Northern Territory Government Inquiry into Hydraulic Fracturing

Submission by Santos Limited June 2014

Santos
We have the energy.

"Ensuring that we meet our obligations to communities, governments, staff and our business partners, is a responsibility that your Board takes seriously. We have four principles that underpin all decision making. One, we prioritise the safety of our people, our processes, our operations. Two, environmental safety is essential. We must have proper processes in place to monitor, and protect the environments in which we operate. Three, we operate ethically, and treat all stakeholders with respect, and, four, we do our best to make positive, meaningful contributions to the communities in which we operate."

Chairman of the Santos Limited Board, Ken Borda, at the Santos AGM 16 May 2014.

Front page photograph

Tanumbirini exploration well site, McArthur Basin, Northern Territory 2014

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Executive Summary

Hydraulic stimulation is an established practice used by the energy industry and Santos. We have safely employed this technology for nearly 40 years to enhance oil and gas recovery. Over 900 of our wells have been hydraulically stimulated in South Australia, Queensland and the Northern Territory, with over 1,500 individual hydraulic stimulation stages undertaken. No material impact or environmental harm has resulted from these activities.

Santos welcomes the opportunity to provide the following submission to the Northern Territory Government's Inquiry into Hydraulic Fracturing. This document details our position on current and future hydraulic fracturing (also known as **hydraulic stimulation**) for hydrocarbons in the Northern Territory. It includes a description of hydraulic stimulation and associated activities and the effectiveness of measures to mitigate any potential risks and impacts. It is intended to assist the Inquiry to address its published Terms of Reference.

Based on our significant experience and strong track record in safely and sustainably developing Australian natural gas reserves, Santos believes that appropriately regulated hydraulic stimulation presents a prime opportunity for the Northern Territory to become a major contributor to the Australian oil and gas industry. Hydraulic stimulation is a safe process. Santos considers that the key principles for undertaking hydraulic stimulation activities are:

1. Responsible operations and adopting industry best practices.
2. Robust science-based regulations.
3. Stakeholder engagement.

Responsible operations and adopting best practices

There are no risks associated with Santos' hydraulic stimulation activities that cannot be appropriately managed and Santos adopts best practice procedures and operational controls to mitigate any potential risks associated with hydraulic stimulation. These procedures are developed, implemented and monitored predicated on the guidance, specification and recommended practices of the American Petroleum Institute (API); considered to represent international best practice. Santos' engineering and operational controls may include, but are not limited to, well and well lease design and construction, well integrity management, chemical handling and fluid flowback management, construction of associated facilities, bunding, fluid recovery to appropriately contained facilities, fencing, signs, stormwater controls, maintenance of minimum freeboards in containment facilities, etc. These controls minimise the potential for uncontrolled releases to the environment and prevent unauthorised access.

Monitoring is undertaken throughout all stages of hydraulic stimulation activities, and includes robust surveillance to ensure well integrity. This monitoring provides confidence that our objectives are achieved without material impact to the environment.

Robust science-based regulations

To complement our industry best practice operating procedures, Santos supports robust science-based regulation that has clear and effective objectives and transparent oversight. The Northern Territory Government legislation for the petroleum industry provides a sound and thorough framework to effectively address potential risks, whilst taking a balanced approach recognising the significant economic and environmental benefits that the petroleum industry is delivering. This legislation is administered by numerous Northern Territory Government Departments, providing multilateral review and assessment. Santos is supportive of the Northern Territory Government as it continues to promote and implement contemporary and practical legislative and policy reform.

Stakeholder engagement

Santos undertakes engagement activities to ensure that the key stakeholders are aware of the components of petroleum activities and we are committed to upholding our long-held standing as a trusted Australian energy company. We always seek to establish and maintain enduring and mutually beneficial relationships with the communities in which we operate; ensuring that our activities generate positive economic and social benefits for, and in partnership with, these communities. As part of our operational procedures we seek to establish and maintain communication links with our stakeholders. In the Northern Territory our stakeholders include local communities, landholders, pastoral leaseholders, Traditional Owners and Aboriginal Peoples, representatives of Local Government, Northern Territory Government Departments, media, NGOs and industry bodies.

The key principles outlined in the preceding paragraphs accord with those of Australia's state government agencies, respected authorities such as the Australian Council of Learned Academies (ACOLA) and industry bodies including the Australian Petroleum Production Exploration Association (APPEA). Environmental impacts that are experienced are generally temporary and related to infrastructure footprints (e.g. roads and well leases), which can be optimised for shared use (e.g. roads) and minimised through appropriate project planning.

It is Santos' experience, in the Northern Territory and other areas, that hydraulic stimulation can be undertaken safely and successfully. This has been achieved whilst co-existing with other land users, and achieving mutually beneficial social, environmental and economic outcomes.

A summary of Santos' responses addressing the Terms of Reference published for the Northern Territory Government Inquiry into Hydraulic Fracturing is provided here, with more detail in the submission body.

	Term of Reference and Submission Summary	Document Reference	Page
1	Historical and proposed use of hydraulic fracturing of hydrocarbon deposits in the Northern Territory	Section 1.2 Section 1.3 Section 2.2 Section 3.8	2 2 7 16

Santos has conducted hydraulic stimulation activities in the Northern Territory since 1993, including the hydraulic stimulation of four wells in 2014. Future plans are contingent on the results of exploration and appraisal activities.

Please refer to the Australian Petroleum Production Exploration Association and Northern Territory Department of Mines and Energy submissions for broader industry context with respect to historic and proposed stimulation activities in the Northern Territory.

2	Environmental outcomes of each hydraulic fracturing activity for hydrocarbon resources in the Northern Territory (number of wells; frequency of types of known environmental impacts)	Section 3.8 Section 4 Section 6 Section 6.1	16 18 41 41

To date, Santos has hydraulically stimulated 31 wells at Mereenie in the Northern Territory, with no material impact to the environment.

Santos has stringent engineering and operational controls that are designed to mitigate any potential risks and impacts associated with hydraulic stimulation. These include, but are not limited to, well and well lease design and construction, well integrity management, chemical handling and fluid flowback management, construction of associated facilities, bunding, fluid recovery to appropriately contained facilities, fencing, signs, stormwater controls, maintenance of minimum freeboards in containment facilities, etc. These controls are detailed further in the body of this submission.

3	Frequency of types and causes of environmental impacts from hydraulic fracturing for hydrocarbon deposits in the Northern Territory and for similar deposits in other parts of the world	Section 4.2.4 Section 6	23 41

Hydraulic stimulation has not been associated with any material environmental impacts in Santos' activities within the Northern Territory or other areas of operation. Undertaken in the context of robust regulation and responsible operations, hydraulic stimulation is an environmentally sound practice. Potential associated environmental impacts identified through risk assessments may include:

- Surface footprints of related infrastructure (e.g. roads, well leases).
- Impacts to soil and shallow groundwater associated with unintended releases at surface.

These risks are mitigated with appropriate controls, such as negotiated location of infrastructure for shared use, wherever possible, and the use of earthen bunds and storage facilities for material containment.

Studies conducted by US authorities (including the EPA and the Groundwater Protection Council) have also concluded that hydraulic stimulation is safe and non-threatening to the environment or public health.[1] The

[1] Fisher, K. 'Data Confirm Safety Of Well Fracturing', Pinnacle Resources, American Oil and Gas Reporter, July 2010

	Term of Reference and Submission Summary	Document Reference	Page
	overall risk of groundwater pollution from a producing well is extremely low for most quality operations as found through a worldwide review of data sets from over 600,000 wells. Leak numbers that could be justifiably allocated to oil, gas or injection wells indicate an overall percent of leaking wells in the range of 0.03% to 0.005% of wells in service.[2]		
4	The potential for multiple well pads to reduce or enhance the risks of environmental impacts	Section 4.3 Section 5.2	25 27
	Multiple well pads reduce the surface footprint of well leases and the number of drill rig mobilisations. This reduces the requirement for access track construction and use, and emissions associated with mobilisation. In the Cooper Basin, multiple well pad development has resulted in up to 55% reduction in surface disturbance compared to individual single well pads. The use of multi-well pad technology will be key to minimising the surface footprint of shale gas development. Santos uses multiple well pads wherever practical and is experienced in using multi-well operations across other jurisdictions within Australia. Multiple well pads are only used during the appraisal and development phase where closely spaced wells are employed to extract the sub-surface hydrocarbons; they are not used during exploration activities. Multiple well pads are not currently used in the Northern Territory. It is not currently feasible at the Mereenie field to space wells close enough to enable drilling from a single well pad; whilst other regions are in exploration phase. Santos has the environmental vision of continually lightening our footprint and as such will continually assess the use of multi-well pad technology to reduce the surface disturbance in our operations.		
5	The relationship between environmental outcomes of hydraulic fracturing of shale petroleum deposits with geology, hydrogeology and hydrology	Section 4 Section 6 Section 6.2	18 41 43
	Geology, hydrogeology and hydrology (e.g. locations of hydrocarbon reservoir, faults and aquifers; separation distances between these reservoirs and aquifers) are a significant consideration in determining where a well is to be drilled. Consideration is also given to surface features, including local populations and populated areas, the natural environment, existing infrastructure and access roads, and water management options. Understanding the geology and hydrogeology allows for site-specific controls to be incorporated into drilling, and determines the need for hydraulic stimulation, and any associated restraints. Leading practice well design and construction methods are used to prevent sub-surface connection of aquifers and to isolate the targeted reservoir. This appropriately mitigates potential risks associated with hydraulic stimulation, and ensures optimum recovery of hydrocarbons. Advances in hydraulic stimulation technology have enabled Santos to use non-potable water (including from other oil and gas activities) and to minimise water use through capture and recycling.		

[2] King, G. & King, D. 'Environmental Risk Arising from Well Construction Failure: Difference Between Barrier and Well Failure, and estimate of Failure Frequency Across Common Well Types, Locations and Well Age'. SPE 166142 *Society of Petroleum Engineers*, 2013.

	Term of Reference and Submission Summary	Document Reference	Page
	Monitoring is undertaken throughout the life of a well (including all stages of hydraulic stimulation activity) to ensure and demonstrate the success of control measures to protect groundwater and surface water quality and availability.		
6	The potential for regional and area variations of the risk of environmental impacts from hydraulic fracturing in the Northern Territory	Section 4.2.1 Section 6	20 41
	Regional and area variations are considered in detail in the assessment of risk of environmental impact from hydraulic stimulation and associated activities. Specifically, risk assessments of activities consider and address: • identification of, and proximity to, sensitive receptors (flora, fauna, surface water, groundwater, land users etc.) • geology and hydrogeology (faults, separation distances between reservoirs and aquifers etc.) • climate. Consideration of these site specific risks allows for site specific controls to be implemented.		
7	Effective methods for mitigating potential environment impacts before, during and after hydraulic fracturing with reference to:	Section 6	41
	a) the selection of sites for wells	Section 4.2.1	20
	b) well design, construction, standards, control and operational safety	Section 4	18
	c) well integrity ratings	Section 4.2.4	23
	d) water use	Section 5.7	39
	e) chemical use	Sections 5.5, 6.5, 6.10	35, 51, 56
	f) disposal and treatment of waste water and drilling muds	Section 6.6	54
	g) fugitive emissions	Section 6.8	55
	h) noise	Section 6.7	55
	i) monitoring requirements	Section 6.4	48
	j) the use of single or multiple well pads	Section 4.3	25
	k) rehabilitation and closure of wells (exploratory and production) including issues associated with corrosion and long term post closure	Section 6.11	56
	l) site rehabilitation for areas where hydraulic fracturing activities have occurred	Section 6.11	56
	It is the view of Santos and the broader industry that hydraulic stimulation is a safe and environmentally responsible process. This view is shared by government agencies.[3] With proper regulation and responsible operation, any risks associated with hydraulic stimulation are able to be effectively mitigated. The hydraulic stimulation of wells at Mereenie and the Cooper Basin are testament to this over the past 30+ years as they have resulted in no environmental harm. Santos undertakes risk assessments of its hydraulic stimulation activities at all locations to identify potential impacts and appropriate controls to ensure risks are appropriately managed.		

[3] DEHP, 'Fraccing and BTEX', Department of Environment and Heritage Protection, Queensland Government, March 2013

Term of Reference and Submission Summary	Document Reference	Page
The best practice controls employed by Santos in the Northern Territory are consistent with leading industry practices and reduce risks to As Low As Reasonably Practical (ALARP[4]). As a result of these controls, the environmental risk associated with our hydraulic stimulation activities is low. Environmental impacts are generally temporary and related to the surface footprint of associated infrastructure (roads and well leases). Project planning is undertaken to optimise infrastructure location for shared use (e.g. roads) and minimise impacts.		

4 A risk can be described as ALARP where the outcome cannot be further reduced without significant costs and insignificant benefit to be gained and/or where the solution will be impractical to implement.

1. Introduction

On the 20th February 2014 the Northern Territory Government announced an inquiry into hydraulic fracturing, including an assessment of any associated environmental risk.

Dr Allan Hawke AC has been appointed the Commissioner of the Inquiry under the *Northern Territory of Australia Inquiries Act* and will present to the Government a report based on the terms of reference (included at Appendix 1).

Santos makes this submission for the Inquiry to consider under its cited terms of reference with respect to current and future hydraulic fracturing (also known as **hydraulic stimulation**) in the Northern Territory.

Santos strongly endorses the use of hydraulic stimulation as a safe and environmentally responsible technology that improves the economics of producing natural gas and oil. The technology will be key to the safe and sustainable development of the Northern Territory's vast onshore resource potential.

1.1. About Santos

A proudly Australian company, Santos is a leader of the Australian natural gas industry, with 60 years of responsible gas exploration and production across the nation, since establishment in Adelaide in 1954.

We are one of Australia's principal producers of natural gas to the domestic market, with the largest exploration and production acreage position in Australia. We have also developed major oil and liquids businesses throughout Australia, operating in all mainland Australian states and the Northern Territory.

In 2013, our total production was 51 million barrels of oil equivalent (mmboe), and as at 31 December 2013 the company had a substantial proven and probable (2P) reserves base of 1,368 mmboe. Santos has exploration and production acreage of approximately 300,000 square kilometres, employs 3,500 people across our operations in Australia and Asia, and is among the 20 largest companies listed on the Australian Securities Exchange (ASX).

Safety and sustainability are integral parts of Santos' operating ethos. We are committed to responsibly managing our environmental impact, working in partnership with the communities in which we operate and reliably managing our business.

1.2. Our history

This section addresses Terms of Reference 1

Our operations date back 60 years, originating in the Cooper Basin, in north-east South Australia and south-west Queensland. Having discovered and developed oil and gas fields in that area, Santos and its joint venture partners have expanded operations to include onshore oil and gas interests in Queensland, New South Wales and the Northern Territory. Santos also has offshore interests in Victoria, Western Australia, Northern Territory and Asia.

In 60 years of exploration and production, Santos has drilled over 3,500 wells, of which 34 are in the Northern Territory. Currently, Santos produces from approximately 1,500 oil and gas wells; 31 of these wells are in the Northern Territory.

Hydraulic stimulation activities are not new to the energy industry or to Santos. The practice was first employed by Santos in the late 1960s, and has consistently been used since the early 1980s to enhance oil and gas recovery.

To date, over 900 wells have been hydraulically stimulated in South Australia, Queensland and the Northern Territory, with over 1,500 individual hydraulic stimulation stages undertaken. These hydraulic stimulation activities have resulted in no environmental issues.

Santos works in partnership with host communities, governments, business partners and stakeholders to achieve outcomes of mutual benefit while pursuing safe and sustainable exploration for, and production of, natural gas and oil.

1.3. Our presence in the Northern Territory

This section addresses Terms of Reference 1

Santos has an enduring presence in the Northern Territory through our major interests in onshore and offshore oil and gas assets; our name “Santos” being an acronym for “South Australia Northern Territory Oil Search”.

Onshore in the Northern Territory, Santos has operated the Mereenie field since 1993. This field is located west of Alice Springs in the Amadeus Basin (Figure 1), and for many years provided the main supply of domestic gas in the Northern Territory. Oil and condensate from Mereenie are transported to Port Bonython in South Australia. To date, Santos has hydraulically stimulated 31 wells at Mereenie. In 2013 and 2014 Santos has undertaken a major appraisal and development program at Mereenie, targeting hydrocarbons in the sparsely drilled western and central areas of the field.

Our company also has an exploration program operating in the southern Amadeus Basin, including the drilling of a well at Mount Kitty, 225 kilometres south west of Alice Springs, and approximately 1,300 kilometres of seismic surveying.

To the east of Katherine, Santos has acreage in the McArthur Basin. We have recently completed 500 kilometres of seismic surveying over one of our permits, and are drilling an exploration well at the time of this submission (Tanumbirini 1).

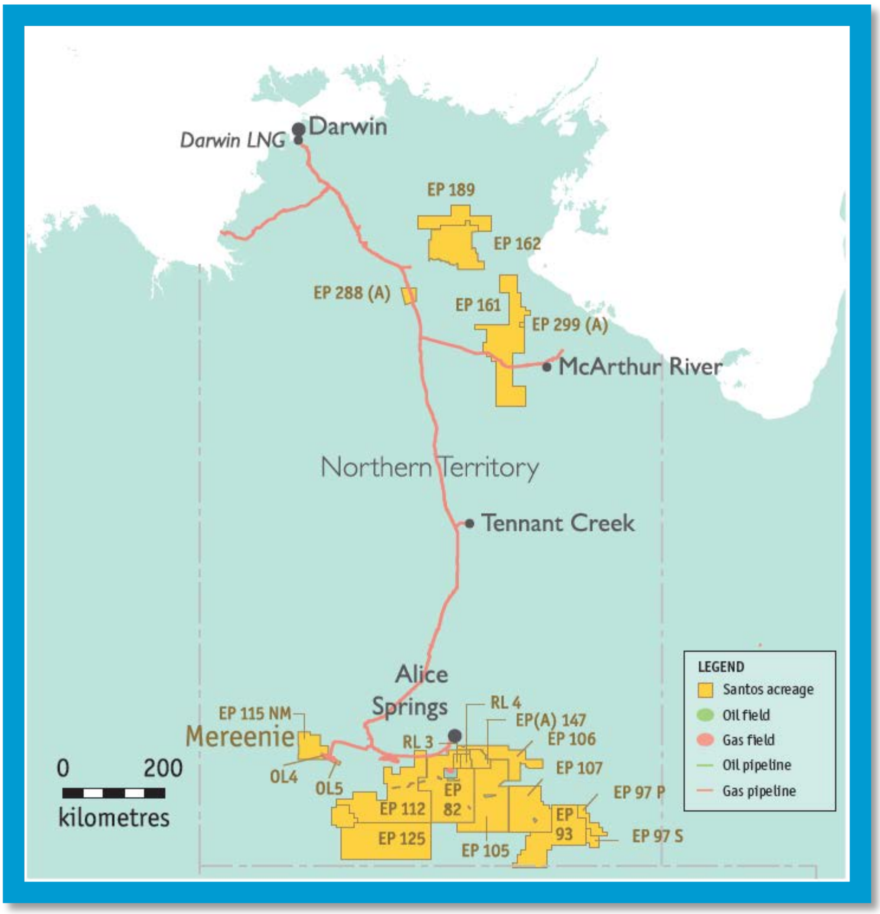

Figure 1: Santos operations in the Northern Territory

1.4. Our approach

At the recent 2014 Santos Annual General Meeting, our Chairman of the Board, Mr Ken Borda, highlighted the four principles that underpin all of Santos' decision-making:

1. We prioritise the safety of people, our processes and operations.
2. Environmental safety is essential, we must have proper processes in place to monitor and protect the environments in which we operate.
3. We operate ethically and treat all stakeholders with respect.
4. We do our best to make positive, meaningful contributions to the communities in which we operate.

At Santos, our core purpose is the discovery, development and production of oil and gas resources that underpin our society's standard of living.

Santos has a strong 60 year history of discovering and producing Australia's natural gas resources to the benefit of our key stakeholders, local communities, State and Federal Governments and our shareholders. Santos is, and will remain, a company focused on providing this essential resource to our customers. When it comes to the development of Australia's essential natural gas resources, Santos has a demonstrated capacity to operate safely and to work side-by-side with rural and regional communities and landholders.

1.4.1. Stakeholder engagement

Santos is committed to upholding its long-held standing as a trusted Australian energy company. Santos seeks to establish and maintain enduring and mutually beneficial relationships with the communities of which we are a part; ensuring that our activities generate positive economic and social benefits for, and in partnership with, these communities.

The Santos Environment, Health and Safety Management System (EHSMS) (Appendix 2) sets out the framework within which we establish and maintain communication links with our stakeholders. Our stakeholders in the Northern Territory include local communities, landholders, pastoral leaseholders, Traditional Owners, Aboriginal Peoples, representatives of Local Government, Northern Territory Government departments, media, NGOs and industry bodies.

Santos undertakes consultative processes to ensure that key stakeholders are aware of the components of petroleum activities. The purpose of our consultation is to:

- Get to know our stakeholders and understand how we can work most effectively and collaboratively with them.
- Build relationships and work within communities and regions as a responsible and contributing member of society.
- Listen to, discuss and address concerns or queries.
- Engage with stakeholders on why and how Santos operates.
- Share information with stakeholders about the elements of proposed activities.
- Develop and implement commitments within agreements with the Traditional Owners that are in place for all the areas in which we operate in the Northern Territory.

Santos hosts a 'Get To Know You' event at Circus Oz in Alice Springs 2013

The components of our engagement program include:

- Discussion and consultation sessions including face-to-face get togethers to share information, listen and address concerns and queries.
- Distribution of key information via meetings, briefings, media engagement, websites, social media and letter writing.
- Opportunities to get to know our people and for us to get to know people on whose land we work, with whom we work, and within the communities we operate.
- Opportunities for community capacity building through local employment, supply and partnership opportunities.

In addition to our own community information sessions, Santos also participates in information roadshows conducted by Australian Petroleum Production and Exploration Association (APPEA) and the Department of Mines and Energy (DME) throughout the Northern Territory. Previously this has included information sessions at Alice Springs, Darwin, Katherine and Mataranka.

Discussion topics during consultations include:

- environmental disturbance and the use of chemicals
- sacred site protection and heritage issues
- potential impact on the groundwater
- impact to roads through increased traffic
- hydraulic stimulation treatments
- well integrity
- economic benefits from increased activity, including local employment and training, funding, sponsorships and capacity building for local businesses
- local procurement of goods and services.

Intract at Work in Mereenie 2013

In undertaking our activities, Santos always seeks opportunities for inclusion of local engagement in employment and on-the-job training.

In our Northern Territory activities in 2013, opportunities were provided for Aboriginal employment and on-the-job training through:

- Intract Indigenous Contractors undertaking civil works for the Mereenie Appraisal Development Drilling project
- Terrex Seismic for Southern Amadeus Seismic Program
- Rusca Bros Services while undertaking McArthur Basin drilling activities in 2014.

1.4.2. Robust regulation

Santos supports robust science-based regulation of the petroleum industry. We endorse regulation that is best-practice and based on clear and effective objectives and transparent oversight. We support legislation that is effective in addressing problems, and efficient in maximising the benefits of that regulation, whilst taking a balanced approach recognising the significant economic and environmental benefits that the petroleum industry is delivering.

Santos is supportive of the Northern Territory Government as it continues to promote and implement reform to deliver regulation that is:

- appropriate to the nature and scale of the project
- underpinned by sound science and evidence
- objective-based, and does not impose unnecessarily prescriptive conditions
- supported by appropriate guidance
- considered in the context of all legislation, including at Commonwealth, state and local government levels to ensure that conflicting objectives are identified and minimised.

Drilling at Mount Kitty, Southern Amadeus Basin, NT

Where possible, Santos uses local companies to supply goods and services. The Mount Kitty earthworks were undertaken by a local earth moving contractor; Lyndavale Pty Ltd.

2. Background

2.1. The role of natural gas, now and in the future

Natural gas is the fuel of the future. It will play a critical role in Australia's transition from traditional fossil fuels such as coal to renewable energy sources. With vast natural gas resources, this fuel will grow Australia's economy, safeguard our energy security, and meet the energy demands of the growing Asian region.

2.1.1. Natural gas to reduce Australia's greenhouse gas emissions

The generation of electricity using natural gas will significantly reduce Australia's greenhouse gas emissions. When used in its own right to generate electricity, the energy produced from natural gas generates up to 70 per cent less greenhouse gas emissions than traditional coal-fired power generation.[5]

Natural gas is a facilitator for the development of renewable energy sources. It will have an important role as a transitional fuel. Gas fired power is not limited by weather conditions or the time of day. It can be brought online quickly, making it suitable for both base load and peak power generation. Natural gas can 'fill in the gaps' when used in conjunction with low emission energy sources such as wind and solar. The combination of natural gas and renewables can provide reliable energy supply while reducing Australia's greenhouse gas emissions.

As LNG, natural gas can cut emissions in overseas export markets. For every tonne of greenhouse gas emissions generated by LNG production in Australia, up to 4.3 tonnes are avoided in Asia when this gas is substituted for coal in electricity generation. An LNG project exporting 10 million tonnes of LNG per annum to China could avoid more than 32 million tonnes of global CO_2 emissions each year, and over a 30-year project life, such a project could avoid 968 million tonnes of CO_2, almost double Australia's total annual greenhouse gas emissions.[6]

2.2. Natural gas development in the Northern Territory

This section addresses Terms of Reference 1

The development of the Northern Territory's natural gas resources presents a wealth of opportunity for the Northern Territory and its people. At present, approximately 45% of the Northern Territory's total energy consumption is derived from natural gas.[7] Finding and developing additional supplies of natural gas will enable expansion of the domestic market and assist to build industry in the Northern Territory.

By expanding its LNG production capacity and by constructing pipelines to the Eastern states, the Northern Territory could make a substantial contribution to meeting the growing energy needs of the Eastern states of Australia and into Asia. The Northern Territory stands to reap significant economic benefits while securing jobs for the future by establishing new pipelines to hubs such as Moomba. These new pipelines could support the development of the Northern

[5] APPEA, 'Factsheet: Climate Change Policy Principles', Nov 2010, page 6.
[6] Worley Parsons, 'Greenhouse Gas Emissions Study of Australian CSG to LNG', Apr 2011, page 4.
[7] Australian Government Bureau of Resources and Energy Economics, *Energy in Australia,* May 2013, page 27.

Territory's gas resources on a far greater scale.

In addition to offshore gas operations, onshore gas fields will become an important source of natural gas for the Northern Territory. Development of this resource will benefit regional areas and the Northern Territory Government through increased royalties while ensuring the Northern Territory's enduring energy security.

2.3. Sources of natural gas and oil

Natural gas, oil and other hydrocarbons are found in sedimentary basins, in a number of geological settings and within various rock types. This submission uses the term 'hydrocarbon' to refer to both natural gas and oil.

The terms 'conventional' or 'unconventional' refer to the type of rock formation that the hydrocarbons are extracted from and the methods for their extraction. Hydrocarbons are found in both conventional and unconventional reservoirs in the Northern Territory.

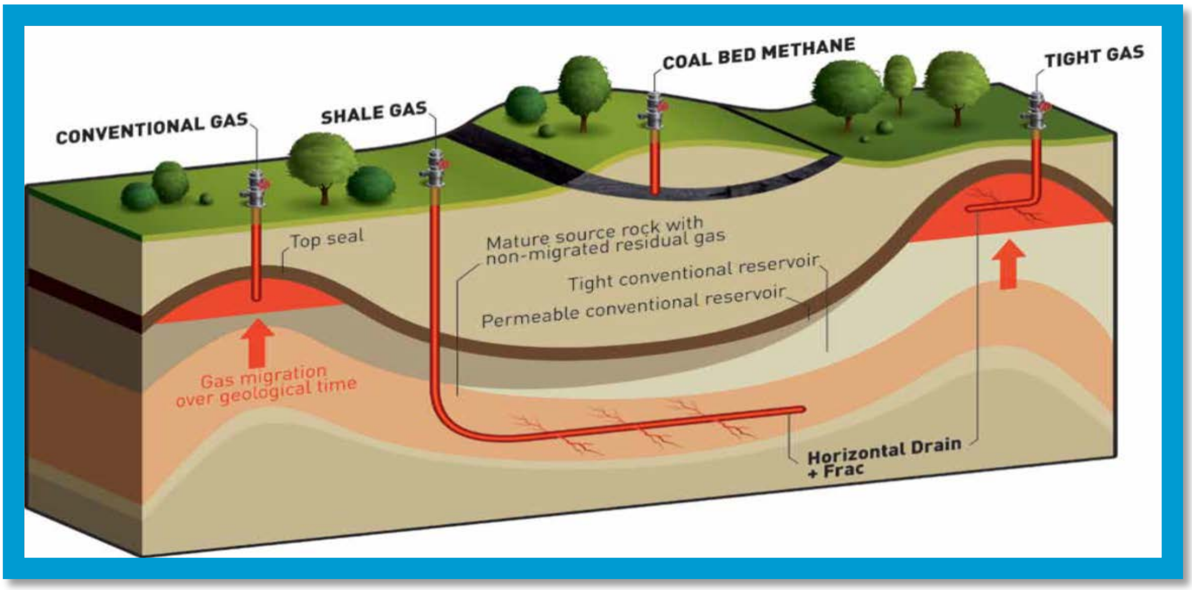

Figure 2: Conventional and unconventional gas reservoir settings

2.3.1. Hydrocarbons in conventional reservoirs

Conventional natural gas and oil is trapped in porous and permeable reservoir rocks, such as sandstones, and is caused by folding and/or faulting of sedimentary layers. These hydrocarbons are released into pores or spaces of the rock and when these spaces connect, the rock is termed as "permeable". Permeable rocks allow the migration of hydrocarbons to travel upwards towards lesser pressure and accumulate into a specific area into which a well can be drilled to extract the hydrocarbons (Figure 2). To date, most of the oil and gas that has been produced, globally and in Australia, has been conventional. The Amadeus Basin is an example of where conventional hydrocarbons are currently being extracted, however, the Basin also has the potential for hydrocarbons in unconventional reservoirs too.

2.3.2. Hydrocarbons in unconventional reservoirs

Hydrocarbons in unconventional reservoirs are found in locations that do not have as permeable geological characteristics. They require special extraction technology, such as hydraulic stimulation, to be recovered at economic rates.

2.3.2.1 Coal Seam Gas

Coal Seam Gas is natural gas that is extracted from coal. The gas is trapped in the natural fractures or “cleats” of the coal and is also absorbed into the organic matter within the coal matrix.

For the gas to flow, the coal seam needs to be de-pressured (to allow the gas to desorb) by dewatering the coal. Coal has differing degrees of permeability. For coal with low permeability, hydraulic stimulation may be used to increase the permeability of the coal to enable the gas to flow at an economic rate.

Coal seam gas is produced on an ongoing basis in many parts of the world and has been extracted in Queensland for the past 20 years. At this stage, there are no known coal seam gas resource prospects in the Northern Territory and Santos has no plans to explore for coal seam gas in the Northern Territory.

2.3.2.2 Tight oil and gas

Tight oil and gas are similar to hydrocarbons in conventional reservoirs in terms of their geological setting. The difference is that tight oil and gas is located in reservoir rock with a low permeability. This makes it more difficult to extract than hydrocarbons that are situated in conventional, higher permeability sands.

Extracting tight oil and gas often requires hydraulic stimulation to increase the permeability of the reservoir rock. Tight oil and gas has been produced in the Cooper Basin for over 30 years utilising hydraulic stimulation.

2.3.2.3 Shale

Shale oil and gas occurs in fine-grained, low permeability organic rich sediments usually in deeper parts of basins. The permeability of the rock must be enhanced in order to allow the oil or gas to flow from the rock at an economic rate. This is achieved through hydraulic stimulation and the use of horizontal wells. These are wells with long horizontal or lateral sections in the reservoir rock that provide greater contact with the reservoir rock.

Shale oil and gas resources are usually located between one to five kilometres below ground level. These resources are generally separated from near-surface freshwater aquifers by at least a kilometre of impermeable rock. The McArthur Basin is an example of where shale hydrocarbons are expected to be found in the Northern Territory.

3. Overview of oil and gas exploration, development and production

The oil and gas extraction industry can be classified into four major processes[8]:

- exploration surveying
- exploration drilling and appraisal
- development and production
- decommissioning and rehabilitation.

These processes are summarised below.

3.1. Exploration surveying

The first stage of petroleum exploration involves searching for hydrocarbon-bearing rock formations. Initial information can be obtained from reviewing geological maps and aerial photography. However, more detailed information must be obtained through field geological assessment followed by one of three main geophysical survey methods: gravitmetric, magnetic and seismic.

For the petroleum industry within the Northern Territory, seismic surveys are the most common methodology used to do this work. The process involves an energy source that creates sound (sonic) waves that travel into the earth and reflect off the various sub-surface geological features.

The 'reflections' are recorded by geophone receivers placed along the seismic line. The recorded information is processed and interpreted so that geoscientists can look for sub-surface structures that may hold oil and/or gas. A survey can take from a few weeks to several months. Once the geoscientists have identified sub-surface structures or 'targets' that may hold oil and or gas, the drilling team moves in to drill the wells.

3.2. Drilling

Once a 'target' has been identified, exploratory boreholes are required to confirm the presence of hydrocarbons and the thickness, internal pressure of a reservoir, and properties of the rocks and fluids contained within. The location of a borehole is determined by the sub-surface attributes of the underlying sub-surface geological formations. The protection of cultural heritage, consultation with landholders and the surrounding environment also informs the decision on where to drill.

There are three drilling phases:

- *Exploration Drilling:* an exploration well is the first well drilled in a field. Generally a well in the Northern Territory would be up to 4 kilometres deep. As the well is drilled, rock cuttings come to the surface and electric logs are taken and are assessed by geological specialists to ascertain the presence of oil or gas. If natural gas or oil is

[8] United Nations Environment Programme Industry and Environment Office, 'Environmental Management in Oil and Gas Exploration and Production', 1997, Part 1.

found this is known as a ‘discovery’.

- *Appraisal Drilling:* if natural gas or oil is discovered, further wells known as appraisal wells may be drilled to estimate the quantity and quality of the gas or oil to determine whether a discovery can be commercialised.
- *Development/Production Drilling:* if natural gas or oil discovery is confirmed to be in commercial quantities, approvals are sought for further wells are drilled to enable production.

3.3. Development and production

If sufficient quantities of hydrocarbons are found, and they can be economically and safely recovered, then, with relevant approvals in place, they can be produced, processed and then sold to customers. A producing natural gas or oil well has a wellhead on the surface that maintains control of the flow of substances from the sub-surface reservoir. The wellhead contains barriers, valves and seals. It allows the pressure of the well and the flow of fluids to be controlled at the surface. Producing wells also often have storage tanks for oil or water and separation equipment on location.

3.4. Decommissioning and rehabilitation

Once operations on a site cease and access is no longer required, the area is rehabilitated and can be returned to its original land use.

If natural gas or oil is not found, the well will be decommissioned and the borehole sealed using a series of cement plugs. The cement seal prevents any cross-flows between formations, as well as isolating all downhole zones from the surface. The wellhead and steel casing is cut off approximately 1.5 metres below surface level, capped with a metal identification plate and buried. All other surface equipment is removed.

For further details on decommissioning of wells and rehabilitation see sections 4.2.6 and 6.11.

3.5. Legislation

Santos supports robust regulation of the petroleum industry, supported by effective and pragmatic legislation and policy.

Santos believes that the current Northern Territory legislation establishes a sound and thorough framework to support the safe and sustainable conduct of petroleum activities. Santos is supportive of the Northern Territory Government as it continues to promote and implement contemporary and practical legislative and policy reform.

A brief summary of current key legislation governing petroleum activities onshore Northern Territory is provided below.

3.5.1. *Petroleum Act 2011 (NT) and Petroleum Regulations 1994 (NT)*

The *Petroleum Act 2011* (NT) (Act) and the *Petroleum Regulations 1994* (NT) (Regulations) form the legislation governing onshore petroleum exploration and production in the Northern Territory. The legislation provides a framework for the exploration and production of petroleum resources to ensure that activities are undertaken safely and sustainably and that optimum value of the resource can be returned to the Northern Territory.[9]

The Act and Regulations require all petroleum activities to be undertaken in compliance with set performance standards. Petroleum exploration and production and associated activities must be carried out pursuant to a licence (also known as a 'petroleum authorisation') granted under the Act.

With respect to hydraulic stimulation activities specifically, prior approval is required before any hydraulic stimulation is undertaken.

The Act and Regulations also require activity-specific environment plans to be agreed between the Department of Mines and Energy (DME) and licence holders as part of licence requirements to undertake activities associated with exploration for and production of petroleum resources.

For example, operations at the Mereenie Field (Licences OL4 and OL5) are governed by the *Environmental Management Plan – Mereenie.* The activity-specific environment plan provides project-specific information and details environmental risks for hydraulic stimulation, completion, workover and recompletion activities proposed to be undertaken. In accordance with Section 8.1 of that plan, Santos must provide the DME with an activity specific environment plan for new project proposals if the plan does not cover the particular hazards that could arise from the proposed activity.

3.5.2. *Environmental Assessment Act 1982 (NT)*

The environmental impact assessment process in the Northern Territory begins when a proponent applies for approval of a 'proposed action' under Northern Territory legislation. The Minister responsible for administering that legislation may refer the proposed action to the Northern Territory Environment Protection Authority to determine whether or not environmental assessment is required. Under the *Environmental Assessment Act 1982*, an environmental impact assessment will be required for proposed actions that are capable of having a 'significant effect' on the environment.

3.5.3. *Native Title Act 1993 (Cth)*

The *Native Title Act 1993* (Cth) is Commonwealth legislation that recognises native title in lands over which native title is not extinguished. The Act requires proponents seeking to undertake activities on lands that are, or may be subject to, native title rights, to undertake processes to negotiate and agree terms of consent to undertake proposed activities on that land. With respect to the exploration for and production of natural gas or oil, these processes most commonly take the form of a Right to Negotiate process or negotiation for an Indigenous

[9] Section 3, *Petroleum Act 2011* (NT)

Land Use Agreement.

3.5.4. *Aboriginal Land Rights (Northern Territory) Act 1976 (Cth)*

The *Aboriginal Land Act 1976* establishes a framework for the recognition of aboriginal land ownership based on traditional occupation. Under that Act, traditional Aboriginal owners have the right to refuse access to Aboriginal land and the right to refuse consent to petroleum activities on their land. A petroleum permit cannot be granted unless the traditional Aboriginal owners consent under the process set out in that Act.

3.5.5. *Northern Territory Aboriginal Sacred Sites Act 2004 (NT)*

The *Aboriginal Sacred Sites Act 2004* (NT) is administered by the Aboriginal Areas Protection Authority (AAPA). The Act provides for the location, recognition, description and protection of sites sacred under Aboriginal tradition. All sacred sites (even if not registered) are protected under the Act. Section 69 of the Act provides that a person shall not enter and remain on land in the NT that is a sacred site. Santos engages with Land Councils and AAPA to give us the required approval and information and, wherever possible Santos seeks to secure both an AAPA Sacred Site Certificate (SSC) and a SSC from the relevant Land Council.

3.5.6. *National Environment Protection Council (Northern Territory) Act 1994 (NT)*

The *National Environment Protection Council (Northern Territory) Act 1994* establishes the National Environmental Protection Council to set national environmental goals and standards for Australia through the development of National Environment Protection Measures (NEPM). Section 14(1) of the National Environment Protection Council Act prescribes that NEPM may relate to any one or more of the following:

- Ambient air quality.
- Ambient marine, estuarine and fresh water quality.
- The protection of amenity in relation to noise.
- General guidelines for the assessment of site contamination.
- Environmental impacts associated with hazardous wastes.
- The re-use and recycling of used materials.

Santos has developed mitigation and management measures in accordance with these NEPM.

3.5.7. *Other Legislation*

Other legislative instruments relevant for activities relating to the exploration for and production of petroleum resources in the Northern Territory include:

- *Petroleum (Prospecting and Mining) Act 1954* (NT) *and Petroleum (Prospecting and Mining) Regulations 2001* (NT) – legislation pre-dating the current Petroleum Act and Regulations relevant for leases granted prior to 1984.
- *Schedule of Onshore Petroleum Exploration and Production Requirements 2012* (NT) – includes safety, reporting and operational requirements applicable to drilling and workover operations, including hydraulic stimulation.
- *Environment Protection and Biodiversity Conservation Act 1999* (Cth) – this

Commonwealth Act establishes a framework for environmental assessment of actions that have or are likely to have a significant impact on a matter of national environmental significance. Where an action will have or is likely to have such an impact, the person proposing to undertake the action must submit a referral to the Commonwealth Minister for the Environment. An 'action' includes 'any project, development, undertaking or any activity or series of activities'. A bilateral agreement is in place between the Commonwealth and the Northern Territory enables the Northern Territory Government to assess whether or not a matter of national environmental significance will be or is likely to be significantly impacted.

- *Heritage Act 2011* (NT) – this Act enables members of the community to nominate areas, places, sites, buildings, shipwrecks and heritage objects, including Aboriginal objects and places, for inclusion in the heritage register. If the Minister agrees that these features are of special significance to the heritage of the Northern Territory, the place is added to the Northern Territory Heritage Register. The place will then be protected from accidental and deliberate damage or harm.
- *Waste Management and Pollution Control Act 2009* (NT) – the purpose of this Act is to protect the environment through objectives and approvals, encouraging effective and responsible waste management and reduction and response to pollution. The Act establishes a process for notifying the NT EPA about incidents causing, or threatening to cause pollution. Schedule 2 of the Act requires environment protection / licensing for certain activities. Santos currently has no activities that require licensing as all waste is transferred offsite to NT EPA licensed facilities.
- *Territory Parks and Wildlife Conservation Act 2006* (NT).
- *Soil Conservation and Land Utilisation Act 1980* (NT).
- *Weeds Management Act 2001* (NT).
- *Dangerous Goods Act 1998* (NT).
- *Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Act 2011* (NT).
- *Traffic Act 2012* (NT).
- *Work Health and Safety Act 2011* (NT) and *Work Health and Safety Regulations 2011* (NT).
- *National Greenhouse and Energy Reporting Act 2007* (Cth).
- *Clean Energy Act 2011* (Cth).

3.6. Industry Codes of Practice and the Santos EHSMS

Santos follows the following Industry Codes of Practice to undertake hydraulic stimulation:

- Australian Petroleum Production and Exploration Association (APPEA) Code of Environmental Practice (2008).
- APPEA Code of Practice for Hydraulic Fracturing.
- American Petroleum Institute including various standards and recommended practices for hydraulic fracturing.

Furthermore, Santos supports the Golden Rule Principles[10] established by the International Energy Agency to address environmental and social impacts, which are:

1. Measure, disclose and engage.
2. Watch where you drill.
3. Isolate well and prevent leaks.
4. Treat water responsibly.
5. Eliminate venting, minimise flaring and other emissions.
6. Be ready to think big.
7. Ensure a consistently high level of environmental performance.

The Santos Environment, Health and Safety Management System (EHSMS) has been developed by Santos to provide a company-wide approach to effectively manage Environment, Health and Safety (EHS) risks and to allow for continual EHS improvement.

It provides structured, comprehensive and efficient EHS practices for Santos' activities and operations and is compliant with both Australian Standard 4801:2000 Occupational Health and Safety Management Systems – Specification with Guidance for Use and AS/NZS ISO 14001:2004 Environmental Management Systems – Specification with Guidance for Use.

Further detail on Santos' robust EHSMS is provided in Appendix 2**.**

3.7. What is hydraulic stimulation?

Hydraulic stimulation is a process used in circumstances where hydrocarbons are tightly held in low permeability reservoir sands, coals and shales, to enhance the permeability of the formation and to enable the hydrocarbons to flow at economic rates. When used, its advantage is that it substantially enhances the productivity of a well and, as a result, reduces the number of wells that would otherwise be required to produce these resources.

Hydraulic stimulation is a process that has been used in the oil and gas industry since 1947. The Society of Petroleum Engineers estimates that over 2.5 million hydraulic stimulation treatments have been undertaken in oil and gas wells worldwide, with over 1 million in the United States. Hydraulic stimulation has been successfully used on wells in the Cooper Basin for nearly 40 years and in Mereenie for over 30 years without incident. Hydraulic stimulation is currently performed in many basins around Australia.

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[10] International Energy Agency, 'Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas', November 2012

3.8. Hydraulic stimulation in the Northern Territory

This section addresses Terms of Reference 1 and 2.

At the time of early development of the Mereenie Field, reservoirs of this quality had typically not been considered for hydraulic stimulation. Due to very limited production arising from the field, an attempt to overcome this was made through seven hydraulic stimulation treatments performed between 1983 and 1987 with limited commercial success. However, improved hydraulic stimulation treatments during late-1991 to mid-1992 resulted in significant improvements in both short- and long-term post-stimulation performance and opened up the Mereenie Field for further development.

Table 1 sets out the number of wells now operated by Santos that have been hydraulically stimulated in the Amadeus Basin in the Northern Territory.

Table 1: Wells that have been hydraulically fractured in the Northern Territory

Well Name	Year	Well Name	Year
EM 3	Jan-90	**EM 34**	Sep-93
EM 15	Nov-90	**EM 32**	Oct-93
WM 6	Jul-91	**WM 8**	Nov-93
EM 29	Aug-91	**EM 35**	Nov-94
EM 28	Dec-91	**EM 37**	Jul-95
EM 16	Jan-92	**EM 36**	Jul-95
EM 19	Jan-92	**EM 38 (P4)**	Oct-95
EM 11	Mar-92	**EM 38 (Upper)**	Nov-95
EM21	Mar-92	**EM 39**	Jun-96
WM 5	Jul-92	**EM 40**	Sep-96
EM 7	Jul-92	**EM 41**	Sep-96
EM 14	Oct-92	**EM42**	Sep-96
EM 20	Oct-92	**EM 13**	Aug-97
EM 30	Oct-92	**EM 42**	Oct-97
EM 6	Nov-92	**WM 12**	Nov-97
EM 22	Nov-92	**WM6**	Feb-06
EM 31	Jan-93	**WM3**	Feb-06
EM 17	Jun-93	**WM23**	Mar-14
WM 7	Jun-93	**WM20**	Mar-14
WM 4	Sep-93	**WM24**	Apr-14
EM33	Sep-93	**EM35**	Jun-14

Santos also has obtained relevant approvals and consents for the hydraulic stimulation of the following wells in Mereenie field in 2014:

- East Mereenie 12
- East Mereenie 26
- West Mereenie 8
- West Mereenie 19.

Santos has tentative plans to hydraulically stimulate the exploration well Tanumbirini 1 which is being drilled at the time of this submission. Hydraulic stimulation treatment of this well is planned for 2015 and will only be performed after thorough planning and review and approval by the appropriate bodies and stakeholders such as DME, Aboriginal Traditional Owners and relevant landholders.

Further wells in the appraisal and development of the oil reservoirs in Mereenie will also use this technology and are being considered for 2015 and beyond.

4. Well design and best practice

This section addresses Term of References 2, 5, and 7(b)

The design, location and quality of well construction is of paramount importance in mitigating any risks associated with hydraulic stimulation. Santos applies best practice in its drilling techniques and related activities.

Prior to drilling a well, Santos must obtain a permit or licence over a particular parcel of land which is subject to the provisions of the *Petroleum Act 2011* (NT). Once a grant of tenure is provided, a Petroleum Project Approval must be sought in accordance with the Act and '*The Schedule of Onshore Petroleum Exploration and Production Requirements 2012*' (the Schedule). The Act, the Schedule and the Petroleum Project Approval can also influence the design, location and quality of well construction. For example, the Schedule requires a licensee to address and submit to DME the well design, construction, standards, control and operational safety and well integrity ratings for assessment and approval.

Well design starts with having a thorough understanding of surface and sub-surface formations and issues, which include:

- Undertaking geologic studies to determine locations of all groundwater and aquifers that require isolation.
- Reviewing surface receptors such as proximity to infrastructure (e.g. roads, fencing, etc.), the surface terrain, potential sensitive receptors like houses, watercourses/creeks, etc.
- Ensuring a well location is not near any sub-surface faults.

This initial assessment phase helps determine well location, well casing points and cementing objectives as part of the overall well design.

Geological assessment is undertaken to understand the nature of the geology and consider factors such thickness of formations, location of aquifers and the permeability of the formations. A stratigraphic cross-section of the western Amadeus Basin is shown in Figure 3. It displays the typical depth from surface in the Mereenie oil and gas field wells and is based on the East Mereenie 17 well.

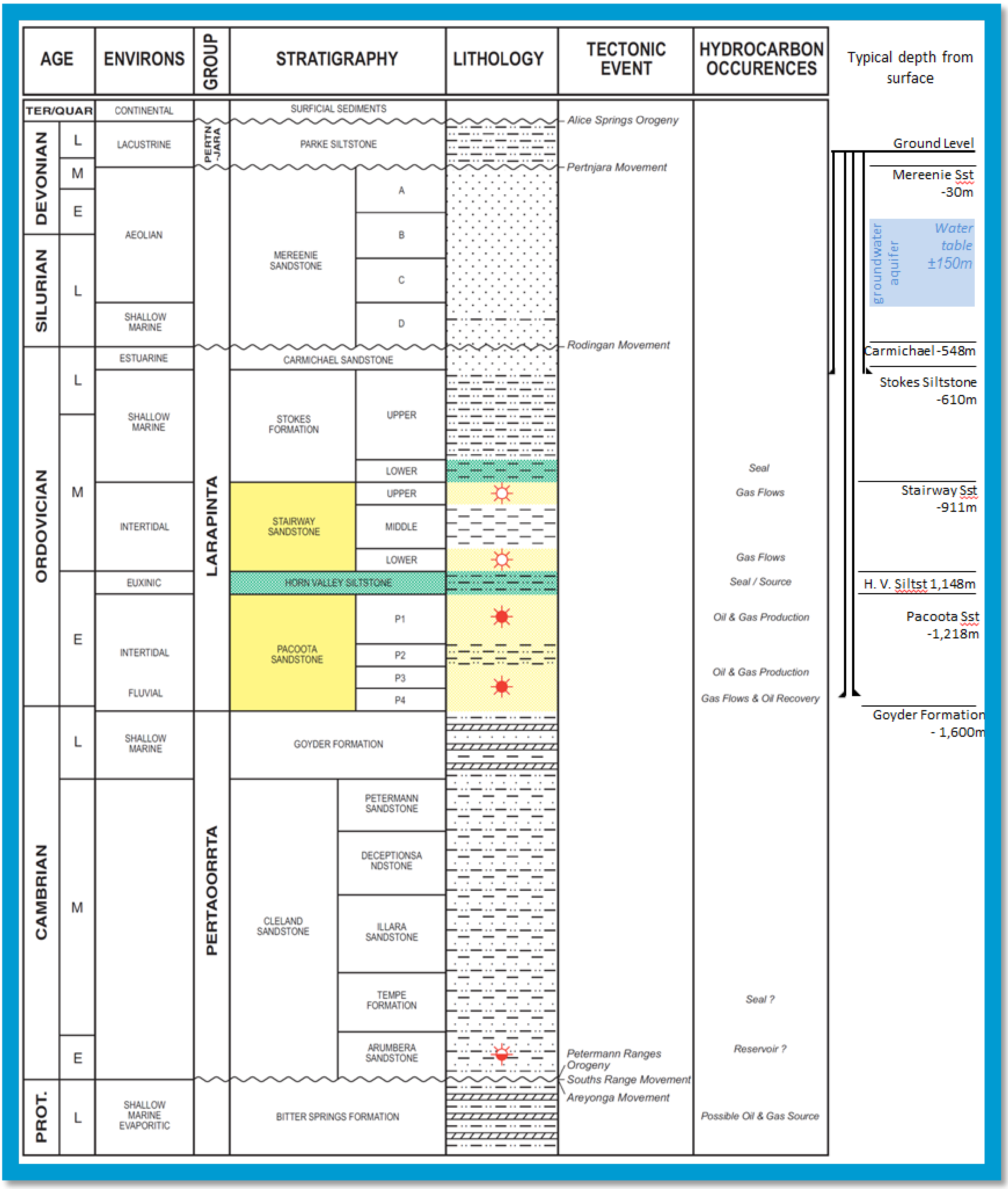

Figure 3: Stratigraphy of the western Amadeus Basin used to assess geological conditions

4.1. Comparison to international best practice

The oil and gas industry uses experienced drilling and hydraulic stimulation contractors. These contractors, along with operating companies, have developed and defined industry best practice in the field of drilling and hydraulic stimulation in over 60 years of experience and technological innovation. International experiences and practices are communicated and shared via academic training, professional and trade associations, extensive literature and documents and, importantly, industry standards and recommended practices. These practices have been adapted for applicable operations in Australia.

The industry best practice guidelines, arising from this body of knowledge, experience and leading-edge research, are distilled in a series of guiding documents published by the API. Santos operates in accordance with API documents representing international best practice.

Santos uses rigorous pre-qualification criteria, including technical and operational competency requirements, in the selection of contractors for all field operations, including hydraulic stimulation and well construction operations.

The key international best practice guidance documents relevant to operations in the oil and gas fields of the Northern Territory include those in Appendix 3.

4.2. Well mechanical integrity and integrity testing

4.2.1. Choosing where to drill and establishing a well site

This section addresses Terms of Reference 6 and 7(a)

The decision of when and where to drill and whether the application of hydraulic stimulation is warranted depends on a range of factors including:

- Surface related issues such as:
  - local population and populated areas
  - surface infrastructure already present including roads, dams, pipelines etc.
  - natural environment and local ecology
  - availability of water
  - ability to handle and dispose of wastes generated appropriately.
- Sub-surface issues such as:
  - the location of faults and aquifers
  - location of groundwater systems
  - the depth and permeability of the formation in which the hydrocarbons are present.

Sensitivity to these factors at the development stage can minimise the impact of the activity on current and future land use.

The first stage of developing any hydrocarbon well is to prepare the site. Santos engages in discussions with the key stakeholders of the land before a site is located to ensure the concerns/activities of these stakeholders are considered. Site construction typically involves creating a levelled site to provide a suitable working platform for drilling and well operations. In addition, small pits with impervious liners are used to store source water. Pits to contain produced fluids are excavated and lined. Access roads for the transportation of equipment and materials to and from the site may be established if necessary. Other associated infrastructure may include temporary and/or permanent camps, water supply bores, borrow pits and processing facilities.

4.2.2. *Drilling and well construction*

Well drilling is the process of drilling a hole in the ground for the purpose of extracting hydrocarbons. Santos uses proven drilling techniques, and our 60 years of experience in well drilling ensures our ability to implement these techniques effectively.

Well designs are prepared by engineers, and are based on the Santos Drilling and Completions Management System (DCMS) and standards. The DCMS reflects our many years of drilling experience. In addition, Santos complies, as a minimum, with best practice American Petroleum Institute (API) standards of well construction.

Drilling can take several days or many weeks, depending on the geology, depth of the well, and whether the well is vertical or directional. Well construction, drilling and well completions typically consist of activities including:

- building the well pad
- setting up the drilling rig
- drilling the hole to required depth
- running formation evaluation tools (logs) to determine what types of rocks have been penetrated and what fluids are contained within them
- open hole flow testing, where appropriate
- for appraisal or development wells, running the steel casing to line the wellbore
- cementing the casing in place
- moving the drill rig off the hole
- logging the casing to ensure bonding of cement to the formation and casing and the top of the cement relative to formation depths
- perforating the casing
- stimulating the well if required
- installing production tubing and surface equipment
- production of oil or gas from the well
- monitoring well performance and well integrity
- reclaiming/rehabilitating parts of the well pad no longer used (i.e. reducing the well pad size).

The processes used for drilling hydrocarbon wells are significantly more stringent than those that apply to domestic and irrigation bores. Santos' wells are:

- constructed to deliver hydrocarbons
- constructed to appropriately manage the risk to people, the environment and property
- designed to isolate water and hydrocarbon formations, contain drilling fluids and support pressure containment equipment
- monitored and pressure tested in-situ.

4.2.3. Casing and cementing

This section addresses Terms of Reference 7(c)

As the well hole is drilled, multiple layers of steel casing are inserted and cemented into place providing a barrier between the contents of the well and the surrounding rock (Figure 4). Specially engineered cement is pumped down the inside of the casing and back up between the wall of the drill hole and the casing exterior, fixing it in place and sealing the gap. The composition, volume and placement of cement are fundamental considerations for well integrity. The pumping process is undertaken to ensure that cement binds tightly to both the steel casing and the rock, leaving no cavities through which liquids and gases could travel. The cement serves two purposes: it provides protection and structural support to the casing, while also providing zonal isolation between different formations, including groundwater bearing formations. Pressure testing is carried out at each casing stage to ensure the long-term integrity of the cement.

Santos uses multiple casing string designs.[11] Casing must retain its integrity throughout the life of the well and withstand the forces it will be subject to from natural formation pressure, as well as those from well completion, hydraulic stimulation and production operations. Wells may have from 2 to 5 casing strings that extend between different depths depending on individual well design requirements and conditions encountered.

Detailed assessment of the sub-surface formations is undertaken including the location and quality of aquifers. The assessment is used to determine appropriate casing depths to ensure isolation and protection of aquifers, and ensure the well is able to be drilled safely and efficiently to the hydrocarbon bearing zones.

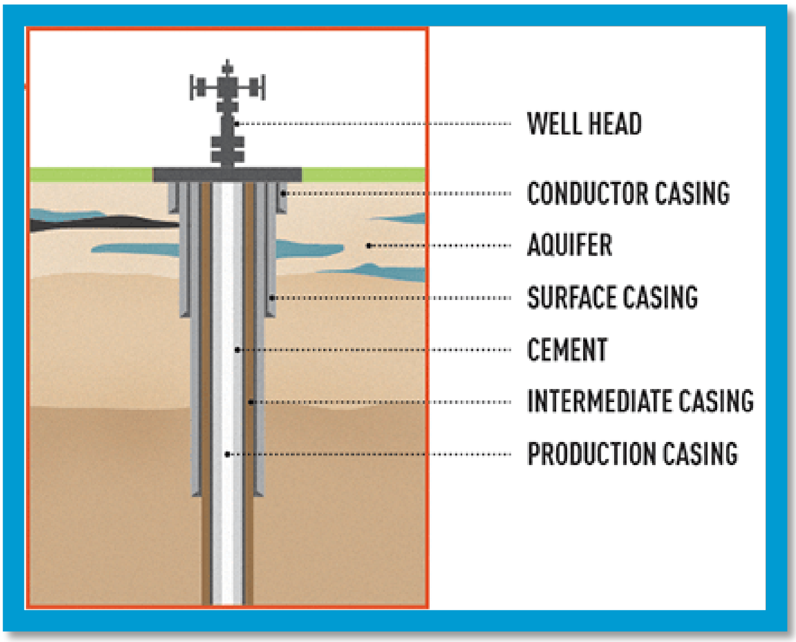

Figure 4: Diagram of a well

[11] A casing string is a succession of large diameter steel rods that are screwed together, which is run into a core hole or well and cemented in place.

4.2.4. Well integrity

This section addresses Terms of Reference 3

Wells must be constructed in a manner that ensures their robustness and longevity in order to protect groundwater. The well is required to isolate production fluids from groundwater bearing formations during its construction, working life and beyond, even after it has been formally decommissioned. It is this robustness of construction that permits the well to maintain its integrity. Well integrity is essential for two reasons:

1. To isolate the internal conduit of the well from the surface and sub-surface environment. This prevents the migration of fluids between sub-surface layers and is critical for protecting groundwater, and the surface and sub-surface environment.
2. To isolate and contain the well's produced fluid (i.e. the hydrocarbons) to a production well casing pipe within the well.

Throughout the well construction process, stringent quality control and testing is undertaken to ensure the integrity of the casing and seals. These quality control procedures are also implemented through the material selection and sourcing process and installation.

Groundwater is protected from the contents of the well during drilling, hydraulic stimulation, and production operations by a combination of drilling fluids used in the process, steel casing and cement sheaths, and other mechanical isolation devices installed as a part of the well construction process. Well design and construction seeks to construct the well to be stronger than the impermeable rock formations that lie between the petroleum-bearing formations and the groundwater which have effectively isolated the groundwater over millions of years.

The main method for protecting groundwater during drilling operations consists of drilling the well borehole through the groundwater bearing formations and then cementing this steel casing into place using specialised engineered cement types, prior to advancing into deeper petroleum units. The casing and cement is specifically selected to accommodate a number of factors including formation types, groundwater quality, gas characteristics and operational conditions. The steel casing protects the zones from material inside the wellbore during subsequent drilling operations. In combination with other steel casing and cement 'sheaths' that are subsequently installed, the casing protects the groundwater with multiple layers of protection for the life of the well.

To ensure long term casing integrity, Santos has developed detailed specifications for all well casings and well completion materials. These materials have been specifically designed and selected for the proposed application and lifecycle of the well. Completed Santos wells have API certified wellheads installed and have been pressure tested, with results provided to regulatory bodies such as the Department of Mines and Energy.

Regular monitoring takes place during drilling and production operations to ensure that these operations proceed within established parameters and in accordance with the well design, well plan, and regulatory requirements. Santos has in place management systems for all of its wells. These systems establish, based upon risk assessment, the frequency of the required well integrity testing. Wells that are either cased and suspended or are on production are monitored regularly, which includes visual checks, casing annulus pressure readings and individual well risk rating assessments. More monitoring details are outlined in section 4.2.5.

A review of data sets of over 600,000 wells worldwide found the overall risk of groundwater pollution from a producing well is extremely low for most quality operations. Leak numbers that could be justifiably allocated to oil, gas or injection wells indicate an overall percent of leaking wells in the range of 0.03% to 0.005% of wells in service.[12]

4.2.5. Well safety

Santos has stringent safety standards and practices in place at every level of its operations that, as a minimum meet, regulatory requirements and industry standards. Santos identifies and mitigates safety and environmental risks through ongoing monitoring and maintenance of equipment and hydrocarbon wells. Santos routinely monitors oil and gas fields by conducting on-site operator inspections. Electronically collected data that checks the integrity of our facilities is closely scrutinised to ensure ongoing integrity. Monitoring continues throughout the life of the well.

Santos manages well safety in accordance with a series of safety management standards and regulatory approvals to ensure safe operation. This ensures standards are enforced for:

- design, construction, commissioning, operations, maintenance and decommissioning
- environment, health and safety
- ignition control
- structural and mechanical integrity
- training and competency
- emergency preparedness
- incident and non-conformance investigation, corrective and preventative action.

Santos carefully assesses and thoroughly understands the condition of each well. Risk factors are understood and are appropriately managed through comprehensive planning and testing regimes, including pressure and integrity testing.

Production variables at wellhead facilities such as pressure, temperature and flow rate are monitored. Deviations outside the normal operating envelope result in a physical inspection of the well. In the unlikely event of a loss of containment of hydrocarbons from wellhead facilities and equipment, the well is shut in to repair the leak. As wellbores are constructed with multiple layers of protective pipe and cement, were a failure to occur within a hydrocarbon-bearing section, it would not result in a leak to groundwater but would be contained in the next steel pipe annulus. With frequent surveillance, this is picked up and addressed quickly minimising the potential for hydrocarbons to leak outside of the wellbore to the surrounding formations

Santos has emergency response and well control plans in place at every site for all aspects of operations, including well management. These detailed plans outline actions, roles and responsibilities for emergency response to help ensure the safety of people and the protection

[12] King, G. & King, D. 'Environmental Risk Arising from Well Construction Failure: Difference Between Barrier and Well Failure, and estimate of Failure Frequency Across Common Well Types, Locations and Well Age'. SPE 166142 *Society of Petroleum Engineers*, 2013.

of the environment and property. Well sites and production/processing facilities are secured and hazards are clearly signed.

4.2.6. Decommissioning and restoration of wells

When a well reaches the end of its productive life, it must be shut down and decommissioned and the surface location restored. A final well survey is undertaken once production activities at the well site have been completed.

Following depletion, the well is shut down, decommissioned and restored in accordance with Santos policies and procedures and all regulatory requirements. This decommissioning and rehabilitation work involves removing equipment from the well, draining the well sumps, filling and compacting the sump, and plugging the well with a number of cement plugs. High quality materials, including corrosion inhibitors, are used to permanently plug and isolate the hydrocarbon zone from the aquifer. The placement and verification of the integrity of these plugs is a critical step to ensure that any remaining hydrocarbons cannot leak into overlying formations and cause contamination.

After plugging, the wellbore is hydrologically tested to confirm integrity and the topsoil is replaced to a depth of approximately two metres. Best industry practice is used to ensure that the cement is of suitable composition with the result that the previously drilled well is permanently sealed by a combination of the remaining steel (that previously cased the well bore) and the final cement seal. Various methods of testing are used to ensure wellbore and cement integrity, including pressure testing, mechanical testing and obtaining downhole log data.

The combination of cement and steel ensures all geologic layers are hydraulically isolated from one another resulting in there being no material difference in the risk of a threat of leakage or cross contamination than exists in the surrounding undisturbed area. As the cement plugs are placed and tested to ensure that no fluid flow is possible both within and around the outside of the well and the cement and casing is not in contact with air, the well essentially becomes part of the rock and will afford protection in perpetuity.

Once the sub-surface plugs are in place and their integrity verified the casing and cement is cut off below the surface and removed so that land can be returned to other uses. Gravel hardstand is removed from the site and any remaining foreign objects such as equipment, buildings, tanks and other infrastructure are disassembled and removed.

4.3. The use of single or multiple well pads

This section addresses Terms of Reference 4 and 7(j)

A multiple well pad is a single pad from which several wells are directionally drilled. While the size of the pad required for multiple wells is slightly larger than required for a single well, the number of pads required is reduced and therefore the total area required is less. This substantially reduces the environmental footprint of activities and increases the efficiency of well construction. Using multiple well pads reduces land disturbance by over 50% compared to single wells. In the Cooper Basin, multiple well pad development has resulted in up to 55% reduction in surface disturbance compared to individual single well pads.

Multiple well pads also reduce the number of drill rig mobilisations, which reduces the requirement for access track construction and use, as well as emissions associated with mobilisation.

Horizontal or high angle well completions increase the surface area of the hydrocarbon bearing rock that is exposed to the well, increasing the hydrocarbon flow rate and volume recovered per wellbore. The US Department of Energy reports that just six to eight horizontal wells from one surface location can access the same or greater shale reservoir volume as more than 16 conventional vertical wells that each require their own well pad, roads and pipeline.[13]

Santos uses multiple well pads wherever practical and is experienced in using multi-well operations across other jurisdictions in Australia. Multiple well pads are only used during the appraisal and development phase where closely spaced wells are employed to extract the sub-surface hydrocarbons. They are not used during exploration activities.

Currently, multiple well pads are not used in the Northern Territory because shale is still at the exploration stage and the Mereenie field development plans do not foresee the need for closely spaced wells that can be drilled from a single well pad. Santos has the environmental vision of continually lightening our footprint and as such will continually assess the use of multi well pad technology to reduce the surface disturbance in our operations. If exploration for shale hydrocarbons is successful the application of multi-well pad technology will be used to reduce the environmental footprint and any proposed development project.

[13] See the International Gas Union, 'Shale Gas: The facts about the Environmental Concerns', June 2012.

5. Overview of hydraulic stimulation

5.1. Purpose of hydraulic stimulation

Hydraulic stimulation is employed in the petroleum industry to improve the production efficiency of many gas and oil producing wells. This is achieved by creating an area of increased conductivity or flow path within the reservoir. This increased reservoir contact, through a highly permeable fracture, creates an efficient pathway for the flow of gas and oil. In the majority of cases, the low permeability nature of the hydrocarbon bearing reservoirs are too tight to produce from at economic rates. Without this increased flow potential, many of the wells across Northern Territory may not sustain economic flow rates.

Hydraulic stimulation is not an explosive or high impact process. It is not part of the drilling process, but is a completion technique applied after the well is drilled and the drill rig has moved to another well. It is a process that, through the application of hydraulic pressure, results in the creation of fractures in the rock to allow the oil and gas in the rock to move more freely into the wellbore and enable economic production of them. It involves pumping water and a specific blend of chemicals to carry proppants such as sand or ceramic beads down a well at sufficient pressure to create fractures in the low-permeability rock. The proppant material keeps the fractures propped open against earth stresses once the pump pressure is released and serves to improve the production of the well.

Santos has decades of experience using this technology in both the Amadeus Basin at Mereenie and in the Cooper Basin, with the first hydraulic stimulation treatment in 1969.

The design and quality of the well construction is of paramount importance in managing, and avoiding, any potential environmental risks associated with hydraulic stimulation. Santos applies best practice in our drilling techniques and activities.

Production wells may be subject to multiple fracturing events during the completion process. In order to produce from the reservoirs intersected by a well, Santos uses methods to selectively isolate and individually fracture each hydrocarbon-bearing zone. As a result, a typical gas well will have more than one hydraulic stimulation treatment. The current average number of treatments is approximately six treatments per well. However, the number of treatments does depend on the type of well design and geological factors. For example, horizontal wells may have up to 30 treatments per well, whilst vertical exploration wells typically require only have three to five treatments.

5.2. Hydraulic stimulation design considerations

This section addresses Term of Reference 4

As detailed in the Well Design section, drilling, open-hole and cased hole logging of the reservoir section provides information required in the hydraulic stimulation design process. Data is acquired providing information on reservoir parameters, as well as lithology variations and stress contrast from layer to layer. This data is processed using a commercially available stimulation software to develop an optimal well design.

The basis of well specific design is to produce hydrocarbon from the reservoirs through an optimal number of hydraulic stimulation stages, fracture length, fracture conductivity, and fracture height within the targeted reservoir formation. A number of considerations influence the final design for each hydraulic stimulation design including the:

- depth and thickness of the target zone
- lithology of target and bounding layers
- minimum horizontal stress across all layers
- thickness of the 'seals' above and below the target reservoir formation
- porosity and permeability
- pore fluid saturations (percentage of pore volume occupied by each fluid, for example oil, gas or water)
- pore fluid properties (e.g. density, water salinity)
- well performance data, including flow rates, formation pressure and produced fluid properties
- formation boundaries (as identified from seismic data)
- bulk density, elastic properties and compressibility
- bedding planes, jointing and mineralisation
- natural fracture networks
- thickness of underlying formations and rock strength
- stress field analysis to determine the maximum principle stress direction and the minimum principle stress direction.

The completion design process accommodates detailed analysis of these parameters to specify a hydraulic stimulation design that is contained within the target formation. The hydraulic stimulation design models can model the fracture geometry; including fracture length and fracture height based on the geomechanical properties of the rock.

5.3. The hydraulic stimulation process

Hydraulic stimulation uses specially designed fluids, primarily consisting of water and sand or ceramic proppant, mixed on the surface. The fluids are injected into the well and through the perforations into the reservoir formation to create the fracture. An example of a wellhead used to inject into and control the well, during fracturing operations, is illustrated in Figure 5.

As detailed in Section 5.1, the hydraulic stimulation process occurs under high hydraulic pressures in order to physically fracture the reservoir rock. The hydraulic stimulation fluids are injected through perforations (10 to 20 mm diameter holes created with jet perforating) in the well casing pipe. The hydraulic stimulation fluids are injected from the surface via the wellhead or "frac tree". A simplified schematic of the created facture geometry is provided at Figure 6.

A fracture created in deep reservoirs, similar to the Amadeus Basin, will propagate laterally from the well in a vertical plane, based on the in-situ stresses. Common dimensional terminology for hydraulic fractures includes fracture half length (xf) and fracture height (hf) and propped width (wf).

Typical dimensions[14] for these are:

- x_f from 100 m to 250 m
- h_f from 30 m to 200 m
- w_f from 3 to 10 mm.

These are dependent on the geomechanic properties of the formation and the planned drainage dimensions of the well.

The hydraulic stimulation places a highly conductive channel into the reservoir to increase the flow capacity. Typically used in low permeability reservoirs that cannot sustain economic production, it is analogous to increasing the effective wellbore radius. This increase in flow area will increase the production rates and, in most cases, can access additional reserves. A number of steps make up the hydraulic stimulation process:

1. Perforate the interval to be hydraulically stimulated. The perforations are through jet perforating or abrasive jetting with coiled tubing and sand to jet holes through the casing and cement.
2. Pre-stimulation injection test to validate and update the design; includes shut-down and decline to evaluate near wellbore entry friction, fracture gradient, fluid leakoff, and minimum horizontal stress. This stage is not always included.
3. Main stimulation treatment; consisting of pad volume, slurry stages with increasing proppant concentrations, and flush stage to displace the last slurry stage to the perforations. On occasion a pre-pad stage including weak hydrochloric acid is pumped to assist with remediating near wellbore entry friction may be pumped ahead of the pad stage.
4. Mechanically isolate the fracture stage, if part of a multi-stage well completion.
5. Perforate the next stage to be stimulated and repeat the process in stages 2 to 4 above until final stage is completed.
6. Remove all mechanical isolation devices.
7. Flowback well to clean up injected fluids and monitor hydrocarbon production.

[14] Economides, M.J., and Martin, T., *Modern Fracturing, Enhancing Natural Gas production. Energy Tribune Publishing Inc.*, 2007

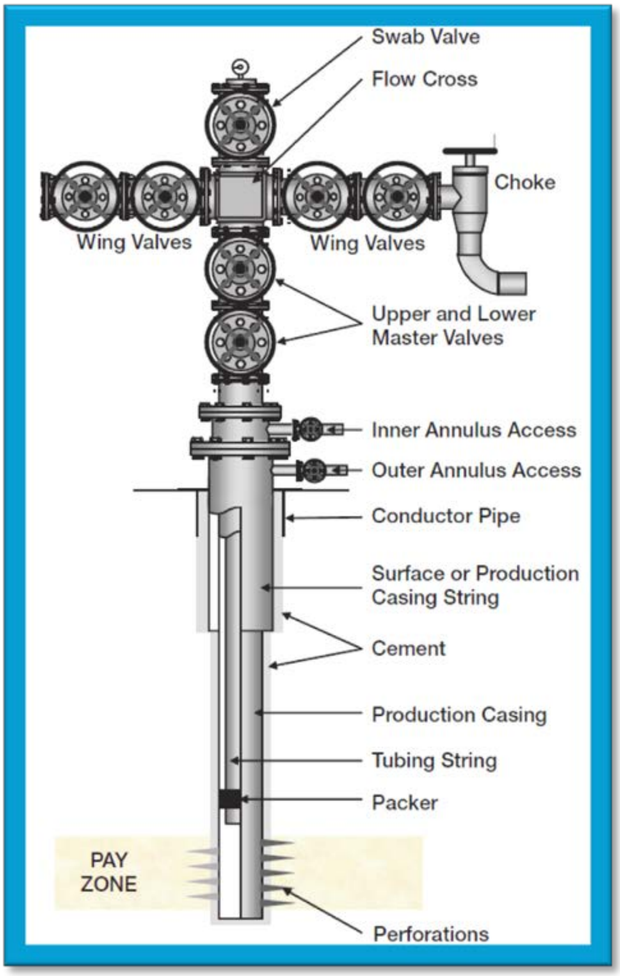

Figure 5: Hydraulic stimulation wellhead fixture example[15]

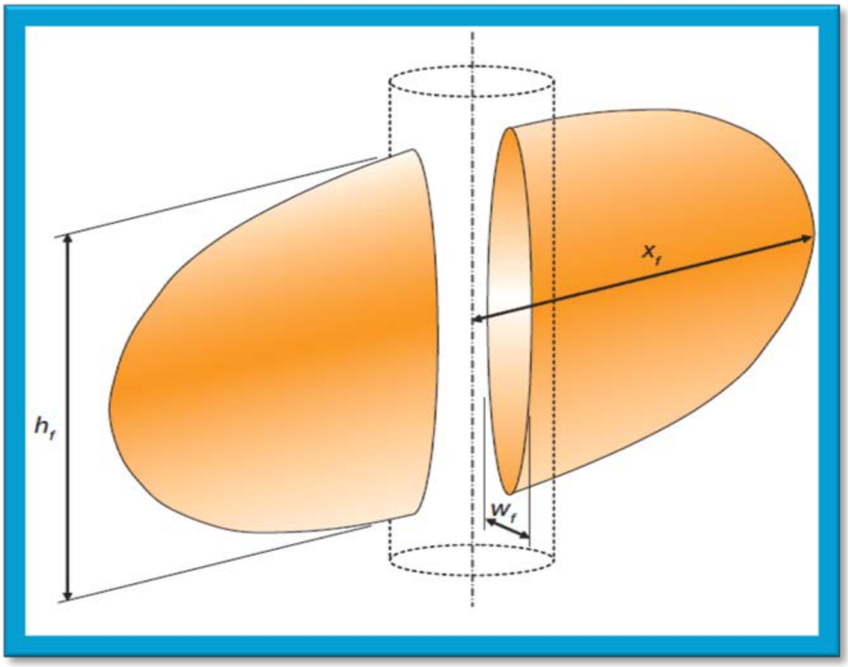

Figure 6: Conceptualised Shape of Hydraulic Stimulation Zone of Influence[16]

15 Ibid.

5.4. Key stages of hydraulic stimulation

5.4.1. *Hydraulic stimulation event design, modelling and monitoring*

Hydraulic stimulation events are individually designed in detail as part of the well completions design process, as described in section 4. This section also describes the design input parameters. Key to a successful and contained hydraulic stimulation event is the inclusion of detailed fracture modelling and fracture monitoring of each targeted reservoir zone using computer modelling methods, calibrated by historical data. Monitoring is undertaken by specialist engineers.

Design outcomes include:

- pumping equipment requirements based on expected treating pressures and pump rate
- fracturing fluid type and volumes required
- proppant types and volumes required
- simulated fracture geometry and expected treating pressure
- fluid pumping schedule describing stage volumes, rates, and proppant concentration
- shut-down and flowback procedures
- site preparations and logistics for material supply and accessory equipment required.

5.4.2. *Hydraulic stimulation treatment monitoring*

The fracture models are undertaken using an industry hydraulic stimulation simulator. Based on the final pumping schedule from the optimised design, a predicted fracture geometry and expected pressures are available.

During the stimulation treatment, key parameters such as surface, bottom-hole and annular treatment pressures, proppant concentrations, volume of injected fluid and fluid additives are monitored (Figure 7). The modelled pressures are compared with the actual pressures. The overall pressure response can provide useful information in evaluating the achieved fracture growth and containment. The mechanical properties of the interbedded sandstones, shales and coals mean that horizontal propagation of the fracture network dominates. Post-treatment parameters are used with the fracture model, following the treatment, to achieve a history match and predict the actual fracture geometry. This is used to refine and improve subsequent designs as part of the continuous improvement process.

Continuous monitoring of the casing pressure and fluid viscosity during the hydraulic stimulation process provides feedback to optimise performance. Significant changes in pressure are monitored in real-time to identify conditions that might indicate loss of well integrity or overburden layer integrity and, if necessary, cease operations.

[16] Ibud.

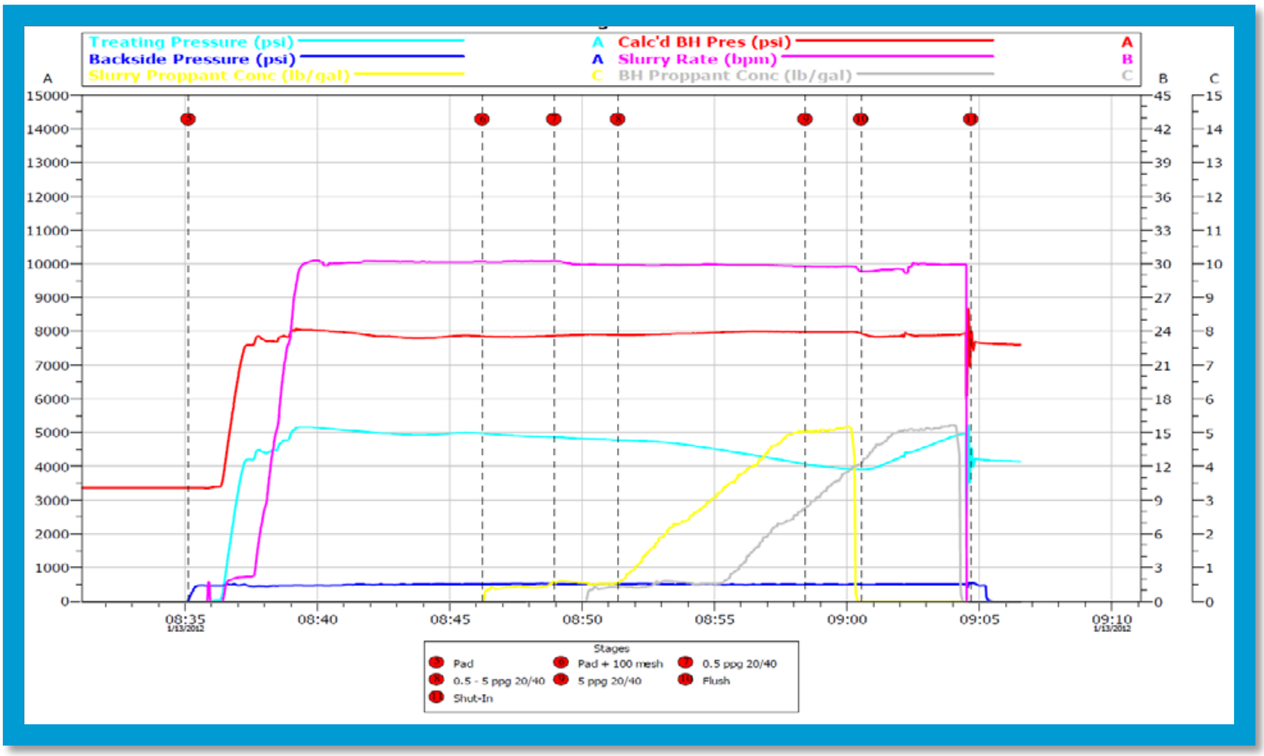

Figure 7: Typical Real Time Stimulation Job Plot, Santos 2012

Pressures are closely monitored or calculated during the activities in two critical areas, which are:

- inside the casing delivering the fluids
- calculated bottom hole pressures based on wellhead pressure, fluid densities and casing diameter and depth to the target formations.

In addition to process pressures, the flow rate and total volumes of hydraulic stimulation fluids are monitored. Changes in the flow rate in conjunction with pressure changes are utilised along with modelled simulations to determine the performance and propagation of fractures. Good process monitoring and quality control during hydraulic stimulation are essential for carrying out a successful treatment.

Sophisticated software is used to design and model hydraulic stimulation treatments prior to their execution and during the treatment to monitor and control treatment progression and fracture geometry in real time. During the hydraulic stimulation treatment, certain parameters are continuously monitored, including surface injection pressure, slurry rate, proppant concentration, fluid rate, and proppant rate. Following a hydraulic stimulation treatment, a close-out report is prepared providing the details of the real-time monitoring, assessments, injection volumes and quality control reporting. The data that is collected is used to refine computer models used to plan future hydraulic stimulation treatments.

If, during pumping of hydraulic stimulation treatments, anomalous pressure readings are noted operations cease immediately and the cause is studied and rectified before re-commencement of operations. If the problem cannot be remedied we will not continue hydraulic stimulation operations and safely shut-in the well.

Computer assisted live monitoring allows for potential problems (surface or down-hole) to be identified and corrected quickly. In the event that a problem develops on the surface (e.g. leak in line, pumps shut down), the use of live monitoring as a control measure for early detection can prevent the problem from escalating. An example of live monitoring applied to down-hole conditions is if pressure communication is seen between the annulus of the well and inside of the well, the well's integrity may have been breached and the treatment is stopped immediately.

In South Australia, Santos has trialled the use of advanced fracture monitoring techniques such as micro-seismic monitoring, which is used to evaluate fracture azimuth, fracture height and fracture half length. This additional information is used to further calibrate the fracturing model predictions. Tiltmeters, an instrument designed to measure very small changes from the horizontal level, can also be utilised to aid this process.[17]

Microseismic monitoring involves the use of a string of sensitive receivers (“geophones”) at the surface or within one or more nearby wells to detect and locate in 3D space the releases of energy associated with the propagation of the stimulated fractures. Figure 8 shows an example of a side-view of the locatable microseismic events that were detected during the multi-stage hydraulic stimulation of Cowralli-10 (in South Australia), with the positions of the events colour-coded by fracture stage. The viewpoint for the figure is at approximately the same depth as the upper fracture stages (shown in red, mid-blue and grey), and shows that the fracture propagation is predominantly horizontal, and that coals are effective in confining the vertical propagation. All locatable microseismic events for each fracture stage were contained within the formation being stimulated.

Figure 9 shows a map view of the locatable microseismic events; these are shown in red, and the ellipses around each well show the expected (modelled) fracture-extents. The modelling and field results show good agreement, however in practice horizontal fracture propagation does not extend as far from the stimulation initiation point location as the modelling predicts. Whilst providing a good mechanism for model calibration, microseismic techniques and tiltmeters are limited by infield requirements such as the presence of at least one pre-existing nearby well (within approximately 500–700 m) for monitoring, and cost. The use of tiltmeters to evaluate fracture growth direction (and potentially height) is being considered for selected unconventional stimulation treatments, the results of which may provide an additional tool for model calibration.

Extensive hydraulic fracture geometry mapping has been performed in unconventional North American shale reservoirs since 2001 providing evidence that there would not be any risks to drinking water from hydraulic stimulation in those locations.[18] Figure 10 is a plot of data collected from thousands of hydraulic stimulation activities in the Marcellus Shale in the Appalachian Basin, USA. Figure 10 illustrates the stimulation top and bottom for all mapped treatments performed. Perforation depths are illustrated by the red-coloured band for each stage, with the mapped fracture tops and bottoms illustrated by coloured curves. The dark blue shaded bars at the top of Figure 10 indicates the deepest water wells. The Marcellus data

[17] Cook, P, Beck, V, Brereton, D, Clark, R, Fisher, B, Kentish, S, Toomey, J and Williams, J (2013). Engineering energy: unconventional gas production. Report for the Australian Council of Learned Academies (ACOLA), available at: www.acola.org.au

[18] Fisher, K. ‘Data Confirm Safety Of Well Fracturing’, Pinnacle Resources, American Oil and Gas Reporter, July 2010

shows a large distance between the stimulation tops and the deepest known water aquifer level.

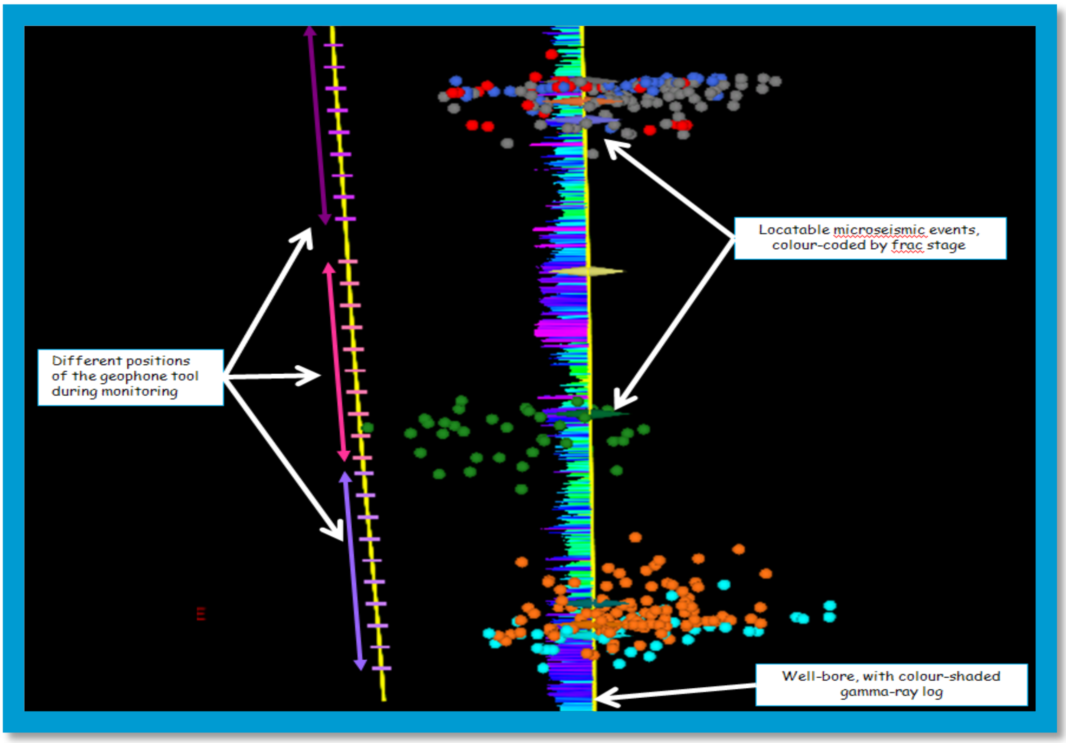

Figure 8: Lateral View of the Locatable Microseismic Events during Monitoring of Multi-Stage Hydraulic Stimulation of Cowralli-10, Santos 2009

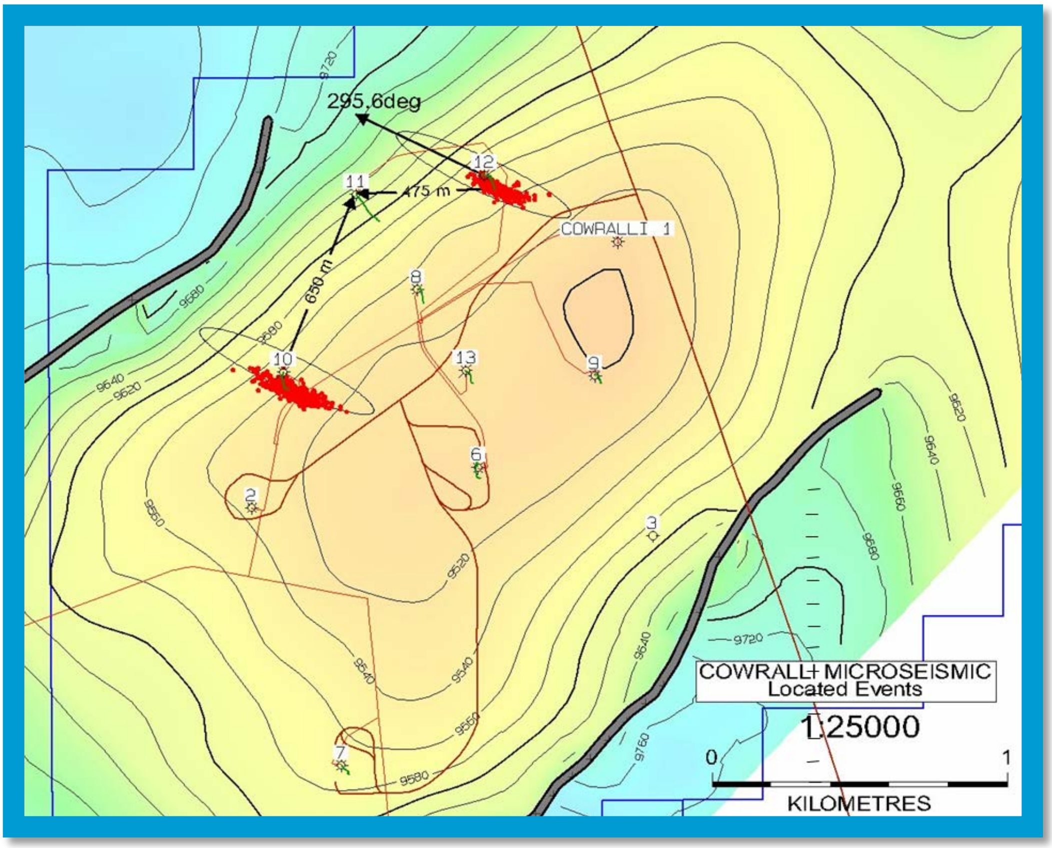

Figure 9: Map View of the Locatable Microseismic Events during Monitoring of Multi-stage Hydraulic Stimulation of Cowralli-10 and Cowralli-12, Santos, 2009

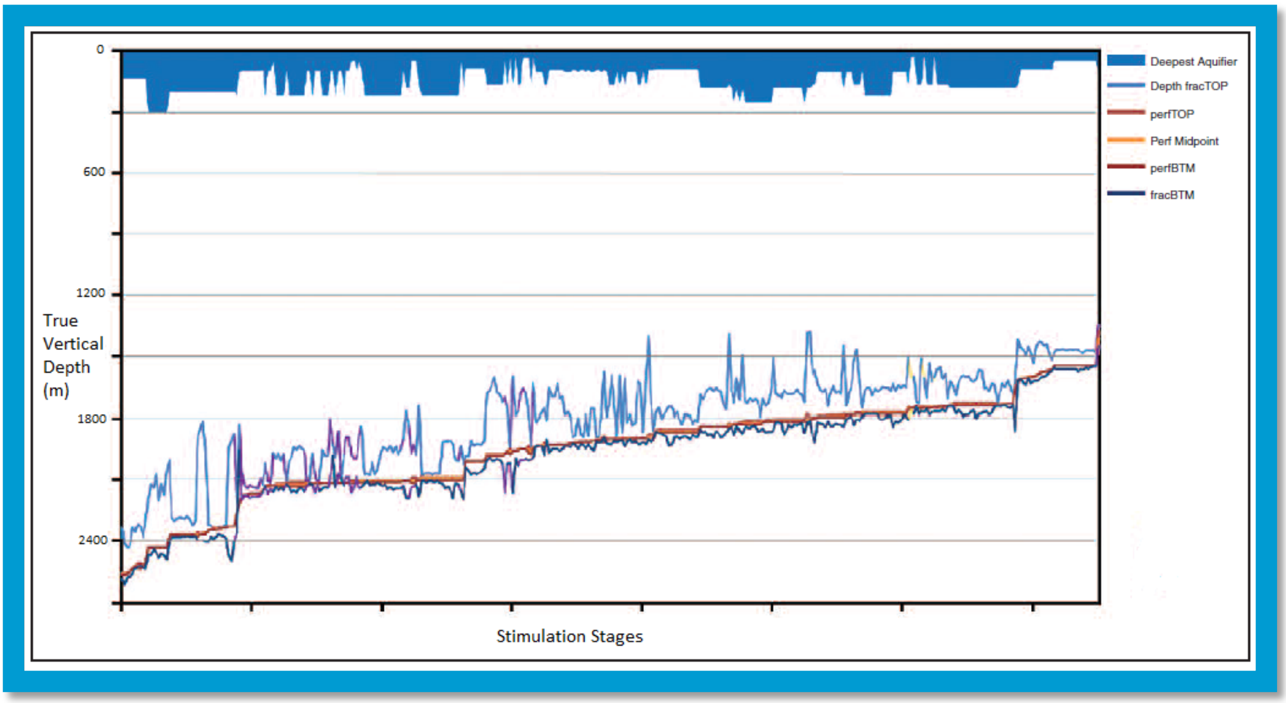

Figure 10: Mapped Stimulation Treatments form US, Marcellus Shale

5.4.3. Timing of hydraulic stimulation process

Hydraulic stimulation treatment of a gas well typically takes between 7 and 10 days to complete, depending on the number of stages. The flowback period may extend from 3 to 10 days depending on the reservoir and clean up profile. At the end of the clean-up phase, completions engineers design the production tubing and associated completion equipment such as packers, nipple profiles, tubing hanger, and the production tree.

5.5. Hydraulic stimulation fluid

This section addresses Term of Reference 7(e)

Water accounts for approximately 90% of the fluid used for hydraulic stimulation and sand or proppant material accounts for about 9%. Chemicals account for the remaining 1% of the mixture and assist in carrying and dispersing the sand in the low-permeability rock. The fluid is controlled and does not come into contact with groundwater at any point in the hydraulic stimulation process due to the cement and casing surrounding the wells.

Santos' use of chemicals is kept to the lowest level possible. We also work with our hydraulic stimulation specialist contract companies to ensure usage of the most environmentally friendly chemicals and lowest possible concentration of chemical components in our hydraulic stimulation operations. BTEX are not present in stimulation fluids, for more details see section 6.5.2.

Santos safely manages the use of chemicals and fuels, and contains recovered stimulation fluids to minimise the environmental footprint of stimulation activities. Most of the chemicals used in hydraulic stimulation fluids are found within products that are used in the home or in industry. All chemicals are approved for use by the Australian Government (Department of Health) and listed on the Australian Inventory of Chemical Substances (AICS) (maintained under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS)). Additives that may be hazardous in concentrated forms are greatly diluted by water when used in the fracturing process and are therefore present in relatively low concentrations.

These chemicals are used for many different household functions and are not specific to hydraulic stimulation. Common uses include toothpaste, baked goods, ice cream, food additives, detergents, cosmetics and soap. Table 2, includes the typical components of hydraulic stimulation fluids.

Table 2: Typical Components of Hydraulic Stimulation Fluid

Components	Purpose	Common Uses
Ethylene glycol monobutyl ether	Mutual solvent	Cleaning products, cosmetics, liquid soaps
Tetrakis (hydroxymethyl) phosphonium sulfate	Biocide	Water treatment
Oxyalkylated alcohol	Reduce fluid surface tension	Scouring agent for textiles
Ethylene glycol	Prevents scaling	Antifreeze, household cleansers, de- icing, caulk
Tetramethyl ammonium chloride	Reduce clay swelling	Type of salt
Crystalline silica (cristobalite)	Proppant	Sand and gravel
Crystalline silica (quartz)	Proppant	Sand and gravel
Hemicellulase enzyme	Reduce viscosity of guar gum	Commercial food processing of coffee gel
Methanol	Reduce fluid surface tension	Windscreen washer fluid, wastewater treatment, alternative fuel blends
Boric oxide	Crosslinker to increase viscosity	Used to produce high strength alloys, glasses, ceramics, detergents
Potassium carbonate	pH buffer	Soap, wine, glass, dyes, water softener
Sodium persulfate	Reduce viscosity of guar gum	Bleach in hair treatments, detergents gel
Petroleum distillate	Guar liquefier	Baby oil, make-up remover
Sodium acetate	pH buffer	Provides the primary flavouring in salt and vinegar potato chips
Guar gum	Thickens fluid to carry sand	Thickener in cosmetics, baked goods, ice cream, toothpaste and sauces
2-methyl-2h-isothiazol-3-one	Biocide	Preservative in cosmetics, shampoo detergents, dishwashing liquids
5-chloro-2-methyl-2h-isothiazolol-3-one	Biocide	Preservative in cosmetics, shampoo detergents, dishwashing liquids
Acetic Acid	Solvent	Additive in the food industry, descaling agent
Boric Acid	Gelling Agent	Antiseptic, insecticides, flame retardant
Diammonium peroxidisulphate	Breaker	Hair bleach
Diatomaceous earth, calcined	Filler	Tooth paste, hydroponics
Ethanol	non-ionic surfactant	Fuel, alcoholic beverages
Hydrochloric Acid (Muriatic Acid)	pH buffer	Multipurpose chemical reagent, food additive, swimming pool maintenance
Magnesium chloride	Salt	Food industry, anti-icer on roads, aquariums
Magnesium nitrate	Salt	Agriculture as a fertiliser, ceramics
Magnesium silicate hydrate (talc)	Filler, stabiliser	Talcum powder, paints, food additive

Components	Purpose	Common Uses
Non-crystalline silica	Filler, stabiliser	Opal jewellery
Sodium Carbonate (Soda Ash)	pH buffer	Water softener, swimming pools, food additive
Sodium Hydroxide (caustic soda)	pH buffer	Cleaning agent, food preparation

Even in low concentrations, Santos handles these additives with care to avoid any potential for impacts on human health or the environment. With Santos' operational controls and management, the overall or residual risk to the environment associated with the chemicals used in hydraulic stimulation is low.

In 2012, Santos engaged Golder Associates to undertake a toxicogical risk assessment of hydraulic stimulation.[19] The assessment included a detailed evaluation of the toxicology of the constituents of hydraulic stimulation fluids and potential risk to ecological and human health associated with exposure to the produced fluids (i.e. recovered hydraulic stimulation fluids and produced formation water). While chemicals were present at detectable concentrations as a result of returned reservoir fluids and potentially the hydraulic stimulation fluids, there were no credible complete exposure pathways, linking chemicals in concentrations of concern to receptors. The report found that the only potentially complete exposure pathway, linking produced fluids to a receptor, would be direct contact by small fauna in a flowback fluid pit. Santos ensures that this risk is mitigated by fencing and pit design.

Chemicals are used in the fluid used for hydraulic stimulation for the following purposes:

1. Viscosity: gelling agents are added to the water to provide viscosity to enable the proppant material such as sand or ceramic beads to be transported down the well and into the created fractures.

2. Friction reduction: to reduce the force required to pump the fluid, friction reducers are added, making the fluid more 'slippery' and easier to pump at the high pressures and rates required to create the fracture network.

3. Biocide: biocides or disinfectants are added to ensure that no microbes or organisms present in the water will destroy the gelling agents and also to ensure they will not enter and contaminate the reservoir.

4. Scale and corrosion: scale and corrosion inhibitors are added to prevent deposition of mineral scales and to prevent corrosion of the steel casing or tubing.

5. Surface tension: surfactants or surface tension modifiers are added to assist the back flow of fluids from the formation.

As part of the hydraulic stimulation process, the sand or proppant material remains in the low-permeability rock while approximately 30–70% of the fluid is recovered to surface along with hydrocarbons during the wellbore clean-up phase. These fluids are separated from the hydrocarbons, which are captured or flared, with the wastewater being captured in lined tanks or ponds for disposal via approved means.

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19 Santos, 'Environmental Assessment Report - Fracture Stimulation Operations in the Cooper Basin, South Australia', Supplement to the Drilling and Well Operations EIR 2003, May 2014

Other chemicals that may be used in association with hydraulic stimulation include chemical tracers. These are chemicals which enable us to determine fluid flowback and production contribution from each individual stimulation zone. This assists in continual improvement to the process.

Santos supports full disclosure of the chemicals used in fracture stimulation operations. More detail is provided in section 6.5.5.

5.5.1. Flowback

The fluid used to create the fracture and place the proppant will restrict the ability of the well to produce hydrocarbons. The use of breakers and reservoir temperature reduces the fluid's viscosity to near water (1 cp) and the well is flowed back to recover injected fluids to enable the hydrocarbons to flow into the created and propped fracture and subsequently into the wellbore.

Following completion of the hydraulic stimulation process, a considerable volume of the injected stimulation fluids are recovered upon flowback of the injected fluid. Studies performed by the US EPA indicated that approximately 60% of the stimulation fluids are recovered in the first three weeks, and total recovery was estimated to be from 68–82%.[20] Santos' experience is that 30–70% of the fluid is recovered during the initial flow back period. Additional volumes will be recovered through the ongoing production period increasing the total fluid volume recovered.

Any fluid that is not flowed back and recovered stays in the hydrocarbon bearing zone and does not migrate to overlying aquifers.

Once pumped into the well, the injected fluids undertake a change in chemical properties and interact and biodegrade to become more benign. Chemicals returning to surface from a well following a stimulation treatment are typically a fraction (usually 20% or less for chemicals and about 40% for polymers) of what was initially pumped.[21] Compounds such as polymers decompose rapidly at temperature, biocides are spent on organic demand and degrade, surfactants are adsorbed on rock surfaces and scale inhibitors precipitate and are returned at 10–15 ppm (parts per million or milligrams per litre) over periods of up to several months.[22]

Hydrochloric acid, which is often used in the initial fluid injection phase, is spent within a short distance of the entry point into the formation and no live acid is returned to the surface. Corrosion inhibitor is used as an additive to the acid (hydrochloric acid) only and is adsorbed onto the steel casing and then onto the formation. Approximately 5–10% of the total volume of

[20] US EPA. "Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs", EPA 816-R-04-003, June 2004

[21] King, G.E. 'Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells,' (2012) Paper SPE 152596 presented at the SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA,6-8 February; Friedmann, F., 'Surfactant and Polymer Losses During Flow Through Porous Media,' SPE 11779, SPE Reservoir Engineering, Vol. 1, No. 3, May 1986, pages 261- 71; Howard, R., Mukhopadhyay, S., Moniaga, N., Schafer, L., Penny, G., Dismuke, K, 'Comparison of Flowback Aids: Understanding Their Capillary Pressure and Wetting Properties,' SPE 122307, 8th European Formation Damage Control Conference, 27 – 29 May 2009, Scheveningen, The Netherlands.

[22] King, ibid.

corrosion inhibitor injected returns to the surface in the produced fluids.[23] Many of the compounds such as acids, corrosion inhibitors or biocides used in the stimulation process that are identified as potentially hazardous on their material safety data sheets (MSDS), are effectively neutralised during and/or directly following treatment and/or are present at significantly reduced concentrations in the produced fluids.

Light condensate, including naturally occurring hydrocarbon compounds such as TPH, PAHs and BTEX, may be associated with gas and therefore present in recovered fluids but simply because they are present naturally. These compounds are not introduced into the fluids by Santos (please refer to section 6.5 for more information about these compounds). Produced fluids are directed into lined pits (e.g. lined with UV stabilised HDPE or equivalent) or tanks and, if required, separators are used to separate water, condensate, and gas for separate handling. The fluids are removed and taken to a nearby facility for discharge into water pond systems. Potential environmental risks are assessed regularly and managed through containment and/or monitoring. Fluid management ponds or containment facilities are constructed in accordance with regulatory standards.

Santos utilises industry best practice in managing surface handling of fluids and is constantly seeking to introduce new technologies for surface handling of fluids and disposal. Santos is undertaking stage-wise improvements towards replacement of lined pits with tanks. An example of this includes the use of specially designed flowback tanks and pit-less flowback operations.

5.6. Unconventional gas well hydraulic stimulation

Hydraulic stimulation processes used for conventional and unconventional reservoirs are largely the same. Differences between unconventional and conventional stimulations include size, job type and horsepower requirements.

Due to the ultra-low permeability of many of the unconventional plays, complex large fractures are required to achieve commercial flowrates. The treatment sizes are larger for unconventional resources mainly because the formation target is often very low permeability and several times thicker than thinly laminated conventional sandstones.

5.7. Hydraulic stimulation water use

This section addresses Term of Reference 7(d)

The source of water for hydraulic stimulation is considered in detail during the project initiation phase. Depending on availability and applicable regulations, water used during hydraulic stimulation is either taken from:

- produced formation water from adjacent oil and gas production facilities
- surface water sources (such as rivers, lakes or the sea)
- local boreholes (which will draw the water from shallow or deep groundwater). This is done in full consultation with the land owner/occupier

[23] ibid.

- ‘town’ supply (trucked to site), where distances exceed ~15 to 20 kilometres from the closest suitable source of water.

Water is a key input for shale gas production. It can take up to 20 megalitres of water to hydraulically stimulate a long horizontal development well. Vertical exploration wells typically will only require up to 5 million litres of water to hydraulically stimulate due to the lower number of stages. This has raised concerns about depletion of local water supplies. It is important to put in context the amount of water used in shale oil and gas production. Typically, the shale gas industry uses a fraction of the total usage for agricultural, industrial and recreational purposes. Further to this, Santos preferences non-domestic water supply. With advances in fluid chemistry, fresh, potable water is no longer required for hydraulic stimulation. As such, Santos endeavours to locate water sources not being used for domestic (potable) or livestock purposes but more saline sources in preference, and we will not obtain water from an aquifer that is not deemed sustainable.

The quantity of water used for stimulating oil wells is much lower than that used for shale gas production. For example, stimulation of oil wells in Mereenie typically use less than 500 kilolitres of water per well.

When Santos moves from the exploration phase to development we also set up facilities to enable the capture and recycle of flowback fluid thus reducing the amount of water required for the hydraulic stimulation operation. This is anticipated to reduce the total additional water requirement to less than 10 megalitres per well.

6. Hydraulic stimulation and the environment

6.1. Environmental risk assessment and control

This section addresses Terms of Reference 2, 3, 5, 6 and 7

Hydraulic stimulation is an environmentally safe process, as recognised by industry and environmental regulators.[24] With proper regulation and responsible operation, the potential risks associated with hydraulic stimulation are able to be mitigated; the hydraulic stimulation of wells at Mereenie and the Cooper Basin over the course of the past 30+ years has resulted in no material environmental harm.

As a result of the best practice control measures employed by Santos to mitigate and minimise any environmental risk associated with hydraulic stimulation, the residual risk associated with hydraulic stimulation activities is low. Environmental impacts that are experienced, are generally temporary and related to infrastructure footprints (roads and well leases). Project planning will optimise infrastructure location for shared use (e.g. roads) and minimise impacts.

Santos undertakes risk assessments of its hydraulic stimulation activities at all locations to identify credible impacts, appropriate controls and ensure impacts are minimised and risks are appropriately managed. Santos' gas hydraulic stimulation activities are conducted such that:

- There are no risks associated with Santos' hydraulic stimulation activities that cannot be managed to As Low As Reasonably Practical (ALARP).
- Santos' operational practices are consistent with leading industry practices.
- The level of management controls Santos employs to control the potential risks to the Northern Territory environment associated with hydraulic stimulation have been and continue to be appropriate.

Santos has developed an Environment, Health and Safety (EHS) Management System (EHSMS) to provide a robust company-wide approach to effectively manage EHS risks and to allow for continual EHS improvement. The framework under which Santos identifies and eliminates, or puts in place appropriate controls, in order to reduce potential harm to people and the environment outlines the requirements to:

- Identify EHS hazards, assess their risk and control them to As Low As Reasonably Practicable (ALARP).
- Identify significant EHS hazards and document how they are being managed to as low as reasonably practicable.
- Have a system to escalate EHS significant hazards to management for approval of continued operation and for management to sign off on EHS significant hazards, controls and how critical controls will be checked.
- Meet legislative requirements that require certain EHS hazards and risks to be managed.

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[24] DEHP, 'Fraccing and BTEX', Department of Environment and Heritage Protection, Queensland Government, March 2013

The potential for risk to the environment as a result of Santos' operations is evaluated based on environmental consequence and likelihood. The levels of consequence describe the severity and/or impact to receptors within the environments such as:

- ecosystems, plants and animals with conservation value
- land
- surface water
- groundwater
- air
- community.

The level of consequence can range from localised and short-term environment or community impact which is easily dealt with or 'negligible' to regional and long-term impact on an area of significant environmental value or 'critical'. The levels of likelihood predict the probability of a hazard occurring and range from remote to almost certain.

The risk assessments identify potential environmental impacts and appropriate controls to reduce potential harm to people and the environment.

The level of risk of environmental impact of petroleum activities, including hydraulic stimulation activities, is related to the receiving environment, and therefore regional and area variations are factors of the risk assessment process. Control measures are adapted to regional and area variations affecting these environmental risks. These variations are identified through assessment of:

- proximity to sensitive surface receptors
- proximity to sensitive groundwater receptors (e.g. bore users)
- geology and hydrogeology, including location of faults and aquifers, and separation between beneficial aquifers and stimulation zone
- climate including rainfall and evaporation rates.

Santos employs best practice control measures to mitigate and minimise the likelihood and consequence of environmental risks associated with hydraulic stimulation, through:

- understanding geology and hydrogeology, including location of faults and aquifers, and separation between beneficial aquifers and stimulation zone
- minimisation of disturbance to protect biodiversity, heritage and current and future land uses
- protection and monitoring of groundwater and surface water quality and water supply
- safe chemical use, including spill and leak prevention
- responsible waste management
- minimisation of noise and air emissions
- protection of public safety
- emergency preparedness and incident response
- effective rehabilitation.

These outcomes, and the control measures used to achieve them, are detailed sequentially in sections 6.2 through to 6.11 of this submission.

In addition to our own robust and company policies, procedures and measures, Santos complies and operates in accordance with the Northern Territory legislation as outlined in Section 3.5.

As part of the Petroleum Project Approval Process, we are required to obtain an approved Environment Plan (EP) from the Department of Mines and Energy (DME). The EP approval process involves a high level of rigour and scrutiny, which includes review by other NT Governments agencies, such as the Northern Territory Environmental Protection Agency (EPA). The DME EP process ensures that appropriate environmental management practices are followed whilst undertaking petroleum activities such as hydraulic stimulation. It helps ensure the application of best practice environmental management, allows for the inclusion of conditions of approval, ensures compliance with environmental legislation and that environmental risks are understood and properly managed.

6.2. Understanding geology and hydrogeology

This section addresses Term of Reference 5

Santos employs best practice mitigation, involving the identification and characterisation of local fault structures, avoidance of hydraulic stimulation in the vicinity of active faults, real-time monitoring and control of fracture growth through available sensing technologies and the establishment of ‘cease operation’ triggers based on prescribed measured seismicity levels.

Geophysical interpretation (e.g. seismic, gravity and magnetic data), geological mapping (including outcrop mapping and use of pre-existing well data) and modelling of potential fracture propagation (described below) are used to determine distance of target formations from faults and aquifers (Figure 11).

The hydrocarbon zones being targeted by Santos in the Northern Territory are generally 1000 to 3500 metres below the surface. This is well below regional bores installed for stock and domestic use, which are known, through assessment and monitoring, to be from 5 to 200 metres below the surface.

Figure 11: Vibroseis vehicles gathering seismic data

If a hydraulic stimulation target is deemed to have an unacceptable risk of accessing a high water bearing zone, hydraulic stimulation will not be pursued. These factors will vary both regionally and locally, and risks are therefore assessed on a case-by-case basis.

Prior to hydraulic stimulation, the geology of the area surrounding the wellbore is further evaluated using a variety of methods that include wireline logs, cuttings samples and core samples. The assessment considers data collected in the field, such as formation depth and formation separation, well construction, the design of the hydraulic stimulation operation, as well as clean-up and the quantity of produced hydraulic stimulation fluid called ‘flowback’. This information is integrated with structural maps and correlations to other wellbores to further assess any potential risk factors.

Water production rates throughout the flowback and production phase of a well are monitored to ensure that water production from each zone is within the expected range of deliverability.

Given the operational controls and procedures, Santos has a high level of confidence that it understands the vertical and lateral extent of hydraulic stimulation treatments.

6.2.1. Modelling of potential fracture propagation

Prior to hydraulic stimulation being undertaken, modelling work (for every location) is undertaken to predict the extent and impact of the creation of fractures or ‘propagation’. The model is built using reservoir data collected in the field including, but not limited to, geological and/or hydrogeological logs, formation pressures and ductility, matrix porosity, hydraulic conductivity, stimulation frequency and ratios of anisotropy. Model outputs include fracture network geometry, pressure gradients, estimates for fluid and proppant requirements as well as predicted return rates. The intent of the modelling is to maximize the economic return of the target gas and/or oil horizon by minimising impacts to overlying and underlying formations and limiting the volume of produced formation water.

An informative example can be drawn from the *Mereenie Field Development Activity Specific Environmental Plan* prepared in January 2014, which presented the results of a computer simulation of the proposed fracture using a pseudo 3D vertical model. This model estimated the following dimensions of the fracture propagation based on the stress regime within the field, the elastic properties of the rock layers, the proposed pumping schedule and fluid properties:

- propped fracture half-length of 43 m
- estimated height at the well of 42 m
- average propped width of 3 mm.

Figure 12 is a schematic of geology of Mereenie Field showing the location of aquifer and target formations. Based on the above modelled dimensions, propagation into the regional aquifer is unlikely given the large distances between target formations and the aquifer.

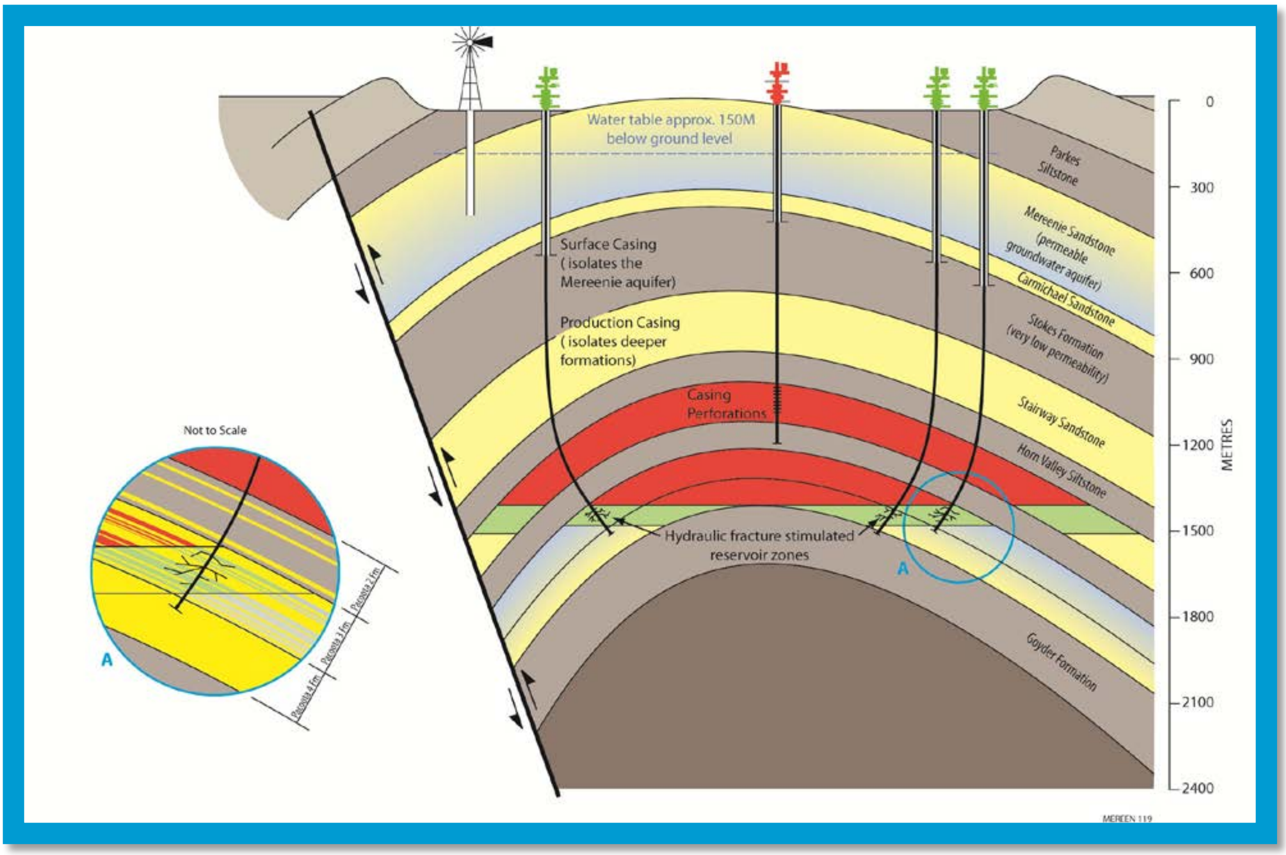

Figure 12: Distances between target formations and aquifers: Mereenie Oil and Gas Field

Extensive micro-seismic mapping of thousands of hydraulic stimulation treatments has taken place in North America. These show that the height growth of the created fractures is limited to a few hundred metres even with the largest hydraulic stimulation treatments.[25]

As modelling changes with the well specific logs, Santos will provide the Department of Mines and Energy with a Stimulation Proposal and labelled schematic for their approval prior to the commencement of hydraulic stimulation of a well.

6.2.2. Microseismic monitoring

Although there is ample evidence in Australia of induced seismic activity associated with large dams, mining operations and geothermal operations, there is currently no seismic risk data for oil and gas-related activity in Australia, such as hydraulic stimulation.

Hydraulic stimulation has been carried out in the Amadeus Basin for 30 years and the Cooper Basin for over 40 years without any issues related to seismicity. Throughout our activity, monitoring techniques have been employed, including microseismic (Moomba 191 and Cowralli Campaign) and surface monitoring across the 2013 Cowralli Pad Project. Monitoring during hydraulic stimulation treatments reported very minor microseismic responses that were not deemed to pose any risk to the seismicity of the region.

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[25] Cook *et al*, 'Engineering Energy: Unconventional gas production – A study of shale gas in Australia', ACOLA, May 2013, page 126.

Microseismic monitoring may be employed for the evaluation of hydraulic stimulation treatment geometry on selected wells.

Modelling of proposed hydraulic stimulation treatments provides additional confidence that potential impacts to the environment are managed appropriately.

6.3. Minimisation of disturbance

This section addresses Term of Reference 7(a)

Santos recognises that the impact that hydrocarbon related activities, including hydraulic stimulation, may have on biodiversity, heritage and current and future use of the land, depends on the location of the particular well and the quality of its design and construction.

Santos works collaboratively with stakeholders to site and construct surface and sub-surface infrastructure. Our adherence to best practice construction methods, along with robust monitoring and regulation, ensures that current and future uses of land are not negatively impacted.

Our existing onshore operations in Eastern Australia demonstrate that agriculture and natural gas extraction can coexist in a safe and sustainable manner. A prominent example is at Roma in Eastern Queensland. Similarly, in the Cooper Basin, where Santos uses hydraulic stimulation extensively, we have co-existed with pastoralists raising beef cattle. These multiple, simultaneous land uses are a necessity in an age of increased domestic, regional and global demand for food and energy.

The surface footprint of hydrocarbon extraction is generally minimal and temporary. Access roads and surface infrastructure such as processing facilities, compressor stations, and some water management facilities are in place for a longer period. These are sited and constructed in ongoing consultation with landholders. Access roads are also planned with landholders, to accommodate shared use.

Hydraulic stimulation often results in a smaller land-use footprint than traditional onshore hydrocarbon operations, by increasing the effective drainage area of the well. This results in fewer wells.

Prior to new disturbance, an ecological assessment is undertaken to evaluate the sensitivity of a proposed location. The results of this assessment (along with cultural heritage compliance requirements – as outlined in section 6.3.1) are used to inform the internal approvals process from which a set of site-specific conditions is generated. The objective of these conditions is to provide a set of guidelines for lease construction and operation and to minimise the likelihood of impacts to the environment outside of the area cleared for operation.

Additional management measures in place to avoid disturbance to vegetation, wildlife and stock include:

- Where areas of sensitive vegetation are identified, they are flagged off and signposted with restricted access.
- Off-road or off-lease driving is prohibited to all Santos personnel and contractors without appropriate prior approval.

- Activities and vehicle movements are restricted to existing, defined well leases and access tracks.
- Stock and wildlife access to fuel, chemicals and flow-back fluid storage is restricted (see section 6.5).
- Waste is securely stored and transported (see section 6.6).

Potential impacts to soil are generally associated with spills and leaks, at surface, of fuel, chemicals or other fluids such as the fluids used in hydraulic stimulation. The control measures used to appropriately minimise the residual risk of soil contamination are described in section 6.5.3.

During the construction phase, wells require an area of up to 1.5 hectares for up to one year, after which this area decreases to approximately 0.05 hectares (500 m^3) for their productive life of approximately 20 to 30 years. At the end of their productive life, the wells are plugged with cement, surface facilities are removed in accordance with Government approvals, guidelines and regulations, and the disturbance rehabilitated. Long-term surface impacts to land are minimal to non-existent (see section 6.11).

6.3.1. Cultural heritage protection

Santos has established a cultural heritage management system to ensure the protection of non-Indigenous and Indigenous cultural heritage. This system supports compliance with all legislative requirements related to Santos' Australian operations, as well as those entered into via agreements with Aboriginal stakeholders, in a comprehensive, documented and auditable manner.

Cultural heritage clearances are the primary control for risk to cultural heritage and sacred or significant sites arising from ground-breaking, ground-disturbance, excavations or project works.

Cultural heritage includes both Aboriginal and non-Aboriginal areas, sites, objects and places:

- Non-Aboriginal cultural heritage includes sites, artefacts and objects that, with written documents, help contribute to our understanding of Australia's recent history.
- Aboriginal cultural heritage includes sacred sites, significant sites, areas, sites, objects and places which document Aboriginal habitation of the country. These include physical traces left by Aboriginal people (such as rock art, stone arrangements and stone tools) but may also include places or features in the landscape that bear no traces of human activity.

For Santos in the Northern Territory, an approved Request For Sacred Site and Cultural Heritage Certificate (RFCHC) is required for all ground-breaking, ground-disturbance, excavation activity or project works. This includes new activity and also variation/modification or expansion of existing project works whether or not there is ground breaking, disturbance activity or prior land use.

The process for seeking a Sacred Site and Cultural Heritage Certificate includes:

- developing a Work Program and apply to the relevant authorities for Sacred Site Certificates

- seeking from the relevant Land Council the Notice of Approved Work Program & Conditions of Works
- seeking an Authority Certificate from AAPA
- ensuring approvals information, with conditions, are uploaded into reporting systems and communicated to the relevant project personnel, including issue of compliance actions to Project Managers and upload of spatial data into Santos' geographic information system
- personnel and contractors undertaking mandatory Cultural Heritage inductions prior to commencement of project works activities.

6.4. Protection of groundwater and surface water quality and water supply

Santos is committed to having a minimal and manageable impact on groundwater and surface water in the Northern Territory. We meet this by:

- understanding the hydrogeology of shallow and deep aquifers (see section 6.2)
- ensuring well integrity
- preventing spills and leaks at surface
- undertaking groundwater monitoring programs.

The control measures undertaken by Santos to ensure the proper construction, design and integrity of our wells are detailed above in section 4.

Potential impacts to shallow groundwater and surface water are generally associated with spills and leaks, at surface, of fuel, chemicals or other fluids such as the fluids used in hydraulic stimulation. The control measures described in section 6.5.3 'Spill and leak prevention' appropriately minimise the residual risk to shallow groundwater and surface water.

Potential impacts from hydraulic stimulation treatments to groundwater supply and consumption are not considered to be plausible risks. Implementation of numerous control systems, including preferential use of oil and gas satellite pond water, lining of well site small dams (to prevent the loss of water stored on site though seepage), and compliance with regulations, ensures that the risk of impact to supply to other groundwater users is negligible.

Studies conducted by US governmental agencies and respected authorities have unanimously concluded that hydraulic stimulation is safe. The US Environmental Protection Agency, the Groundwater Protection Council and the Interstate Oil & Gas Compact Commission all have found hydraulic stimulation non-threatening to the environment or public health. Such studies found no evidence hydraulic stimulation contaminated drinking water. In addition the US EPA found that several factors like the small amount of chemicals contained in stimulation fluids, their dilution in water, the recovery of stimulation fluids, and their absorption by rock formations all minimised the potential risks associated with hydraulic stimulation.[26]

[26] Fisher, K. 'Data Confirm Safety Of Well Fracturing', Pinnacle Resources, American Oil and Gas Reporter, July 2010

6.4.1. Migration

The likelihood of migration of chemicals into aquifers through the fractures created during the hydraulic stimulation process is remote. This is due to the:

- low concentrations of chemicals used in stimulation fluids
- recovery of most fluids
- limited and understood extent of stimulation (see section 6.2)
- reliable well design, construction and operation including the presence of cement set above and below the hydrocarbon-bearing formation at the wellbore (see sections 4.2.2 to 4.2.6).

The likelihood of hydraulic stimulation activities creating vertical pathways into aquifers is further reduced where there is an impermeable layer of rock (cap rock) above the hydrocarbon zone, limiting fracture growth and prevent migration. Gas in shale is unable to freely migrate due to the low permeability of the shale itself unless under large applied drawdowns such as those from production.

Lateral migration of injected fluids away from the hydraulic stimulation initiation point cannot occur. Once hydraulic stimulation has been completed, the well is flowed back creating a pressure differential and a flowpath from the end of the stimulation treatment point back towards the wellbore. This pressure differential continues into the production phase of the well where the production of reservoir fluids increases the pressure differential and ensure migration of stimulation fluids is unlikely. Further to this, the formations selected for hydraulic stimulation activities are low permeability formations in which it is unlikely that any migration of stimulation fluids is able to occur.

An important factor in limiting potential for migration is the significant separation distance between hydraulic stimulation and beneficial aquifers. As per section 6.2, hydrocarbon zones targeted by Santos in the Northern Territory are generally 1000 to 3500 metres below the surface. This is well below stock or domestic bores which are understood, through assessment and monitoring, to be from 5 to 200 metres below the surface, within Santos' areas of interest.

Individual design is being undertaken prior to DME approval for each well bore, but generally the hydraulically created fractures at Mereenie have been designed to be at most 60 metres vertically and extend a maximum horizontal length of 100 metres from the wellbore.

For example, design results for West Mereenie 23 (see Figure 13) indicate that the expected dimensions of the frac are:

- propped fracture half-length of 100 metres
- estimated height at the well of 25 metres
- average propped width of 4 millimeters

Given the separation distance of over 500 metres between the Mereenie aquifer and the designed frac dimension, as well as the presence of the low permeability Stokes Formation, fracture stimulation fluid is highly unlikely to migrate any significant distance beyond the stimulation treatment.

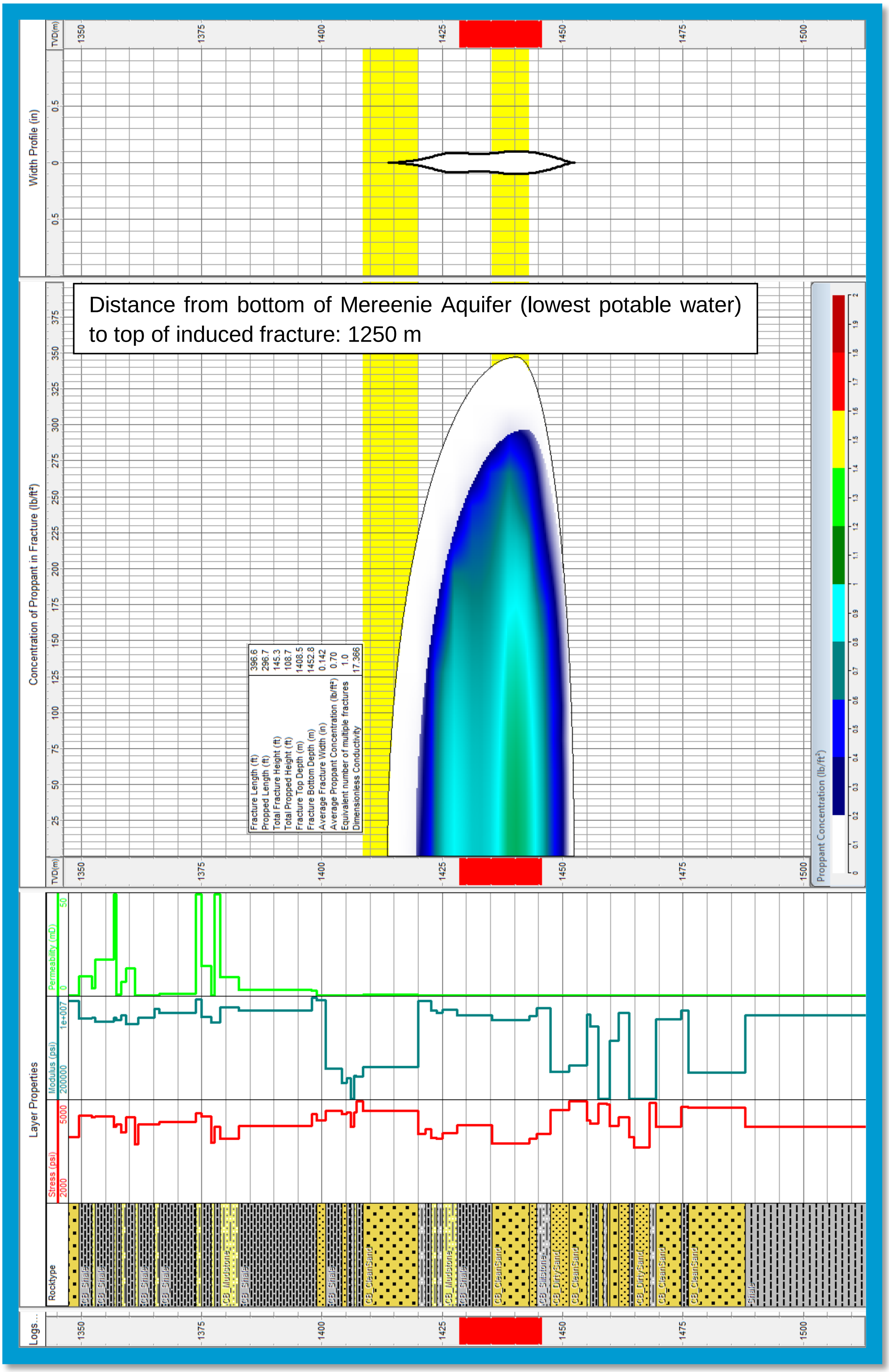

Figure 13: Expected stimulation dimensions and reservoir properties

6.4.2. Baseline monitoring

This section addresses Term of Reference 7(i)

Baseline monitoring is a critically important mechanism for demonstrating the success of control measures to protect groundwater quality and aquifers.[27]

Prior to hydraulic stimulation, an assessment of groundwater conditions by a suitable qualified independent environmental consultancy is undertaken to provide a benchmark against which any future variations in quality can be objectively measured. Data to provide a 'snapshot' of aquifer conditions at the time of the inventory is obtained, as well as information regarding existing bores, and present and historic groundwater use within the vicinity of an operations or project. Data obtained includes groundwater levels, quality, usage, and, where available, information on bore construction. This 'snapshot' data can then be used to assess the impacts (if any) of petroleum activities on groundwater resources.

Santos has undertaken Baseline Water Studies within both the Mereenie and McArthur fields and will continue this practice for future petroleum activities in-line with regulations.

The results of the baseline assessment and subsequent monitoring of local groundwater bores during the Mereenie stimulation program show no significant changes in local groundwater quality (or water supply), and none that can be attributed to be as a result of hydraulic stimulation.

Landholders' bores that are active and located proximal to a hydrocarbon well will be included within the baseline assessment and monitoring program. Santos will arrange for testing of the quality of the bore water, before and after hydraulic stimulation. Results can be made available to the landowners, to provide confidence that their assets are protected and that control measures are successful.

6.5. Safe chemical use

This section addresses Term of Reference 7(e)

The storage, handling and disposal of fuels, chemicals and wastes generated as part hydraulic stimulation treatments is undertaken in accordance with Santos, industry and regulatory standards and guidelines to minimise potential impacts to soil, surface water, shallow groundwater, stock and wildlife.

All chemicals used within Santos' petroleum activities are provided to the Department of Mines and Energy (DME) as part of the Environment Plan approval process. These chemicals, and their associated Material Safety Data Sheets, are made available for public record on the DME website.

[27] The Northern Territory Department of Mines and Energy Guideline 'Applications for Drilling or Workover Rig Activities' requires the submission of a Baseline Water Study with Project Applications for hydraulic stimulation .

6.5.1. Hydraulic stimulation fluid

The chemicals used in hydraulic stimulation, in the quantities and methodologies employed, do not pose an unacceptable risk. These chemicals have been assessed by the relevant government agencies and have had requisite Material Safety Data Sheets (MSDS) prepared.

Section 6.5 outlines the outcomes of toxicological risk assessments of fracture stimulation fluids.

With our operational controls and management, any potential risks to the environment associated with the chemicals used in hydraulic stimulation are able to be mitigated.

6.5.2. BTEX

The chemicals used in the hydraulic stimulation process do not contain BTEX or polycyclic aromatic hydrocarbons as additives, which are recognised carcinogens. Furthermore, BTEX chemicals are not permitted for use in hydraulic stimulation in the Northern Territory.

BTEX compounds (known as ‘volatile organic compounds’) are found in petroleum derivatives such as petrol and general lubricants and are also naturally occurring. They are also some of the most common chemicals that people come in to contact with on a daily basis, with petroleum based products being in such regular use. Popular soft drinks contain BTEX of up to 50 parts per billion (or 50 micrograms per litre), the air we breathe contains BTEX at a level such that we receive, on average, approximately 220 micrograms per day and while refilling a car a person breathes in approximately 220 micrograms.

Extremely low levels of BTEX may be detected in oil and gas and domestic irrigation wells as a result of grease that is used to lubricate the drill pipe or from the pump that is used to extract the water.

6.5.3. Spill and leak prevention

To prevent salinisation of soils and shallow groundwater, water used for hydraulic stimulation is stored in above ground temporary tanks installed in accordance with manufacturer specifications, or in temporary pits lined with UV stabilised high-density polyethylene (HDPE) liner (or equivalent).

Flow-back pits are also lined with UV stabilised HDPE (or equivalent) liners, and the average pit capacity is 350 m^3 to limit the volume of fluid stored on site. Earthen bunds are installed around flow-back pits to prevent surface water ingress.

During operations, tanks and ponds are inspected daily (at a minimum) for potential breaches or leaks, and repair works are undertaken when and where required. A minimum of 300 millimetres freeboard in tanks and pits is maintained to prevent overflow associated with flooding or surface water ingress.

Routine inspection of flow-back lines, connections, high-pressure equipment and trip systems is undertaken to prevent operation above design limits; repairs are undertaken as required. Emergency shutdown systems are installed on equipment to prevent uncontrolled releases of flow-back water, fuel and/or other chemicals. Design, inspection and shutdown procedures for hydraulic stimulation equipment (i.e. high pressure equipment) reduce the risk of soil and shallow groundwater contamination from fluids used in hydraulic stimulation by minimising the potential volume of fluids released.

Additional control measures include (but are not limited to):

- where practicable, minimisation of chemical utilisation
- where possible, alternate lower toxicity chemicals used
- storage of chemicals in appropriately bunded areas
- road movement by licensed dangerous goods handlers, for relevant chemicals
- appropriate decanting systems employed for safe chemical handling
- ecological assessment on new proposed lease locations to minimise potential impacts to drainage patterns and surface water contamination
- no operations proximal to main surface water channels and/or permanent water holes
- where possible, leases constructed on high ground
- in low lying areas, leases are not built up significantly (e.g. 300 mm)
- closed loop blending system maintained in accordance with manufacturer specifications
- all high pressure equipment rated to manufactures specifications
- training of personnel in emergency spill response, chemical and dangerous goods handling, and the use of spill kits.

In areas of heavy rainfall, work may be prohibited during periods of rainfall or inundation. Weather conditions are monitored for preparation of shutdown. Where flood waters pose a risk to hydraulic stimulation treatments, produced fluids are removed from pits to reduce the volume of fluid stored on site and mitigate the potential for flow-back fluid release to the environment. Fluids are transferred to sites that are not subject to flood risk including satellite facilities, alternative flow-back pits or above ground tanks.

The control measures in place appropriately manage the risk of spills to soil, surface water and shallow groundwater.

6.5.4. Stock and wildlife access

Stock and wildlife access to fuel, chemicals and flow-back fluid storage presents a potential hazard, which is controlled by:

- ecological assessment of new proposed lease sites to evaluate sensitivity, including habitat assessment
- storage of fuels and chemicals in designated areas
- scheduled (and/or upon request) removal of waste from operational sites
- immediate clean-up of fuel or chemical spills
- pit construction including steep sided edges to prohibit vegetation growth and/or creation of beaches which could attract birdlife
- installation of stock proof fencing following cessation of flow-back operations

- regular and ongoing inspections (by site operators) to ensure fence integrity.

6.5.5. Chemical disclosure / intellectual property

Santos supports full disclosure of the content of fluids used for hydraulic stimulation and the provision of eco-toxicological reports and material safety data sheets (MSDS) that detail how the substances should be handled and emergency response steps to ensure that the public and other stakeholders are aware of what chemicals are being used.

Santos also supports the protection of intellectual property (i.e. while chemicals should be disclosed, disclosure of compositions of total fluids is not necessary to manage the risks). This protection will enable the industry to continue to develop best-practice and improved chemicals such as more environmentally friendly chemicals or innovations that enhance production from a down-hole environment. We support the protection of intellectual property to a level where these products cannot be reverse engineered.

Santos also supports the disclosure of information through publically accessible mediums such as “FracFocus” in the USA and we are working with regulators in Australia to achieve the same level of disclosure in Australia.

Santos supports full disclosure of the ingredients that make up hydraulic stimulation fluid, but not the overall formula (which specialist hydraulic stimulation companies have developed as latest generation proprietary fluids) to prevent the risk of reverse engineering by competitors.

6.6. Responsible waste management

This section addresses Term of Reference 7(f)

Santos strives to optimise waste avoidance, reduction, reuse and recycling.

Generation, storage and disposal of waste associated with hydraulic stimulation are undertaken in accordance with Santos’ robust EHSMS requirements and relevant legislation and guidelines. Licenced waste management contractors are used to transport waste material to approved waste management facilities for disposal.

Waste streams generated as a result of fracture stimulation activities include:

- produced fracture stimulation fluids
- fracture stimulation solids/proppant
- IBCs
- wooden pallets
- bulky bags
- paper
- putrescibles.

The largest waste streams generated as a result of fracture stimulation activities are produced fluids and solids/proppant. Produced fluids are flowed back to a lined pit (UV stabilised HDPE or equivalent) or tank and then transported to a nearby facility for disposal or treatment in a lined pond systems. Solids and proppant are treated at landfarms, if necessary.

In Santos' current Northern Territory operations, produced fluids are evaporated at approved facilities.

6.7. Noise minimisation

This section addresses Terms of Reference 7(h)

Landowners are consulted with respect to proposed operations and consultation processes initiated to ensure appropriate procedures in place to mitigate any noise impacts. Noise emissions from well sites during hydraulic stimulation are localised and short term. Further, well sites are typically remotely located and are not likely to have a significant impact.

Noise assessments are undertaken and controls implemented accordingly to manage the noise exposure of personnel on site. Relevant Personnel Protective Equipment is utilised as required. Noise assessments are displayed on site.

6.8. Air quality

This section addresses Terms of Reference 7(g)

Air emissions (including dust generation) from well sites during hydraulic stimulation are localised and short term and are not likely to have a significant impact on air quality.

Well sites are typically remotely located, however landowners are consulted with respect to proposed operations and processes initiated to ensure appropriate procedures in place to mitigate any impacts.

Fugitive emissions are minor losses from equipment (e.g. from valves on pipelines) which account for less than 1% of our total annual emissions, and less than 0.01% of production.

Santos' Climate Change Policy commits to emission reduction and energy efficiency. The impact of emissions is minimised through maintenance (including use of an infra-red camera to detect fugitive emissions at flanges, gauges and couplings), technology and use of flaring as opposed to venting. Santos' environmental policy and operational practice is to always flare waste gas where possible rather than vent it.

Emissions from flaring and venting are controlled, measured and reported. Fugitive emissions are estimated and reported.

6.9. Protection of public safety

Potential sources of risk to the public and other third parties as a result of hydraulic stimulation activities could principally arise from unauthorised access resulting in exposure to site hazards, and the use of roads and movement of vehicles and heavy machinery.

Hydraulic stimulation operations are undertaken at established well leases where public access is restricted. Most sites are relatively remote from public roads and have little or no public access. Measures such as signage and fencing are in place to warn of hazards at the site and restrict access into the site. Potentially hazardous areas such as sumps and lined pits are securely fenced with warning signs in place.

Hydraulic stimulation operations can result in short term and localised increase in vehicle traffic. Santos employs controls to manage the risks of road use, including adherence to specified speed limits, In Vehicle Monitoring (IVMS) of speed, route and harsh breaking, minimising night-time driving and driver education programs.

6.10. Emergency preparedness and incident response

This section addresses Term of Reference 7(e)

Santos utilises Wellsite Emergency Response Plans (WERP) to provide Santos and contractor personnel with guidance for responding to an emergency at, or near, a wellsite. A WERP applies to all Santos onshore wellsites and related activities, and provides an overview of:

- how to prepare for and respond to an emergency at a wellsite or while moving between wellsites
- the basic guidelines for an emergency response
- the interface with other Santos emergency and incident plans.

Santos and contractor personnel are required to undertake emergency response drills to practice and prepare for potential incidents on site.

Santos investigates incidents to:

- identify the cause and prevent similar incidents in the future
- identify any new hazards
- identify and choose appropriate hazard management controls
- to inform the work group of causes and what remedial action has been undertaken
- to comply with legislation.

Incidents (including near misses) with higher potential consequence are subject to major investigation, using a process such as TapRoot®, ICAM or DEM. Incidents with lower potential are subject to a minor investigation, to capture basic information for trending and determine whether risk controls should be revised.

6.11. Effective rehabilitation

This section addresses Terms of Reference 7(k) and (l)

The primary focus of our rehabilitation practices is to return the land to its previous state. That objective includes measures to replace the soil profile and vegetation type, to eliminate any contamination of land and waters, and to ensure there is no introduction of weed species. Monitoring of rehabilitation outcomes is undertaken to ensure the results of rehabilitation are fed into the improvement of rehabilitation practices.

Prior to Santos commencing site activities, sites are surveyed and photographed. Once buildings and infrastructure have been removed following decommissioning, the land surface is re-contoured to a stable landform similar to its previous state and to that of surrounding undisturbed areas. The surface is ripped in order to promote natural revegetation. Surface drainage lines are reshaped and topsoil is re-spread over the distributed area and then harrowed and seeded with the aim of achieving at least a 70 per cent ground cover within one month after the rehabilitation work is completed.

Within one month of the rig being released from site, an appropriately trained and competent environmental auditor undertakes a rehabilitation audit. Six months after rig release, the site is revisited and checked against the completed audit to ensure the site is still compliant, with particular attention to weeds and compaction around the sumps. The site is not considered rehabilitated until the Landholder is satisfied with the outcomes.

Figure 14, Figure 15 and Figure 14 show an example of our rehabilitation practices at a former well site at Brawboy, near Gunnedah, NSW.

Figure 14: Pilot well site at Brawboy, near Gunnedah, NSW

Figure 15: The same site during rehabilitation

Figure 16: The same site six months later

7. Conclusion

Santos' decades of experience in the Cooper Basin and in Mereenie demonstrates that hydraulic stimulation does not cause harm to the environment or impact the use of the land in a material or on-going manner.

We consider that the following are key principles with respect to the use of hydraulic stimulation:

- Responsible operations and adopting industry best practices.
- Robust science-based regulation.
- Engagement with stakeholders.

This approach is shared by Australian Government regulators (e.g. the Western Australian Environment Protection Authority,[28] the Western Australian Department of Mines and Petroleum,[29] the South Australian Department of Manufacturing, Innovation, Trade, Resources and Energy (DMITRE)[30]) and respected authorities/industry bodies (e.g. the Australian Council of Learned Academies (ACOLA)[31] [32] and APPEA[33]).

For example, ACOLA undertook a study of shale gas in Australia looking at: resources, technology, monitoring, infrastructure, human and environmental impacts, issues communication, regulatory systems, economic impacts, lessons learned from the coal seam gas industry, and impacts on greenhouse gas reduction targets. The study considered within it hydraulic stimulation, with the report findings acknowledging that the potential environmental risks "…can be minimised where an informed and supportive community, and transparent and effective regulations and companion codes of practice".

Employing best practice in these areas has led to safe, environmentally sustainable and successful operations for Santos. The logging, well design, well completion and well cementing methods outlined in this submission ensure that the risk of any impact to the containing formations is negligible. These processes ensure that well completion quality and integrity is maintained. These processes are carried out to ensure that the aquifer layers intersected by the well do not become impacted by subsequent hydraulic stimulation activities or gas

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[28] WA EPA, 'Submission to the Standing Committee on Environment and Public Affairs — Inquiry into the Implications for Western Australia of Hydraulic Fracturing for unconventional gas', Western Australian Environment Protection Authority, 25 March 2014

[29] DMP, 'Submission to the Standing Committee on Environment and Public Affairs — Inquiry into the Implications for Western Australia of Hydraulic Fracturing for unconventional gas', Department of Mines and Petroleum, Government of Western Australian, October 2013

[30] Goldstein *et al,* 'Roadmap for Unconventional Gas Projects in South Australia', Department for Manufacturing, Innovation, Trade, Resources and Energy, Government of South Australia, December 2012

[31] ACOLA combines the strengths of the four Australian Learned Academies: Australian Academy of the Humanities, Australian Academy of Science, Academy of Social Sciences in Australia, and Australian Academy of Technological Sciences and Engineering to provide a nexus for true interdisciplinary cooperation to develop integrated problem solving and cutting edge thinking on key issues for the benefit of Australia such as on the topic of unconventional gas production in Australia

[32] Cook, P, Beck, V, Brereton, D, Clark, R, Fisher, B, Kentish, S, Toomey, J and Williams, J (2013). Engineering energy: unconventional gas production. Report for the Australian Council of Learned Academies (ACOLA), available at: www.acola.org.au

[33] APPEA, 'Submission to the Standing Committee on Environment and Public Affairs — Inquiry into the Implications for Western Australia of Hydraulic Fracturing for unconventional gas', 3 October 2013

production activities through the operating life of the well concerned. The veracity of Santos' practices is demonstrated by over 50 years of operations in Australia without impacting the viability of aquifers and successful co-existence with other land uses.

In conclusion, hydraulic stimulation is a sustainable practice that has been a part of the production of natural gas and oil in Australia, and around the world, for decades. Santos strongly endorses the use of hydraulic stimulation as a safe and environmentally responsible technology that improves the economics of producing natural gas and oil.

> *"For Santos, sustainability means supplying energy for the future, and doing business in a way that improves outcomes for shareholders, employees, business partners, governments and community stakeholders.*
>
> *We do this by considering a comprehensive set of criteria beyond traditional economic measures that assess the full impact of the Company's activities, thereby enabling better business decisions to be made.*
>
> *The Board acknowledges that a key determinant of our future success relies on the ability of Santos to gain the trust of the communities in which we operate. We take very seriously our responsibility to deliver safe and sustainable operations and understand that the ongoing support of communities and shareholders is paramount to achieving this outcome."*

Ken Borda, Chairman & David Knox, Managing Director and CEO
Santos Shareholder Review 2013

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Figures

Figure 5 and Figure 6: Economides, M.J., and Martin, T., *Modern Fracturing, Enhancing Natural Gas production. Energy Tribune Publishing Inc.*, 2007

Figure 10: Fisher, K. ‘Data Confirm Safety Of Well Fracturing’, Pinnacle Resources, American Oil and Gas Reporter, July 2010

Appendix 1: Inquiry Terms of Reference

"Hydraulic fracturing for hydrocarbon deposits in the Territory, including the assessment of the environmental risks and actual environmental impacts of hydraulic fracturing and the effectiveness of mitigation measures, and more particularly the matters mentioned in the following clauses:

1. Historical and proposed use of hydraulic fracturing (exploration, appraisal and production) of hydrocarbon deposits in the Northern Territory (number of wells; locations; timeline).
2. Environmental outcomes of each hydraulic fracturing activity for hydrocarbon resources in the Northern Territory (number of wells; frequency of types of known environmental impacts).
3. Frequency of types and causes of environmental impacts from hydraulic fracturing for hydrocarbon deposits in the Northern Territory and for similar deposits in other parts of the world.
4. The potential for multiple well pads to reduce or enhance the risks of environmental impacts.
5. The relationship between environmental outcomes of hydraulic fracturing of shale petroleum deposits with geology, hydrogeology and hydrology.
6. The potential for regional and area variations of the risk of environmental impacts from hydraulic fracturing in the Northern Territory.
7. Effective methods for mitigating potential environment impacts before, during and after hydraulic fracturing with reference to:
    a) the selection of sites for wells
    b) well design, construction, standards, control and operational safety
    c) well integrity ratings
    d) water use
    e) chemical use
    f) disposal and treatment of waste water and drilling muds
    g) fugitive emissions
    h) noise
    i) monitoring requirements
    j) the use of single or multiple well pads
    k) rehabilitation and closure of wells (exploratory and production) including issues associated with corrosion and long term post closure
    l) site rehabilitation for areas where hydraulic fracturing activities have occurred."

For ease of reference throughout the document, we have assigned a numbering system to the points listed in Term of Reference 7.

Appendix 2: Santos Environment, Health and Safety Management System

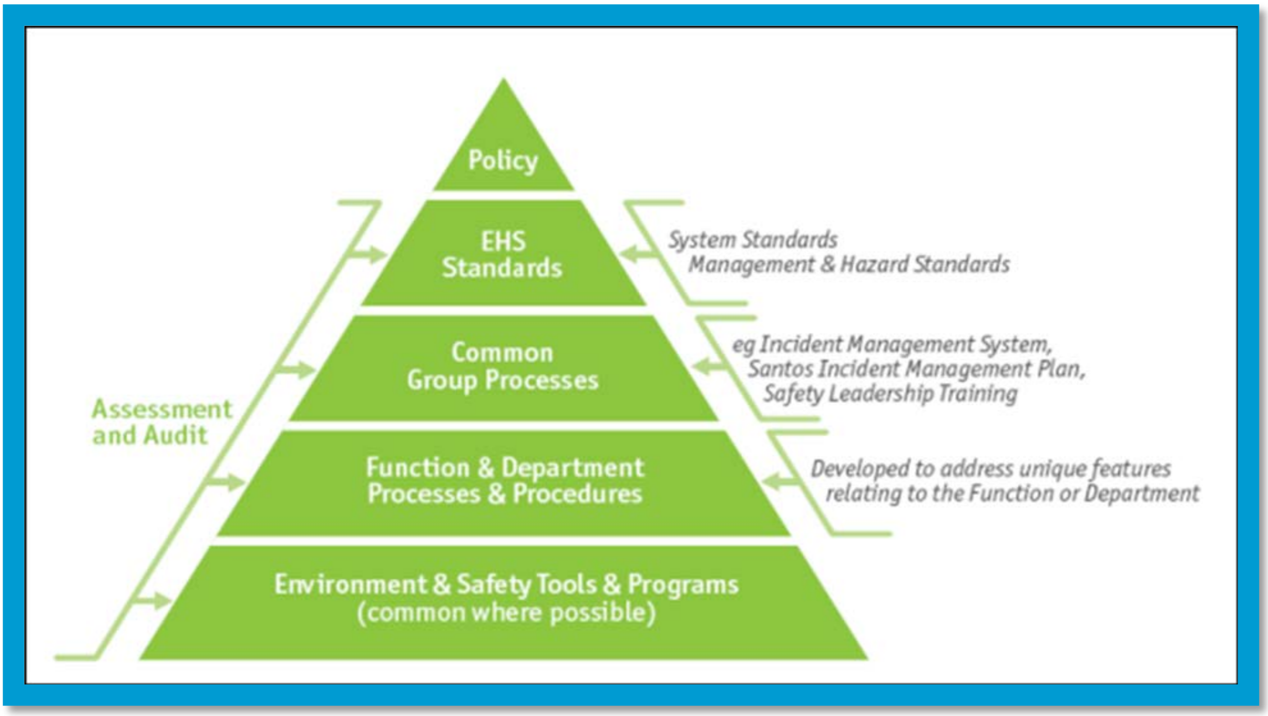
The Santos Environment, Health and Safety Management System (EHSMS) has been developed by Santos to provide a company-wide approach to effectively manage Environment, Health and Safety (EHS) risks and to allow for continual EHS improvement.

It provides structured, comprehensive and efficient EHS practices for Santos' activities and operations and is compliant with both *AS 4801:2000 Occupational Health and Safety Management Systems – Specification with Guidance for Use* and *AS/NZS ISO 14001:2004 Environmental Management Systems – Specification with Guidance for Use*.

The EHSMS is multi-layered and comprises policies, standards, processes and procedures with Management and Hazard Standards forming the key components of the Framework. The upper layer of the framework comprises the overarching EHSMS policies which outline Santos' direction and objectives in relation to the EHS and demonstrates the commitment Santos has made to continual improvement in respect of EHS performance. These policies include:

- Health and Safety Policy
- Environmental Policy
- Climate Change Policy.

The Santos Environmental Policy, which applies to all Santos operations within Australia, is provided below.



Management Standards define the requirements necessary to ensure that environmental, health and safety risk is systematically managed. These Standards include, but are not limited to:

- EHSMS02 – Legal Obligations and Other Requirements
- EHSMS03 – EHS Objectives, Targets and Improvement Plans
- EHSMS05 – EHS Responsibility and Accountability
- EHSMS06 – Training and Competency
- EHSMS07 – Consultation and Communication
- EHSMS09 – Managing EHS Risk
- EHSMS09.2 – Hazard Studies
- EHSMS10 – Contractor Engagement and Management
- EHSMS11.1 – Design Basis - Facilities and Equipment
- EHSMS11.2 – Facilities Design and Construction
- EHSMS11.3 – Pre Startup EHS Review
- EHSMS11.4 – Structural Integrity
- EHSMS11.5 – Mechanical Integrity
- EHSMS11.7 – Critical Protection Systems
- EHSMS11.8 – Operating Procedures and Safe Practices
- EHSMS11.9 – Maintenance
- EHSMS11.11 – Decommissioning and Abandonment
- EHSMS12 – Management of Change
- EHSMS13 – Emergency Preparedness
- EHSMS14 – Monitoring, Measurement and Reporting
- EHSMS15 – Incident Investigation and Response
- EHSMS 15.2 – Environmental Incident Response
- EHSMS 16 – EHS Audit and Inspection.

Environmental and Health & Safety Hazard Standards detail the controls required to manage the risks of specific hazards to acceptable levels. The Standards contain specific requirements for planning and undertaking activities and include checklists and references to internal and external approvals, controls and auditing guidelines. Hazard Standards developed under the EHSMS include:

- EHS01 – Biodiversity and Land Disturbance
- EHS02 – Underground Storage Tanks and Bunds
- EHS03 – Produced Water Management
- EHS04 – Waste

- EHS05 – Air Emissions
- EHS06 – Environmental Impact Assessment and Approvals
- EHS07 – Energy Efficiency
- EHS08 – Contaminated Sites
- EHS09 – Pest Plants and Animals
- EHS10 – Water Resources
- EHS11 – Cultural Heritage
- EHS12 – Noise Emissions
- HSHS02 – Land Transportation
- HSHS08 – Chemical Management
- HSHS09 – Radiation
- HSHS12 – Occupational Noise.

Environmental Policy

Santos

Our Environmental Vision:

"We will lighten the footprint of our activities"

At Santos we are adopting the principles of sustainable development. We recognise our responsibility to meet community expectations and we are committed to the continuous improvement of our environmental performance. We believe that environmental stewardship is both a management obligation and the responsibility of every employee.

To achieve this we will:

- Maintain and continuously improve the Environment, Health and Safety Management System (EHSMS) across the organisation.
- Ensure that all employees and contractors receive appropriate training to fulfil their individual EHSMS and environmental responsibilities.
- Proactively pursue the identification of all hazards and eliminate or, if not possible, manage the risk to as low as reasonably practicable.
- Establish annual environmental objectives and targets and implement programs to achieve them.
- As a minimum comply with relevant legal and other requirements.
- Ensure that we have the resources and skills necessary to achieve our environmental commitments.
- Incorporate environmental performance in the annual appraisal of employees and contractors and recognise accordingly.
- Implement strategies to minimise pollution, manage waste effectively, use water and energy efficiently and address relevant cultural heritage and biodiversity issues.
- Formally monitor, audit, review and report annually on our environmental performance and EHSMS requirements against defined objectives.
- Require that companies providing contract services to Santos manage their environmental performance in line with this Policy.
- Steward the environmental performance of Joint Venture activities operated by others.

As Chief Executive Officer and Managing Director, I am committed to working with Santos personnel to ensure that this policy is communicated, understood, accepted and successfully implemented by all Santos employees and contractors.

David Knox
Chief Executive Officer and Managing Director
Revision 2

Santos Ltd ABN 80 007 550 923 File No: POLICY P040

Appendix 3: Key International Best Practice Operational Guidance Documents

- API Guidance Document HF1, Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines.
- API Guidance Document HF2, Water Management Associated with Hydraulic Fracturing.
- API Guidance Document HF3, Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing.
- API Specification 5CT/ISO 11960, Specification for Casing and Tubing.
- API Specification 6A/ISO 10423, Specification for Wellhead and Christmas Tree Equipment.
- API Specification 10A/ISO 10426-1, Specification for Cements and Materials for Well Cementing.
- API Recommended Practice 10B-2/ISO 10426-2, Recommended Practice for Testing Well Cements.
- API Recommended Practice 10B-3/ISO 10426-3, Recommended Practice on Testing of Deepwater Well Cement Formulations.
- API Recommended Practice 10B-4/ISO 10426-4, Recommended Practice on Preparation and Testing of Foamed Cement Slurries at Atmospheric Pressure.
- API Recommended Practice 10B-5/ISO 10426-5, Recommended Practice on Determination of Shrinkage and Expansion of Well Cement Formulations at Atmospheric Pressure.
- API Recommended Practice 10B-6/ISO 10426-6, Recommended Practice on Determining the Static Gel Strength of Cement Formulations.
- API Specification 10D/ISO 10427-1, Specification for Bow-Spring Casing Centralizers.
- API Specification 10D-2/ISO 10427-2, Recommended Practice for Centralizer Placement and Stop Collar Testing.
- API Recommended Practice 10F/ISO 10427-3, Recommended Practice for Performance Testing of Cementing Float Equipment.
- API Technical Report 10TR1, Cement Sheath Evaluation.
- API Technical Report 10TR2, Shrinkage and Expansion in Oil Well Cements.
- API Technical Report 10TR3, Temperatures for API Cement Operating Thickening Time Tests.
- API Technical Report 10TR4, Technical Report on Considerations Regarding Selection of Centralizers for Primary Cementing Operations.
- API Technical Report 10TR5, Technical Report on Methods for Testing of Solid and Rigid Centralizers.
- API Specification 13A /ISO 13500, Specification for Drilling Fluid Materials.
- API Recommended Practice 13B-1/ISO 10414-1, Recommended Practice for Field Testing Water-Based Drilling Fluids.
- API Recommended Practice 13B-2/ISO 10414-2, Recommended Practice for Field Testing Oil-based Drilling Fluids.
- API Recommended Practice 45, Recommended Practice for Analysis of Oilfield Waters.
- API Standard 53, Blowout Prevention Equipment Systems for Drilling Wells.
- API Recommended Practice 65, Cementing Shallow Water Flow Zones in Deep Water Wells.
- API Standard 65-2 - Isolating Potential Flow Zones During Well Construction.