow fluid to flow into the rock. These techniques speed up the fracture stimulation process. Similar techniques with sleeves activated by coiled tubing are also being applied in the industry.

Beach will initially use standard perforation techniques but will, where appropriate, look to incorporate these technological advances to improve efficiency and understand the potential of the resource. In all cases the integrity of the well and isolation of aquifers will be applied in the well design process.

1.4 Fracture Stimulation

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

Pad stages 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 fracture. 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 job additional pad volumes may be used to sweep proppant into the reservoir.

Proppant stages Once the fracture has initiated proppant is introduced. In order to carry the proppant in suspension to the rock the fluid is viscosified with a gelling agent. 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 aid in later recovery of injected fluids from the fracture.

Flush/Displace A final volume of water to push the sand from the well bore into the rock to clean the well bore for the next stimulation job.

Plug/Perforate Once the stimulation treatment is placed, a wireline unit is rigged up to run a plug that will isolate the zone that was stimulated from the next interval to be stimulated. In some cases it may be operationally more effective to utilise a sand plug to isolate the previous stage, removing the need for a mechanical plug and simplifying post stimulation cleaning up of the well. The wireline will also perforate the casing ready 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.

In a vertical well with potential for approximately 1,300 m of gas bearing interval, it is anticipated that as few as five but potentially up to ten zones may be fracture stimulated. In a horizontal well, with a length of 1,500 m, stimulation treatments are likely to be placed every 100 m requiring 15 treatments in the well.

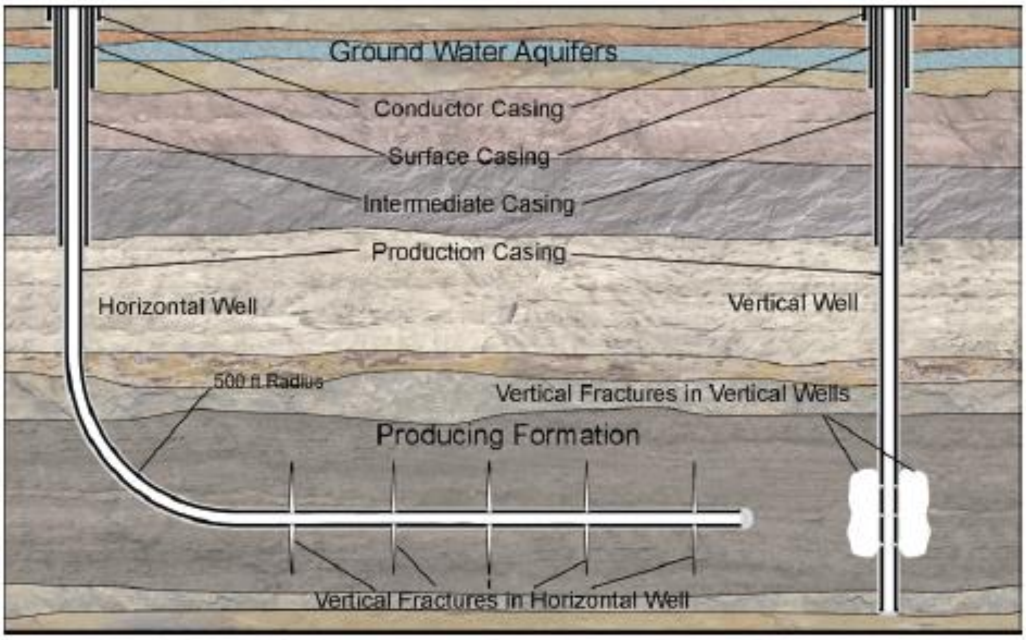


Figure 5: Example of fracturing in a horizontal and vertical well (Source: API 2009)

1.4.1 Fracture Stimulation Equipment

The fracture stimulation process requires equipment for pumping, proppant loading, blending, pipework and valves, tanks, chemical additives and monitoring. The monitoring equipment is used to track the volume of fluids and 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.

This fracture stimulation equipment for the activities requires approximately 20 truck loads plus an additional 30 trucks for associated camp facilities accommodating up to 50 personnel. For a full, 15 stage shale fracture stimulation an additional 50 trailers of proppant and 6 trailers of additives will be required. A vertical well requires approximately one third of the quantity of proppant and additives that is required for a horizontal well.

A wireline perforation truck will also be required to conduct perforations prior to each fracture stimulation stage. A coiled tubing unit, consisting of a reel of tubing mounted on a truck and the associated wellhead equipment to run the tubing into the wellbore, is also likely to be on location during the stimulation to assist with operational requirements. It can be used to clean out sand plugs and assist with placing treatments.

It is anticipated that the fracture stimulation equipment would be mobilised as required. At each well, operations would typically involve a two day set-up, one day per zone stimulated and two days to rig-down and demobilise to the next well.

Plate 1: Fracture stimulation operations at Beach Energy's Holdfast-1 well (Cooper Basin) in 2011

1.5 Fracturing Fluids

Water is the main component of fracture stimulation treatments and forms the vast majority of the fluid injected during fracturing operations, typically around 97%. The proppant is the next largest constituent. Proppant is a granular material, typically sand or small ceramic beads 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. Chemical additives 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 . A similar hydraulic stimulation design is likely to be utilised in the onshore Bonaparte Basin.

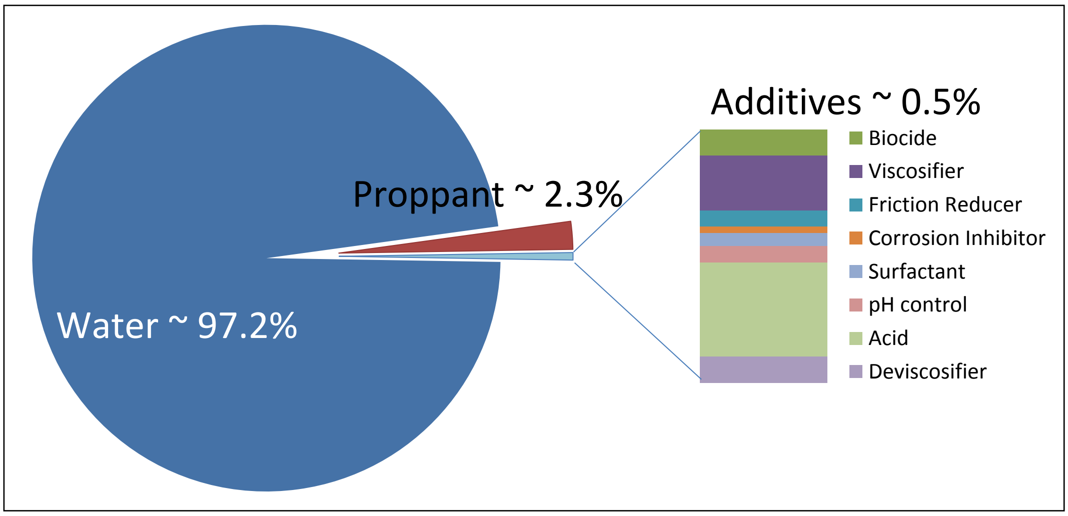


Figure 6: Example of overall percentages of additives in a deep shale gas well fracturing operation in the Cooper Basin (based on data from fracture stimulation of the Holdfast-1 well)

As discussed in Section 1.4, 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 and help carry the proppant. 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 fracture stimulation of unconventional hydrocarbon targets in the Bonaparte Basin 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 fracturing 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 chemicals and fuels which is discussed further in Section 1.11.

Table 1: Additives in typical deep fracture stimulation fluids

Additive	Purpose
Acid / Solvent	Removes scale and cleans wellbore prior to fracturing treatment

Additive	Purpose
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 suite of stimulation additives.

However, 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 chemicals 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 along with a demonstration that the level of risk posed by these additives can be monitored and managed to maintain environmental outcomes. Chemical disclosure requirements across Australia vary. If necessary for State requirements or where stakeholder considerations dictate, Beach will utilise additives that the service providers do not consider proprietary and are 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 chemicals 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 when in their concentrated product form, they are diluted by the water and are present in fracturing fluids in relatively low concentrations. However, even in low concentrations some of these additives need to be handled with care to avoid any potential for impacts on human health or the environment.

Beach aims to keep utilisation of chemicals to the lowest level possible, and will safely manage the use of chemicals and fuels and contain recovered stimulation fluids to minimise the environmental footprint of the stimulation activities. The following strategies will be implemented:

- Pumping as low a concentration of chemicals as is needed to perform the treatment
- Requiring that the material handling and safety aspects of these additives, as managed by the contractor, are in accordance with MSDSs and relevant standards and guidelines including AS 1940, EPA guidelines and the Australian Dangerous Goods Code (where relevant)
- Auditing the contractor's management systems and conduct 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
- Containment of recovered flow back fluids in lined ponds, above ground tanks or other appropriate holding tanks, as discussed in Section 1.9**Error! Reference source not found.**, dependent on the required water management solution to keep fluids contained at surface for treatment or disposal
- 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.
- Management of ponds and/or tanks to ensure integrity of containment
- Removal of pond liner to a licensed waste facility following evaporation/treatment/disposal
- Rehabilitation of pond and lease sites post activities.

Beach will investigate methods to further reduce chemical utilisation and incorporate findings during the monitoring of flow back fluids 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.

BTEX in Fracturing Additives

Fracturing fluid additives containing the volatile aromatic compounds benzene, toluene, ethylbenzene and xylene (collectively referred to as BTEX) have been identified as a potential concern in some areas where fracture stimulation operations are carried out much closer to water supply aquifers.

Although the level of risk posed by additives containing BTEX is relatively low (the target petroleum reservoirs can naturally contain BTEX and are not near water supply aquifers), it is not proposed to use additives where BTEX is present in significant quantities. Some additives in the acid blend (e.g. hydrochloric acid, corrosion inhibitor and acid penetrating agent) can contain trace levels of BTEX, however the dilution of the acid blend by subsequent stages of the fracture stimulation would result in very low levels, which would be below drinking water guidelines. Suppliers and fracturing contractors have been working to ensure that levels of BTEX in fracturing fluids are reduced as far as practicable and are not at significant levels.

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 m (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 800 m, as described in the geological 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 will be monitoring the 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.

Tracer monitoring

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 of 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.

Radioactive tracer monitoring

Small amounts of short half-life material are added to each stimulation stage. Once the treatments are placed the well can be logged to confirm where the proppant has been placed in the well and estimate the fracture height growth near the well bore. Although not definitive, the information can assist with confirming wellbore integrity during stimulation and how far a treatment may have grown adjacent to the wellbore.

Each tracer has a half-life of less than 100 days and the trained engineer responsible for handling the tracer material is subjected to less radiation than a hospital worker and well below the regulatory limit for radiation workers as outlined in the risk assessment in Section 2.5.4.

Micro-seismic Monitoring

As discussed, during fracture stimulation water is injected into the target reservoir at sufficient pressure and rate to split 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 than can be felt is approximately 3 Mw. This scale is logarithmic which means that the biggest events are about 1,000 times smaller than an earthquake that might be felt and the smaller events are 100,000 times smaller.

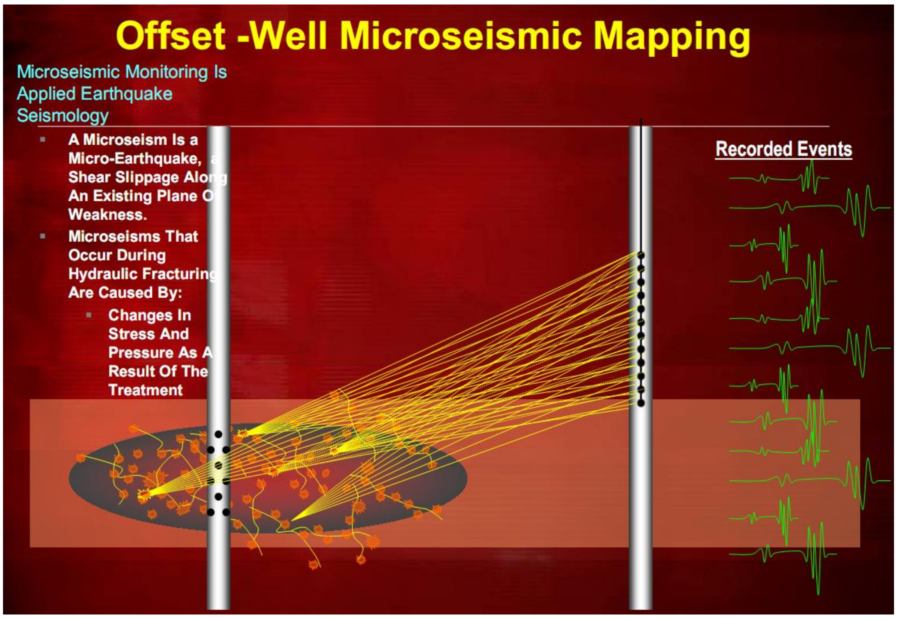
There are two main types of microseismic monitoring applied in the industry, downhole microseismic and surface microseismic which are explained below. Downhole microseismic monitoring is likely to be cost-prohibitive in the exploration and appraisal stages as it requires an adjacent wellbore to monitor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

<u>Downhole microseismic survey</u>

The process, shown in Figure 7 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 such things as 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).



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

Figure 7: Schematic of micro-seismic monitoring of fracture stimulation treatment

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 deg C (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.

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 limited experience with surface microseismic surveys and has observed mixed results. The challenge with applying this technique in the Bonaparte Basin is that, as stated in the overview, the swampy nature of the black soil plains during the wet season, with deep surface cracks forming during the dry, makes acquiring surface seismic difficult. This technique may not be suitable in parts of the Bonaparte Basin.

1.7 Post-Stimulation Completion

Immediately following fracture stimulation, dependent 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 be 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 the interceptor pit 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 wellsite.

The gas stream will be sampled for composition and contaminants. The recovered water will be sampled on a regular basis to evaluate the composition of the recovered fluid.

Figure 8: Separation and vertical flare set up in the Cooper Basin

The onshore exploration of the Bonaparte Basin has yielded several encouraging results but with no commercial production or infrastructure. As such exploration and appraisal wells cannot be connected to gas gathering networks during the testing phase. While on production test the gas will be flared at the well site. Production testing may be carried out for up to 30 weeks. Production logging tools may be run to determine gas contribution from individual zones.

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).

At the end of the test, the recovered fluid will be allowed to evaporate, where possible. However due to the seasonal rainfall in the Bonaparte Basin site specific water management plans will be developed to either

- Treat and dispose of brine
- Reinject into saline aquifers
- Truck to 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.

Additive Concentrations in Flowback

Chemicals returning from a well after a fracturing treatment are usually a fraction (usually 20% or less for chemicals 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 cleanup 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 Bonaparte Basin. As such Beach and the joint venture have not undertaken planning for the requisite water management associated with a potential stimulation effort.

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. It is necessary to truck water where shallow water is not available or the quality of the water is not suitable. Should the Cooper Basin project proceed to development, alternative water sources will be investigated including use of co-produced water available in the basin and recycling of recovered stimulation fluids.

In the Bonaparte Basin, due to high salinity of the shallow water source, water for stimulation may require alternative sourcing including harvesting of natural rainfall in the wet season prior to stimulation, trucking from alternative sources, or other methods that are yet to be assessed. Globally other alternative water storage techniques, both prior to stimulation and for storing recovered fluids, include mobile trailer mounted tankage and other free-standing tanks. All of these aspects may form part of the solution should fracture stimulation be required in the Bonaparte Basin and will be assessed for application in the specific environment should stimulation be required.

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% and 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.

As discussed above, it is expected that a significant proportion of the injected fluid will remain trapped underground and less than 50% of the placed fluid will return to the surface. At the conclusion of the production test, 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 Bonaparte Basin. An environmental assessment will be undertaken prior to stimulation to plan for water management. Some options that may be considered are

- Trucking of recovered fluid for disposal at a suitable facility
- Treatment at site to concentrate up the brine for trucking and disposal at a suitable facility
- Reinjection of concentrated brine, or all recovered fluids into a more saline, un-accessed aquifer or back into the target reservoir (at least in the exploration phase once testing is complete and there is no further use for the well)
- Other alternative that may become evident during current exploration activities and evaluation

Plate 2: Examples of temporary water holding ponds used in the Cooper Basin

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 m by 200 m compared to 130 m by 100 m).

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 stimulation in the Bonaparte Basin, Beach will investigate alternatives for water storage and produced fluid management such as free-standing lined tanks (as shown above) and other fluid storage, treatment and reinjection options. 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.

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) per treatment.

As the onshore Bonaparte is only now being evaluated for potential shale gas and other unconventional targets the requirement for fracture stimulation and the extent of potential fracture stimulation is unknown.

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 five but potentially up to ten zones that may be fracture stimulated. In a horizontal well, with a length of 1,500 m, stimulation treatments are likely to be placed every 100 m requiring 15 treatments in the well.

Consequently, fracture stimulation of a vertical well would require in the order of 8 to 16 ML of water, and a horizontal well would require up to 24 ML.

To minimise trucking of water, water will be obtained, where possible, from shallow water wells within the lease area of the wells. Water quality encountered while drilling for water for the current exploration well may require that the joint venture seek alternative sources of water due to high salinity. The joint venture will investigate these options further should the exploration well results be encouraging.

If the exploration and appraisal phase is successful and Beach is likely to progress to a development phase, alternative water sources are likely to be required. These may include recycling of recovered fracture stimulation fluids where practicable or alternative local water supplies. In this case, detailed investigation and consultation regarding water sourcing would be carried out to ensure that significant impacts to water resources and other users are avoided.

1.11 Other Aspects of Fracture Stimulation Operations

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

Detailed aspects of drilling and well operations such as preparation of the well lease, drilling, casing and cementing of the well, camps, well operation and monitoring, well abandonment and well lease restoration are consistent with well established and understood methods for conventional onshore drilling for hydrocarbons and are not revisited in this submission.

1.11.1 Waste Management

A range of wastes are generated during fracture stimulation operations. Typical wastes are summarised in Table 2.

Table 2: Typical wastes and disposal methods

Waste	Disposal Method
Domestic Waste	
Sewage and grey water	Camp and sewage would be managed using either a septic or portable aerated treatment system. Septic systems must comply with the NT *Code of Practice for Small On-Site Sewage and Sullage Treatment Systems and the*

Waste	Disposal Method
	Disposal or Reuse of Sewage Effluent (The Code).
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.
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 will be guided by the principles of the waste hierarchy (i.e. avoid, reduce, reuse, recycle, recover, treat, dispose).

Generation of domestic waste (e.g. food waste, paper, plastics, cans and glass) will be limited as most domestic waste handling would occur at the camp. The camp for fracture stimulation is similar to the camp that is utilised during drilling operations and the same management of waste standards are applied. Any domestic waste at the well site would be stored on site in secure bins or skips. Recyclable materials will 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 will be collected in designated skips for eventual recycling or disposal to an appropriately licensed facility. All wastes generated will 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 Hazardous Materials Storage

Each stimulation treatment requires approximately 16,000 L of diesel and storage of sufficient fuel for four to five treatments will be on site. Fracturing additives required for the fracture stimulation operation (see Section 1.5) will also be stored on site. Fuel and chemicals 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 *080/07 Bunding and Spill Management*).

1.11.3 Spills and Emergency Response

Appropriate spill containment and cleanup 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 waste materials would be removed off site as discussed in Section 11.11.1. The site will 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 under the parameters established in the approved Environment Plan.

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 environmental risk assessment, which is summarised in Section 2.6. This risk assessment quantifies the level of risk based on an assessment of the likelihood and consequences of hazardous events occurring.

Sections 2.1 to 2.5 provide a detailed discussion of aspects of the environment that are potentially (or commonly perceived to be) impacted by fracture stimulation activities. Reference is made to the results of the risk assessment where relevant throughout the discussion. The key aspects discussed are:

- Aquifers, where the potential hazards are mainly related to injection of fracture stimulation fluids into the target formations
- Soil, shallow groundwater, surface water and fauna, where the potential hazards are mainly related to storage and handling of fuel, chemicals and flowback fluids
- Other issues such as public safety and risk, cultural heritage, noise and air emissions, radioactivity and seismicity, where the potential hazards are related to a more general range of site activities.

The risk assessment summary table (

Table **3**) in Section 2.6 provides a summary of the key hazards, management measures and resulting level of risk.

2.1 Aquifers

The potential or perceived hazards to aquifers resulting from fracture stimulation activities are discussed below. They include:

- Leakage to aquifers due to loss of well integrity
- Fracture propagation into overlying aquifers
- Leakage to aquifers through geologic media
- Impact on aquifer potential of the target zone
- Lateral migration of injected fluid
- Fracture propagation between pressure cells / aquifers that are normally isolated
- Groundwater impacts from water use.

2.1.1 Leakage to aquifers due to loss of well integrity

A loss of well integrity could result in the leakage of fracturing fluids or hydrocarbons to aquifers or production of aquifer water when the well is flowed. The risk is reduced to as low as possible in the well design process and managed through operational monitoring during each step in the process. In particular:

- The well design and construction provides the mechanical integrity that reduces this risk to as low as possible
- Pressure testing confirms that production casing meets designed pressure specification
- Cement bond logs confirm the integrity of cement that fills the casing-wellbore space and prevents migration
- Pressure safety trip out systems during the fracture stimulation prevent pressure limits of the surface pipework and downhole casing equipment being exceeded
- Pressure monitoring during the fracture stimulation provides confirmation that the stimulation has not resulted in a well integrity issue
- 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 casing design outlined in Figure 2 was reviewed by an independent engineering firm to confirm that the selected production casing and tubing equipment met the operational requirements for application in the high stress, high fracture gradient environment in the Cooper Basin. Standard design safety factors of 10-30 % are applied to the pipe strength in this process to allow for the high temperature environment and the potential pressures and loads on the casing. Conditions in the Bonaparte Basin are expected to result in the well design having higher safety margin.

The design process ensures that the correct casing weight and grade and casing coupling is selected to meet the pressures and loads anticipated after application of the safety and temperature factors. For the well design shown in Figure 2, the maximum well injection pressure is 13,000 psi during the stimulation phase. Wellhead and surface piping equipment is rated to 15,000 psi.

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

As detailed previously, during construction of the well the casing strings are cemented into the ground. As shown in Figure 2, 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.

Well site supervision by experienced personnel ensures that installation of casing, tubing and well head equipment is correctly undertaken to minimise the chance of inadvertent errors such as over tightening of threads which may lead to premature failure.

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.

As outlined in Section 1.3 there have been several recent advances in well design for wells targeting low permeability gas that enable alternatives to traditional cementing and perforation options over the hydrocarbon bearing intervals. Beach will actively investigate the application of these technologies but will ensure that mechanical integrity of the well, as required to isolate the aquifers and meet the operational requirements, is maintained through the design and construction process.

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 may assist with understanding stimulation and production results in the event that unexpected production characteristics develop. The risks posed by poor cement bond quality are discussed below.

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, which will have a negative impact on production but would not affect shallow aquifers. This provides a commercial driver to ensure proper isolation of intervals.

If there is a poor cement bond from the target gas bearing zones up to the base of the surface casing, this would not pose a risk to shallow aquifers which are located a few hundred metres above the base of the surface casing and are cemented behind the surface casing. Any fracture stimulation inefficiency in the intermediate casing would have a negative production outcome but no impact on the overlying aquifer zones.

It is considered that there is a negligible chance that the production casing cement quality (and other isolation methods that may be applied in the optimisation of the production casing well design) intermediate casing cement quality and surface casing cement quality would all be of sufficiently poor quality to enable fracture stimulation fluids to be pumped from the target reservoirs into the shallow aquifers some 400-700 m or more above the planned stimulation targets. Observation of cement returns to surface during the cementing of the casing is taken as an indication of a successful cementing job. Should there be uncertainty in the quality of the cement job a cement bond log can be run on the casing when the well has been drilled to the next logging point. If required, a remedial cement treatment may be applied.

In the horizontal wells a cement bond log will be obtained as deep as is practicable, As the horizontal section of the well is within the same target interval, cement integrity will not impact on cross contamination or production, rather it will result in poor isolation between fracture treatments along the length of the well (which potentially results in a negative production outcome rather than an environmental impact). Options will be investigated to run cement bond logs on coil tubing or by pumping down the wireline logging equipment into the lateral to assist in the understanding of well performance and treatment results.

<u>Pressure protection during stimulation</u>

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. For the well design discussed in this document this pre-set pressure is the 13,000 psi calculated after temperature and safety factors are allowed for.

<u>Monitoring during fracture stimulation</u>

Monitoring of injection pressures is carried out during fracture stimulation and indicates whether there are any issues with casing integrity.

During the fracture stimulation treatment the injection pressure at the wellhead is constantly monitored to understand how the injection is progressing. The injection pressure is used to determine the fracture gradient of the formation. If the fracture gradient is lower than anticipated this may indicate that the well integrity has been compromised. For example, if the fracture initiation pressure was estimated to be 11,500 psi for an interval and during stimulation the injection rate increased suddenly once the pressure got to 10,000 psi, it may indicate that the casing has failed higher in the well. This may arise due to faulty casing material or errors during making up the casing connections while running the casing. 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 reduces the chance of this type of breach to very low levels.

In the event that the injection pressure does not appear to be correct for the zone being stimulated, the stimulation treatment will be suspended and the data reviewed to assess the implications. As the stimulation treatment commences with a small volume of pre-stimulation fluid only a small fraction of the treatment may enter the undesired interval. Dependent on the location of the breach, the well may be repaired with a casing patch or other isolation method or, if the zone accessed was proposed for stimulation, the stimulation may progress foregoing the intervals deeper in the well. If the zone is significantly higher in the well and there is no suitable way to isolate the interval and successfully stimulate the lower intervals, the well may be plugged and abandoned with appropriate plugs set to isolate intervals as required by the regulations.

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 will be monitored for pressure. A sudden unexpected change in the annular pressure is an indication 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 very low as tabulated in Table 3.

2.1.2 Fracture propagation into shallow aquifers

If growth of fractures out of the target formations and into overlying aquifers occurred, it could result in contamination of these aquifers or establish a conduit from the aquifer to the wellbore such that, during production operations, water would be recovered to surface.

Based on extensive fracture height growth monitoring in shale gas plays in the United States it is considered improbable that this type of connection can be established.

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 m (Fisher and Warpinski 2011). Figure 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 Bonaparte Basin stratigraphic section and the location of the shallow surface aquifers are shown on the figure 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 m above the fracture stimulation zone in at least 250 treatments, representing less than a 0.5% chance of occurrence.

The Eagle Ford data is used here as an analogue as there is no local data on stimulation height growth for fracture stimulation of shales in the Bonaparte Basin. Fisher and Warpinski (2011) reviewed height growth data from other key shale plays in the US including the Barnett, Marcellus and Woodford, all with similar limited height growth. The Eagle Ford data is presented because the monitored fracture stimulation treatments were conducted over a similar depth interval to the Bonaparte Basin target zones.

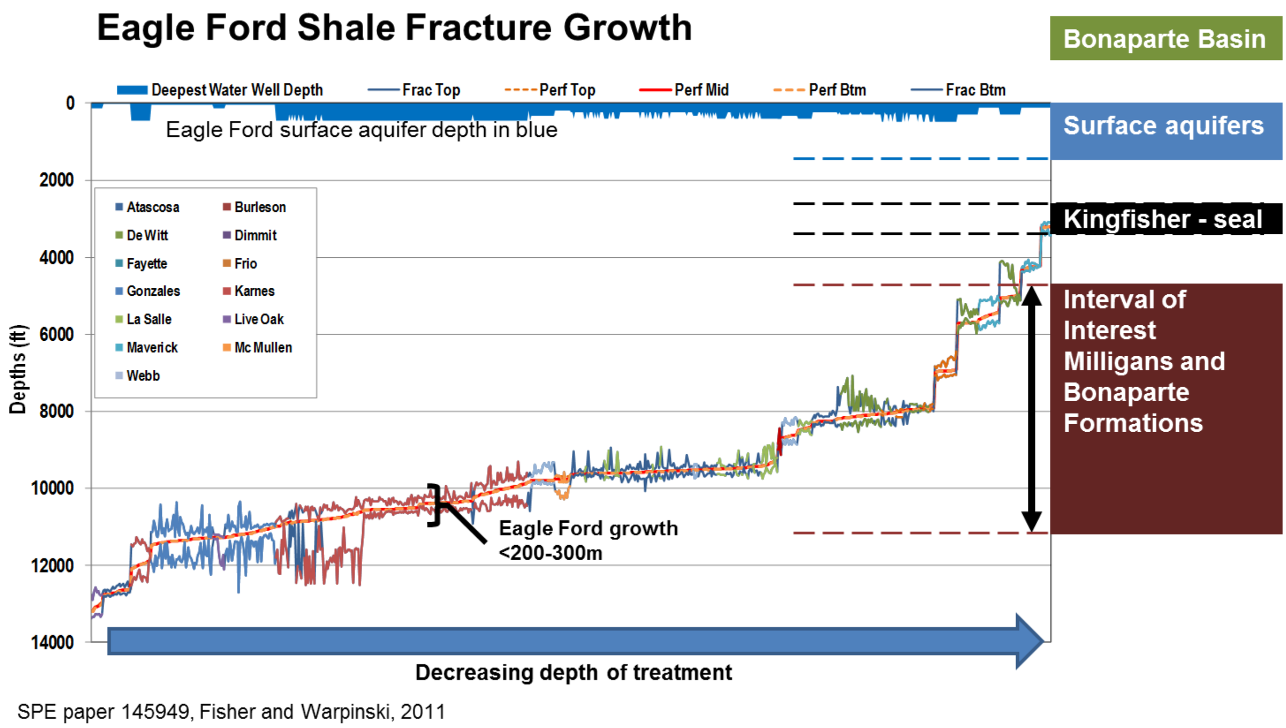


Figure 9: Typical fracture height growth measured during shale gas stimulation in the Eagle Ford (USA) with Bonaparte Basin well section superimposed

If it was considered that a fracture was able to grow 800 m or more into the shallow aquifers, it is not expected that the resultant impact would be significant, for the following reasons:

- Under production conditions, the flow will be from the aquifer to the well ensuring that further fluids do not cross flow into the aquifer.
- Flow from the aquifer production would be identified at the well by the elevated water production rates and analysis of the water chemistry.
- Any further fracture stimulation in the area would use micro-seismic monitoring equipment to ensure treatments are contained within the interval.
- When the well is shut-in or abandoned the aquifer will continue to flow to the lower gas zones until the pressure in the two zones equilibrates.
- Once equilibrated there is negligible pressure drive to enable gas or fluids to migrate towards the aquifer.

The level of risk posed by fracture propagation into overlying aquifers is expected to be low (see Table 3).

2.1.3 Leakage to aquifers through geologic media

Leakage of stimulation fluids to aquifers through the overlying strata could result in contamination of these aquifers. However, this is not considered to pose a credible risk for the project.

As discussed above, the nearest aquifers of any significance are the shallow aquifers of the Keep River Inlet. As indicated in the geological overview the target intervals are separated from the shallow aquifers by approximately 800 m of rock.

The level of risk posed by leakage into overlying aquifers has been assessed as low (see Table 3).

2.1.4 Impact on 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 target units in the Bonaparte Formation are considered to be aquitards (barriers to water flow) not aquifers. The sandier units within the Milligans Formation may be considered to be aquifers if water saturated. However, if the units are water saturated there is no resource potential and the units will not be fracture stimulated.

If the Milligans Formation sands are gas bearing and it is considered that further away form the hydrocarbon well that these sands are aquifers, the zones are not considered to be suitable for use 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 nature of the rocks results in insufficient yield for commercial use
- depth of the zones requires expensive drilling and pumping equipment and is not commercially viable.

The level of risk has been assessed as low (Table 3).

2.1.5 Lateral migration of injected fluid in the target section

Migration of fracture stimulation fluid away from the stimulation treatment will not occur.

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.

The level of risk has been assessed as low (Table 3).

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 will 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 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 the gas flow will be towards the wellbore as this will be lower pressure than the neighbouring strata. This is not likely to have significant environmental impact in these low permeability, gas-saturated formations, 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.

The level of risk has been assessed as low (see Table 3).

2.1.7 Groundwater impacts from water use

Shallow aquifers are often saline, unsuitable for stock or domestic use and are likely not to be suitable for fracture stimulation. Alternative water sources will be required.

If the exploration and appraisal phase is successful and Beach is likely to progress to a development phase, alternative water sources are likely to be required. These may include recycling of recovered fracture stimulation fluids where practicable. In this case, detailed investigation and consultation regarding water sourcing would be carried out to ensure that significant impacts to water resources and other users are avoided.

The level of risk from water extraction for fracture stimulation in the exploration phase has been assessed as low as the water is likely to be unsuitable (Table 3). The management procedures in place to assess and monitor possible impacts, cease extraction, if necessary, and make good, will ensure that significant impacts to existing water users are avoided.

2.2 Soil and shallow groundwater

Potential impacts to soil and shallow groundwater arise mainly from:

- spills or leaks from the storage and handling of fuel or chemicals
- spills or leaks from the sourcing and storage of water in preparation for stimulation
- spills or leaks from handling and storage of flowback fluids at the surface
- separator upset resulting in small volumes of flowback fluid reaching the flare
- storage and transport of waste.

Improper storage and handling of fuel, chemicals and flowback fluids has the potential to result in localised contamination of soil and groundwater.

In order to minimise this risk, chemicals on site will be stored and handled in accordance with relevant standards and guidelines. Bulk fuel and chemicals will be stored with appropriate secondary containment as required. Any spills from chemical handling would be immediately cleaned up and contaminated material removed off-site for appropriate treatment or disposal.

As discussed in Section 1.9, there will be two parts to water management in the Bonaparte Basin. The first part associated with water storage prior to stimulation and the second part 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 is will be in lined ponds, above ground tanks or other surface tankage as is assessed to be appropriate for the activity (assessment yet to be undertaken pending results of the current exploration well). The stimulation fluids recovered during flowback and testing will be captured and contained via the interceptor pit or tank and the separation process and directed to appropriate tankage as defined by an environmental assessment to be conducted prior to stimulation.

Should earthen or surface ponds be utilised, quality control during construction of the ponds is 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 applied, have lower environmental risks associated with entry of large fauna and livestock.

The water sourced for fracture stimulation is expected to be fresher than the water from shallow bores that are brackish or saline. Chemicals are not added to the stored water, however it is desirable to prevent release of the water to soil and potentially to shallower groundwater systems. Should a pond leak develop while these ponds are being used to contain pre-stimulation water, the short term nature of utilisation, the absence of added chemicals and the remoteness from sensitive receptors or sensitive land uses indicate that there will be negligible to minor impacts on the soil and shallow groundwater and this risk is assessed to be low.

If a spill or leak from a pond or tank occurs while it contains flowback fluids, containment and clean-up measures would be implemented. The pond or tank can be decommissioned by pumping fluid to an alternative tank or storage on the lease. Where necessary and possible, escaped fluid may be recovered, for example with a drainage channel to collect the fluid which would then be pumped back to an alternative containment tank. In the event of a major spill or leak, affected areas would be fenced off and assessed, rehabilitated and monitored, in consultation with the regulator and EPA where appropriate.

The water table in much of the region, where present, is close to the surface, and is expected to be predominantly saline. There is very low population density and very limited use of shallow groundwater. Many of the fracturing fluid additives are biodegradable and would be expected to break down over time if a spill or leak occurred. The relatively low permeability of the clay soils that are present at many of the potential exploration well locations would also limit the rate of transport of any spilt contaminants. Consequently, minor seepage from a pond, if it occurred, would be expected to have a low level, localised impact. A large release (e.g. due to pond or tank failure) could affect a larger area and result in a moderate level consequence, but is considered unlikely given the construction, lining, operation and monitoring of the ponds that will be undertaken (as discussed above).

Fracture stimulation requires the injection of high pressure fluids into the wellbore. An equipment failure or leak could result in fracturing fluid being released to the lease area. 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 is pressure tested to ensure integrity and pressure trip out devices are present to shut down pumps before equipment limitations are reached (Section 2.1.1). The design, pressure test and shut down systems reduce the risk of leaks to a very low level. In the unlikely event of a failure, the equipment is quickly shut down from the control van, reducing the volume of the spill to minor amounts.

Small volumes of flowback fluid could potentially flow to the flare if a separator upset occurred during testing. As equipment will be regularly inspected and maintained and flaring will be monitored, this would be very unlikely to occur, and if it did, volumes of fluid would be small and present a low level of risk.

Storage of waste and transport to licensed disposal facilities will be undertaken in accordance with relevant legislation and guidelines. Waste generation will be minimised where practicable, waste will be stored securely and licensed waste contractors will 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. These studies will be used to assess impacts and success of any required remedial action.

Other potential impacts to soil (e.g. soil disturbance, erosion) are 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 in accordance with Environment Plan.

The level of risk to soil and shallow groundwater has been assessed as low for most of these potential hazards. For a major leak or spill, while unlikely, the risk ranking is medium due to the assumed consequence (see Table 3).

2.3 Surface Water

Potential impacts to surface water arise mainly from:

- spills or leaks from the storage and handling of fuel or chemicals
- storage and transport of waste
- spills or leaks from handling and storage of flowback fluids at the surface
- flooding of well leases during fracture stimulation operations.

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

Several of the additives in the fracturing fluids (particularly biocides) have relatively high toxicity to aquatic organisms, particularly in fracturing fluids that have only just been mixed, where the additives have not been used and degraded. Although many of these additives are biodegradable and would be expected to break down over time, a release or spill to surface waters of large volumes of fluids containing these additives would require significant dilution to reduce levels of contaminants to below harmful levels and could result in impacts beyond the immediate area of operations.

The potential mechanisms for such an escape of large volumes of fracturing fluids to surface water include structural failure of ponds or tankage holding flowback fluids (due to overfilling and erosion of the earthen pond walls) or significant flooding such that a pond or tank is inundated.

Construction of ponds, if utilised, with a polyethylene liner, operation with appropriate allowance for rain events and wave action, construction of pond walls higher than the surface grade to prevent surface water drainage to the pond, contouring surface drainage around the ponds and ongoing monitoring of pond condition reduce the risk of structural failure such that it is a very unlikely event. Above ground tanks as shown in Plate 2 naturally prevent surface water drainage into the tank. Selection of appropriate well site and pond locations will 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).

To mitigate the risk of fluid release due to flood inundation, well leases should not be located in areas where frequent flooding is likely. If well leases are to be located in areas where flooding may occur, measures will be undertaken to ensure that ponds are not vulnerable to flooding (e.g. ponds may be located on higher ground out of the floodplain, pond walls constructed higher above grade at these locations, application of surface tanks or use of trailerised tanks, tests not undertaken during known flooding seasons).

Flooding of the well lease while fracture stimulation is being carried out could result in localised contamination from fuel and chemicals held on site. Short term (1-2 weeks), shallow and localised flooding due to localised high rainfall events is unlikely to result in significant risk as the stimulation activity is ceased in advance of storm weather and materials would be appropriately secured.

Prior to undertaking fracture stimulation operations, site-specific assessments will be prepared to demonstrate that environmental objectives can be met. The site specific assessments will indicate risks identified at individual well locations and management strategies required to mitigate these to meet the 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 can be reduced to a very low level.

The level of risk to surface water has been assessed as low for most of these potential hazards. For a major leak or spill to surface water due to pond failure, while this is an unlikely event, the potential level of consequence has been assessed to be major, which results in a medium risk (see Table 3).

2.4 Stock, Wildlife and Vegetation

Potential impacts to stock and native fauna arise mainly from:

- spills or leaks from the storage and handling of fuel or chemicals
- spills or leaks of flowback fluids
- interaction with fluid storage ponds
- use of roads and movement of vehicles and heavy machinery
- activity outside designated / approved areas
- storage and transport of waste.

Access to fuel and chemicals and flowback fluids held in ponds presents a potential hazard to stock and to some native fauna. Stock access to chemicals and fuel will be prevented by storing and handling them in designated areas free from rubbish or waste that may attract fauna, manning of well sites while fracturing activities are being undertaken and immediate containment and clean-up if any spills occur. Stock-proof fencing will be erected around earthen ponds to prevent stock from accessing flowback fluids. Drilling sumps will be fenced following drilling (which is standard practice). Regular inspections will be carried out to ensure the integrity of the fences.

The presence of temporary ponds, whether earthen or above ground, for holding flowback fluids has the potential to attract birds. Due to the nature of the ponds (relatively steep sided and lined with plastic, with no 'beaches', vegetation or food sources) visitation by birds is expected to be restricted to relatively small numbers for relatively short periods of time. Concentration data for fracturing fluids to be injected and available toxicity information (e.g. MSDS information provided by the stimulation service provider) indicate that the concentration of additives of highest concern for fauna (e.g. biocides) is expected to be below levels that pose a significant risk for birds coming into short term contact with flowback fluids. As discussed in Section 1.8, many of the additives in the fracturing fluids are used or degraded in the process (including biocides) or remain in the formation and would return at a fraction of what was pumped down the well. The pH of the flowback fluids is expected to be relatively neutral, as acids are neutralised in the fracturing process (see Section 1.5). Beach's water quality data from previous fracturing of the Holdfast-1 well in the Cooper Basin support this, with recorded pH in the range of 6.2 to 7.7. Ponds will be temporary and will be rehabilitated following removal of liner.

As a consequence, the presence of the ponds is not expected have a significant impact on birds. Beach intends to conduct further investigation to confirm this, including ongoing testing of flowback fluid composition. The ongoing inspection and monitoring of the ponds would also detect bird mortality if it occurs. If necessary, additional measures to discourage bird use will be implemented, which may include installation of flagging or other devices to discourage bird presence.

Plastic lined ponds with relatively steep sides have the potential to trap stock and native fauna. As discussed above, fencing will prevent larger animals from entering the ponds. Based on experience with similar ponds used for holding raw water for drilling or fracturing or for treatment of produced formation water, entrapment of fauna in ponds (in Beach's Cooper Basin experience) is a very rare occurrence. As noted above, the presence of these ponds is temporary. Application of above ground tanks or other tankage, where assessed to be necessary, will mitigate the risk of stock and fauna incursion.

As discussed previously, a pond or tank breach could result in a significant release of fluid. The construction, operation and monitoring of the ponds or tanks reduces the likelihood that this outcome will occur to a low level. In the event that a breach occurs before stimulation, the brackish (or saline) water may affect vegetation in the area of the spill (should it extend beyond the cleared lease area). During flowback, the returned fluid in the pond or tanks will consist of degraded fracture fluids and dissolved ions from the geological strata. As there is less returned fluid than injected water, pond or tank operating levels can be significantly reduced and the risk of failure reduced further. A spill of flowback fluid associated with a breach may affect vegetation (should it extend beyond the lease area) and indirectly stock and fauna that may enter to feed. The spill area can be fenced to prevent stock and fauna entry. As appropriate, drainage channels may be required to drain and gather spilt fluids and pump back to other holding ponds, and further assessment, rehabilitation and monitoring may be undertaken, as discussed in Section 2.2.

Fracture stimulation operations may result in a short term and localised increase in traffic volumes, which could increase the risk of collisions with stock and native fauna. Measures to mitigate the risks are part of standard operating procedures for Beach and include speed restrictions, monitoring of speeds in industry vehicles, driver education programs and restriction of transport movements to daylight hours as far as practicable.

Activities outside defined / approved areas have the potential to impact vegetation and fauna. All activities will be confined to the cleared well lease, with signage and fencing (where required) installed to delineate approved areas and any restricted areas. If flora of conservation significance is present in the vicinity it will be flagged and/or fenced off where necessary to prevent disturbance.

A high standard of waste management will be implemented to avoid impacts to flora and fauna. In particular, secure systems will be used for storage and transport (e.g. covered bins in a designated area) to prevent wind-blown litter or birds and dingoes accessing waste.

Based on the above discussion, impacts to native fauna and flora (including rare or threatened species) are expected to be minimal. Site-specific risks will be addressed in initial scouting and site assessment conducted to demonstrate that objectives with respect to vegetation, stock and native fauna will be met while undertaking the proposed work at the specific well location.

The level of risk has been assessed as low for most of these potential hazards. A medium risk is assigned for a major leak or spill; although it is unlikely to occur, the consequence is moderate (see Table 3).

2.5 Other Issues

2.5.1 Public Safety and Risk

Potential impacts to public safety and risk arise mainly from:

- unauthorised access resulting in exposure to site hazards during operations
- unauthorised access to fluid storage ponds
- bushfire as a result of activities
- use of roads and movement of vehicles and heavy machinery.

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

Most sites are also expected to be relatively remote from public roads and accessed from roads with no public access. Measures such as signage and fencing will be in place at the well lease to warn of the hazards at the site and restrict access into the site. Potentially hazardous areas such as sumps and ponds will be securely fenced with warning signs in place.

The population density in the area is very low. Fracture stimulation activities (and drilling activities in general) would not be carried out in close proximity to station residences.

In order to manage the risk of initiating fires, activities will be confined to the cleared well lease and combustible material will be cleared from around the flare pit. Fire fighting equipment will be maintained in the area as appropriate.

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

The level of risk to public safety has been assessed as low for most of these potential hazards. A medium ranking has been assessed for road use (see Table 3).

2.5.2 Cultural Heritage

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

Fracture stimulation operations are undertaken on a prepared well lease, within the area cleared for activity by the local Aboriginal group during a cultural heritage field survey. Signage and fencing (where required) is 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 are in place to deal with the incidental discovery of cultural heritage material.

Consequently, significant impacts to cultural heritage are not likely to occur and the level of risk has been assessed as low (see Table 3).

2.5.3 Noise and Air Emissions

Potential impacts associated with noise and air emissions include:

- Reduction in local air quality
- Generation of greenhouse gases
- Disturbance to native fauna
- Disturbance to the local community.

Noise and air emissions from the well sites during fracture stimulation will be localised and short term and are not likely to have a significant noise or air quality impact. The sites will not be in close proximity to residences (e.g. station homesteads or local townships). Equipment will be operated and maintained in accordance with specifications in order to minimise noise and air emissions. Flaring during production testing would be kept to minimum length of time necessary to establish resource and production parameters.

The volumes of gas flared will be recorded and estimates of vented gas volumes (dissolved in water stream or associated with initial flowback volumes) will be made. All greenhouse gas emissions will be reported in accordance with the requirements of the National Greenhouse and Energy Reporting Act (NGER Act).

Fugitive emissions from the flow testing equipment will be minimised by pressure testing of lines prior to use to ensure integrity. Due to the depth of stimulation treatment, the relatively small volume of rock that receives induced fractures from the treatments and testing conditions that draws gas towards the well, fugitive emissions through migration through geological strata to surface is not considered a plausible pathway. Migration along the well bore is a potential source of fugitive emissions and this is mitigated by well design and construction methods discussed in Section 2.1, particularly the presence of cemented casing strings, assessment of the cement quality with logging tools and monitoring the well and the lease during flowback.

Greenhouse gas emissions for future production of gas from shales and low permeability sandstones are outside the scope of this document. However, the current exploration phase represents an opportunity to gather data on the shale gas and basin-centred gas resources of the Bonaparte Basin that will be useful in assessing environmental and economic implications related to greenhouse gas emissions from possible future production of gas from this resource.

The level of risk from noise and air emissions has been assessed as low (see Table 3).

2.5.4 Radioactivity

The potential for radioactivity resulting from Naturally Occurring Radioactive Materials (NORM) that are brought to the surface is perceived as a potential issue for fracture stimulation activities.

Based on Beach's experience with Cooper Basin petroleum operations, levels of radioactivity associated with NORM in flowback of fracture stimulation fluids are not expected to be significant and are expected to be well below any levels of concern. NORM are usually only a potential issue when they are concentrated (e.g. by the formation of mineral scales or sludges over time in tanks, piping and facilities). However the Bonaparte Basin is a new exploration area for Beach and monitoring and analysis of recovered stimulation fluids will be used to confirm the expectation that the levels of radioactivity will be well below any levels of concern. In the unlikely situation that NORM above the natural background levels were to occur, appropriate measures for handling and disposal of recovered fluids, pond liners and tanks would be implemented.

Radioactive Tracers

Each tracer has a half life of less than 100 days. Radiation is only a hazard when the tracer is in its concentrated form, prior to injection into the stimulation fluid stream as it is being mixed to be pumped downhole. The storage and injection area on site is restricted to the specialised Engineer that is on-site from the radioactive tracer supply company. With the standard processes in place, expected radiation exposure of the Engineer is 1300milliRem/yr in comparison to a hospital workers exposure of 2000mRem/yr and well below the Regulatory limit for a radiation worker of 5000mRem/yr. Once injected into the stimulation fluid stream the concentration of radiation is significantly reduced and is not a hazard to anyone onsite. Flowback will be managed to enable capture and disposal of any radioactive proppant in the flowback stream. The tracers are certified to not transfer radiation to the pipework they travel in, so the flowback pipework will not transfer radiation to any future sites.

The level of risk has been assessed as low (see Table 3).

2.5.5 Seismicity

The induction of seismic events (i.e. micro-earthquakes) as a result of fracture stimulation is sometimes perceived as a potential issue. There is a slight risk that, due to the presence of regional scale faulting within the area of interest, fracture stimulation of deep shale gas and tight gas targets in the Bonaparte Basin may result in some localised seismicity.

Geoscience Australia's seismic hazard map (Burbidge 2012) indicates that the area is in the lowest category for seismic hazard. Geoscience Australia's website indicates that there have been 10 earthquakes in the general area since 1979 ranging from 2.2 to 4.8 in magnitude, with the most recent being a magnitude 3.3 event on 6 February 2014 at a depth of 10 kilometres.

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 magnitude 3 Mw. As such, the very small seismic events that the sensitive listening equipment detects are 1,000 to 100,000 times smaller than the smallest perceivable earthquake.

While there is a limited risk posed by fracture stimulation operations, due to the significant amount of faulting within the Keep Inlet sub-basin associated with the Halls Creek/Fitzmaurice Mobile Belt (as shown in Figure 10 and Figure 11), there is potential for larger events to occur at these faults. However, due to the relatively small volume of fluid pumped, for an injection of 1.6 ML of water per stage, the maximum release of energy in one event equates to a magnitude 3 event which is seldom felt by humans.

However, prior to undertaking stimulation in the Bonaparte Basin a site specific risk assessment will be undertaken to determine the potential for induced seismicity. If determined in the risk assessment that risk mitigation is required, 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). By utilising surface accelerometers to detect seismicity (induced ground velocity or acceleration) and setting pre-determined tolerance levels, the stimulation can be undertaken and if necessary curtailed in the event that larger seismic events occur.

While there is a chance of elevated seismicity, due to the very low population density and little infrastructure that would be sensitive to small seismic events the level of risk has been assessed as low (see Table 3).

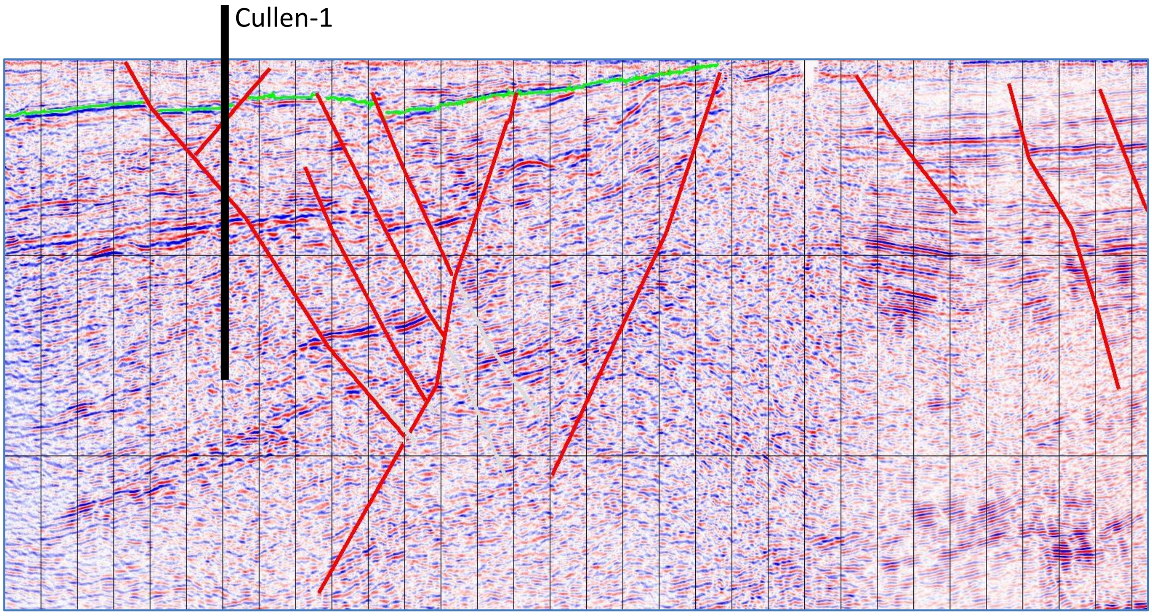


Figure 10: Faulting (red lines) marked on seismic cross section near the Cullen-1 well that is currently drilling in EP-126

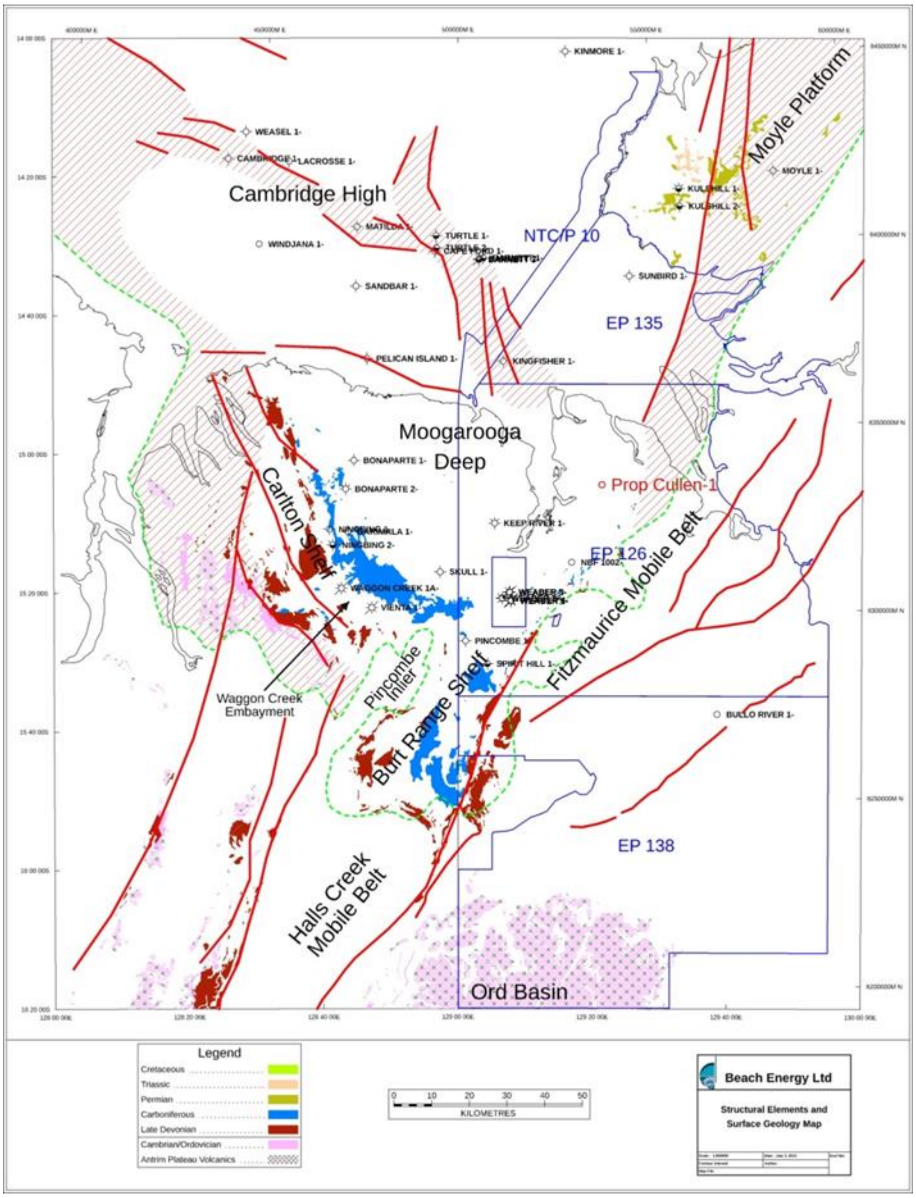


Figure 11: Structural elements showing the Halls Creek and Fitzmaurice Mobile Belt EP-126

2.5.6 Cumulative Impacts

Cumulative impacts of fracture stimulation of scattered exploration and appraisal wells in the context of the Cooper Basin oil and gas province and the existing environment are not considered to be significant. Any impacts will generally be isolated, short term and will affect a very small proportion of the region.

2.5.7 Economic Impact

Certain identified environmental risks have potential for negative economic impact on stakeholders. However, in applying the appropriate measures to minimise the environmental risk, the economic risk is also minimised, as discussed below.

- Noise (Section 2.5.3) has the potential to affect tourism. Activities will not to be undertaken in close proximity to residences and townships to avoid affecting residents and tourists.

- Groundwater use (Section 2.1.7) for stimulation has the potential to impact on existing ground water users. Monitoring of water levels in supply wells and existing stakeholder bores will be used to assess the impact. As required, alternative water supplies will be utilised to reduce withdrawal from groundwater sources and 'make good' measures undertaken.
- Stock and vegetation (Section 0) may be affected by activities. Stock may attempt to access fluids or be exposed to fluids through spills. Ponds are fenced and design and construction minimises risk of breach. As may be required any spill affected areas will be fenced off, assessed, appropriately remediated or rehabilitated and monitored.

The potential economic benefits of the exploration and appraisal for shale and tight gas on owners of the land 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 for royalties to be paid if exploration and appraisal are successful and project economics favourable which benefits State and traditional land owners.
- Potential enhancements to infrastructure or increased maintenance such as roads, airstrips and communication, 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.
- Increased understanding of the geological zones under the ground provides information for other licensees in the area once data becomes open file.

2.6 Environmental Risk Assessment Summary

As outlined at the beginning of this document, the material detailed provides 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. A Bonaparte Basin specific risk assessment would be carried out should Beach and the joint venture encounter success in the current drilling program that warrants stimulation to assess or develop any identified resource. As indicated earlier the principle difference between stimulation in the Cooper Basin and potential stimulation in the Bonaparte Basin will relate to surface water management aspects and potential monitoring for induced seismicity.

This 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

- using a risk matrix to characterise the level of risk[1] .

The level of risk for fracture stimulation in the Nappamerri Trough was carried out by RPS and Beach Energy, based on knowledge of the environment, understanding of proposed operations and experience with similar operations, including Beach Energy, Santos and other companies oil and gas operations in the Cooper Basin. A site specific risk assessment would be carried out for the Bonaparte Basin.

The risk assessment process 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 Energy'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.
- 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.

[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.

Table 3: 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 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 overlying aquifers (~700 m 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 aquifers by 800 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 Milligans Formation 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 considered as aquifers away from the hydrocarbon well, not suitable for use: ▪ if water is present, expected that the salinity will be sufficient to preclude use of the water ▪ low permeabilityof the rocks results in insufficient yield for commercial use ▪ depth of the zones requires expensive drilling and pumping equipment – 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 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 detrimental impact.	Negligible	Possible	Low
Water supply / use	Drawdown of artesian and sub-artesian aquifers Adverse impact on groundwater users Impact on groundwater dependent ecosystems	Water extraction in compliance with licensing and water allocations where applicable. Water supply wells reviewed to ensure that their use does not impact adversely on existing users of groundwater or groundwater dependent ecosystems Shallow aquifers may not be suitable for stimulation, stock or domestic use. 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.

Note: Water table, where present, is expected to be predominantly saline, with very limited and scattered use of shallow unconfined groundwater. This further mitigates the level of risk.</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.
Where well leases have potential for infrequent flooding, measures will be undertaken to ensure ponds are not vulnerable to flooding (e.g. ponds on higher ground, construction of higher pond walls, removal of flowback fluids off-site either during testing or at completion of operations).
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 or flood overtops ponds)</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>Flooding of well leases during fracture stimulation operations</td><td>Contamination of surface water
Death or injury to fauna</td><td>Well leases located on higher ground as far as practicable.
Fracture stimulation not carried out in floodplain areas if significant flooding is reasonably expected or predicted
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).
Emergency/spill response procedures in place with immediate clean up and remediation of spills.
Measures discussed above implemented to ensure ponds are secure from flooding.
Flowback fluids will be monitored closely where ponds are located in areas where there is any potential of flooding.</td><td>Moderate</td><td>Unlikely</td><td>Medium</td></tr>
</table>

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
Interaction of stock or native fauna with storage ponds	Death or injury of fauna or stock	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 will be temporary and will be rehabilitated following removal of liner.	Minor	Unlikely	Low
Personnel and third party access to storage ponds	Injury / danger to health and safety of employees, contractors and possibly the public	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.	Moderate	Remote	Low
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

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
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)). Remote location of well sites. 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 pastoral station 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. Remote location of well sites. Fracturing would not be carried out in close proximity to pastoral station 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
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. Fire fighting 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
Radioactivity from Naturally Occurring Radioactive Materials (NORM) in flowback fluids	Danger to health and safety of employees, contractors and possibly the public Contamination of soil and/or groundwater	Flowback ponds polyethylene lined to prevent soil and groundwater contamination. Monitoring planned at current well sites and fracturing operations to confirm expectation that levels of radioactivity are within acceptable limits. If NORM above the natural background levels were to occur, appropriate measures for handling and disposal of pond liners and contents remaining after evaporation would be	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures / Comment	Consequence	Likelihood	Residual Risk
		implemented. Radioactive tracers have short half life and does not transfer radiation to the pipework. Once in the stimulation stream the radioactive levels are greatly reduced and no longer a risk. Only qualified, experienced service engineer to work with radioactive material for activity.			
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 animals (native / pest species) and access to contaminants by stock and wildlife Litter / loss of visual amenity	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). Hazardous wastes handled in accordance with relevant legislation and standards. Licensed contractors used for waste transport.	Minor	Unlikely	Low

3 References

API (2009). *Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines*. API Guidance Document HF1. American Petroleum Institute, Washington DC.

API (2010). *Water Management Associated with Hydraulic Fracturing.* API Guidance Document HF2. American Petroleum Institute, Washington DC.

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Petratherm (2011). Environmental Impact Report, Paralana-2, Hydraulic Fracturing Stimulation. March 2011 (Petratherm Limited, Beach Energy Limited, TRU-Energy Limited)

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

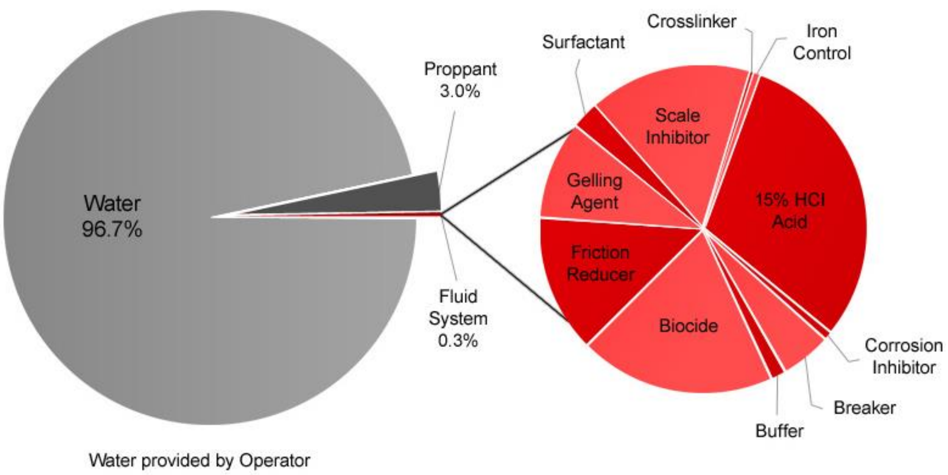
Product Name	Additive	Purpose	Concentration (within stage injected)	Indicative overall % in total fracturing fluid (Holdfast-1)
			acid	
BE-6™	Biocide	Prevents or limits growth of bacteria that can cause formation of hydrogen sulfide and can physically plug flow of oil and gas into the well	0.15 lbs/1000 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.

Table 1: 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.

Table 2: 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.

Table 3: 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** in this document. The level of risk has been assessed based on the assumption that the management measures outlined will be in place.